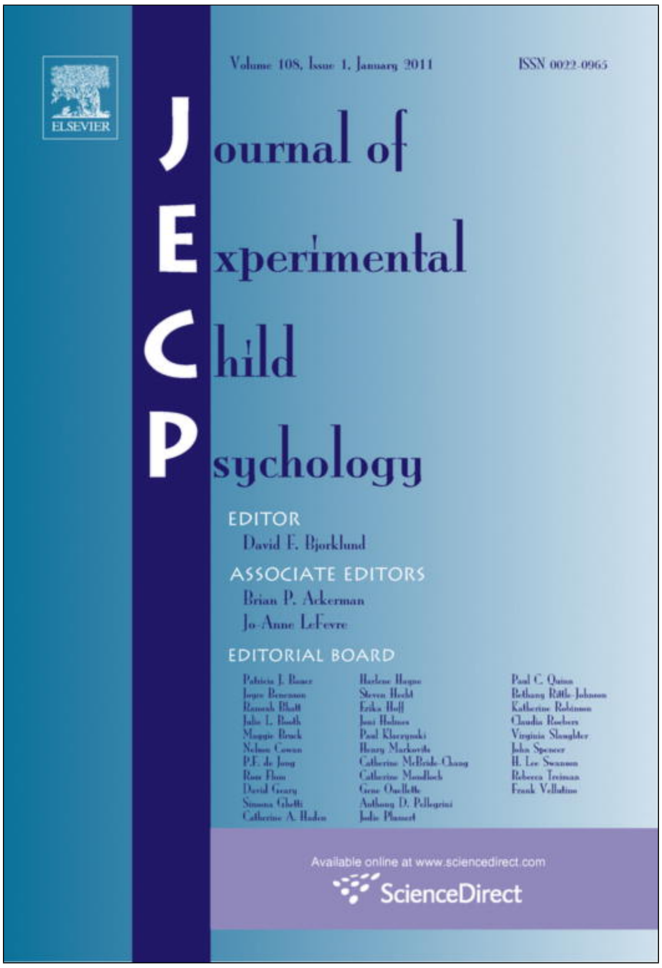
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Relations among language exposure, phonological memory, and language development in Spanish–English bilingually developing 2-year-olds

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ABSTRACT

The relation of phonological memory to language experience and development was investigated in 41 Spanish–English bilingual first language learners. The children's relative exposure to English and Spanish and their phonological memory for English- and Spanish-like nonwords were assessed at 22 months of age, and their productive vocabulary and grammar in both languages were assessed at 25 months of age. Phonological memory for English-like nonwords was highly correlated with that for Spanish-like nonwords, and each was related to vocabulary and grammar in both languages, suggesting a language-general component to phonological memory skill. In addition, there was evidence of language-specific benefits of language exposure to phonological memory skill and of language-specific benefits of phonological memory skill to language development.

Introduction

A substantial body of evidence from the study of first and second language acquisition argues that phonological memory (i.e., the capacity to remember sequences of sounds) is a component of the human language acquisition capacity. Children and adults who have better phonological memory skills acquire language more rapidly than children and adults who are less able to remember novel auditory

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stimuli (Gathercole, 2006). Phonological memory skills appear to have both a general auditory memory component, which operates over all speech-like stimuli without drawing on information in long-term memory, and a component that makes use of knowledge based on prior language experience (Vallar, 2006). Evidence of the influence of language experience includes findings that children show better memory for sound sequences in real words than in nonwords (Chiat & Roy, 2007; Snowling, 1981), better memory for high-frequency sound sequences in nonwords than for low-frequency ones (Edwards, Beckman, & Munson, 2004; Munson, Kurtz, & Windsor, 2005), and better memory for sound sequences that conform to the phonology of their own language than for sound sequences drawn from a foreign language (Thorn & Gathercole, 1999).

The effect of language experience on phonological memory has implications for the process of phonological memory development and its role in bilingual development. The phonological memory skills of children exposed to two languages might include two different language-specific components, each drawing on knowledge of one of their languages. These two knowledge bases might develop at different rates if the children's exposure to one language is greater than their exposure to the other. Furthermore, to the degree that the value of phonological memory to subsequent language development depends on a language-specific capacity to store sound sequences, bilingually developing children's phonological memory skills in each language should have language-specific benefits. The current study was designed to test these hypotheses. In the following sections, we first review the literature that establishes the relation of phonological memory skill to vocabulary and grammar in monolingual development and in second language acquisition. We then outline the theoretical issues and evidence regarding the influence of language exposure and familiarity on phonological memory skill. Finally, we review the literature on bilingual development that is relevant to the hypothesis that bilingual children acquire language-specific phonological memory skills as a result of language exposure and that the value of those skills to subsequent language development is, in part, language specific.

Phonological memory and vocabulary

Phonological short-term memory has been demonstrated to be related to vocabulary knowledge and vocabulary development in first language learning even after considering the effects of age and nonverbal intelligence (Gathercole, Hitch, Service, & Martin 1997; Gathercole, Willis, Emslie, & Baddeley, 1992). Relations between phonological memory skill, measured as accuracy of nonword repetition, and vocabulary have been demonstrated in samples of children between 20 months and 8 years of age (Chiat & Roy, 2007; Gathercole & Adams, 1993; Gathercole et al., 1992; Hoff, Core, & Bridges, 2008).

Phonological memory is important to vocabulary learning in second language learning as well. Among adolescent foreign language learners, repetition accuracy for English-like stimuli has been found to be related to success at English vocabulary learning (Service & Kohonen, 1995). As with first language acquisition, phonological memory seems to play a role at the early stages of second language learning. For example, the relation between English nonword repetition and speed of learning English vocabulary was significant for Cantonese seventh graders (mean age = 12 years) learning English at school who had low English vocabulary skills, but not for those who had high English vocabulary skills (Cheung, 1996).

Phonological memory and grammar

Phonological short-term memory also has been associated with grammatical development in first and second language acquisition. Adams and Gathercole (1995) found that 3-year-olds with good nonword repetition skills differed from children poor at nonword repetition with respect to the variety of vocabulary, the length of the utterances, and the complexity of the syntax used in spontaneous speech. Adams and Gathercole (1996) also found that nonword repetition skills were associated with the length of sentences and the amount of detail in narrations produced by 4-year-olds after controlling for vocabulary knowledge, age, and nonverbal intelligence. Finally, Adams and Gathercole (2000) found that 4-year-olds with good nonword repetition skills produced longer utterances and more varied syntactic constructions than children of the same age and similar nonverbal abilities who had poor nonword repetition skills.

In the realm of second language learning, French and O'Brien (2008) examined the relation between phonological memory and grammar learning in a group of French 11-year-olds enrolled in a 5-month intensive English program. Phonological memory was measured at the beginning (Time 1) and at the end (Time 2) of the program with English nonwords and with Arabic words, which were functionally nonwords to the children. Both English nonword and Arabic word repetition tasks measured at Time 1 explained a significant amount of variance in grammar at Time 2 above and beyond the variance explained by vocabulary knowledge (at Times 1 and 2), nonverbal intelligence, and grammatical knowledge at Time 1. Furthermore, although English nonword and Arabic word repetition accuracy were highly correlated within and across measurement times, the former increased over time, whereas the latter did not. This was attributed to the lack of influence of lexical knowledge on Arabic words relative to English nonwords. Thus, repetition accuracy for Arabic words (in non-Arabic speakers) was argued to be a more sensitive measure of phonological memory.

Effect of language familiarity on phonological memory

Although phonological memory was originally hypothesized to be an unlearned cognitive capacity to process and store phonological information (Baddeley, Gathercole, & Papagno, 1998), phonological memory has more recently been argued to be affected by extrinsic factors such as language input (MacDonald & Christiansen, 2002) and to reflect the quality of children's phonological representations (Gathercole, 2006). In support of this experience-dependent view of phonological memory, Snowling (1981) showed that dyslexic readers (mean age = 12 years) and reading-level-matched normal readers (mean age = 8.4 years) were better at repeating real words than repeating nonwords, and Gathercole, Willis, Emslie, and Baddeley (1991) found wordlikeness effects on nonword repetition accuracy in children from 4 to 6 years of age. Several studies have found that children are better at repeating nonwords containing high-frequency phonemes than repeating nonwords containing low-frequency phonemes (Coady & Aslin, 2004; Edwards et al., 2004; Munson et al., 2005), and Messer, Leseman, Boom, and Mayo (2010) found in young second language learners that this benefit of high phonotactic probability to nonword repetition was greater in children who were more familiar with the language. Adults have shown better memory for sound sequences that conform to the language they know than for sound sequences in a foreign language (Service & Kohonen, 1995; Thorn & Gathercole, 1999). In domains other than language, there is evidence that knowledge of a particular domain results in the development of a representational system that improves memory performance in that domain (Schneider, Bjorklund, & Maier-Brückner, 1996), and phonological memory seems to similarly benefit from the support of a knowledge base. If phonological memory is supported by experience-dependent language knowledge, then bilingually developing children, who have different amounts of experience in knowledge of each of their languages, might have different levels of phonological memory skill in each language. These different levels of phonological memory skill might then, in turn, provide different levels of support for the development of each language.

Phonological differentiation in bilingual development

Although young bilingual children's vocabulary knowledge has been demonstrated to differ between languages as a function of input (Pearson, Fernández, Lewedeg, & Oller, 1997), no studies have directly addressed the question of whether bilingually developing children show different levels of phonological knowledge in their two languages as a result of differences in input. There is evidence that bilingual input affects early phonological development, and there is evidence that bilingually developing children can have separate, if not completely autonomous, phonological systems. For example, infants as young as 10 or 12 months of age who are exposed to two languages retain the ability to hear phonemic contrasts in both languages that monolingually exposed infants lose (Bosch & Sebastian-Gallés, 2003; Burns, Yoshida, Hill, & Werker, 2007). French–English bilingual 2-year-olds have distinct prosodic features in their French and English productions, although they also show cross-linguistic transfer from French into English in their repetition of English and French nonwords

(Paradis, 2001). Also suggestive of separate systems is the finding from two Cantonese–English bilingual children, who were exposed to the second language at 2 years of age, that they produced error patterns and phoneme simplifications specific to each language. In addition, their errors followed the phonotactic constraints of each language, and shared phonemes did not always enter both productive systems at the same time (Holm & Dodd, 1999).

The current hypothesis does not require that bilinguals have two separate systems; it only requires that they have different levels of familiarity with the sounds and/or sound sequences characteristic of each language. For that to be the case, of course, it is necessary that the two languages make use of different sounds and sound sequences. English and Spanish do make use of different phonemic inventories and have different phonotactic patterns (Goldstein, 2004). For example, Spanish words are more likely to end in vowels than in consonants and never end in a consonant cluster, whereas word-final consonants and consonant clusters are common in English. More broadly, differences between Spanish and English in word shapes, word length, stress patterns in multisyllabic words, and the phonetic details of how individual consonants and vowels are articulated make Spanish and English sound very different. One source of evidence that these differences in the sounds of the two languages make encoding of speech difficult for speakers who are familiar with English but not Spanish is data from English monolingual and Spanish–English bilingual kindergartners who were given the task of repeating fictitious Spanish names in English (e.g., "How would you say *Parasco* [pronounced in Spanish] in English?") (Oller, Cobo-Lewis, & Eilers, 1998). The monolingual children performed less well than the bilingual children even though they did not need to produce any Spanish sounds; they only needed to encode them as they were presented orally with Spanish phonology and map them onto their English equivalents.

The current study

The nature of the relations among language exposure, phonological memory, and language development in early bilinguals has not been investigated previously. The current study tests the hypotheses that (a) children's relative exposure to English and Spanish will be related to their phonological memory skills for English- and Spanish-like stimuli and (b) phonological memory skills will show language-specific relations to vocabulary and grammatical development.

Method

Participants

The participants were 41 Spanish–English bilingually developing children (21 boys and 20 girls) who were born in the United States and were living in South Florida. According to parental reports, they had been exposed to both English and Spanish since birth, and the less frequently heard language constituted at least 10% of their input. The balance of language exposure ranged from 10% English and 90% Spanish to 90% English and 10% Spanish, with an average home language input of 49.9% (SD = 29.1). All children were described by their parents as learning both languages, and all children were producing words in both languages at 22 months of age.

Half (50%) of the mothers and 52% of the fathers were native speakers of Spanish, 35.4% of the mothers and 37.5% of the fathers were native speakers of English, 12.5% of the mothers and 8.3% of the fathers described themselves as native Spanish–English bilinguals, and 2.08% of the mothers and 2.08% of the fathers were native speakers of a language other than English or Spanish. Fully 89% of the native Spanish speakers were born in Spanish-speaking countries in South America or the Caribbean, and 11% were born in the United States.

The children were 22 months of age at the start of the study (M = 22.78 months, SD = 0.39). All participants were full term at birth and had no history of medical or sensory problems. In addition, they had normal communicative and language development according to the criterion that they were above the recommended cutoff value of 35 for language delay in the communication section of the Ages and Stages Questionnaire (Squires, Potter, & Bricker, 1999) and were at the 10th percentile or higher in at least one of their languages using the MacArthur–Bates Inventory Scales (Fenson et al., 1993; Jackson-Maldonado et al., 2003). On average, the children were at the 29th percentile for English vocabulary and the 42nd percentile for English grammar, whereas they were at the 23rd percentile for Spanish vocabulary and the 49th percentile for Spanish grammar based on monolingual norms. These numbers are consistent with other evidence that bilingually developing children show somewhat slower rates of development in each language – especially in vocabulary – than monolingual children (Bialystok, 2001; Bialystok & Feng, in press; Conboy & Thal, 2006; Marchman, Martínez-Sussmann, & Dale, 2004). Fully 93% of the children were White Hispanics, 2.4% were Hispanic of African descent, 2.4% were European American, and 2.4% belonged to other ethnicities. Socioeconomic status, as assessed by the parents' educational level, was high, with 89.5% of the mothers and 64.6% of the fathers having at least a 4-year college degree.

Design and measures

The data were collected as part of a larger longitudinal study of early bilingual development. Children's phonological memory skills and the balance of English and Spanish language exposure at home were measured at 22 months of age. Productive vocabulary size and grammatical complexity of speech were measured at 25 months of age ($M = 25.82$ months, SD = 0.34).

Phonological memory

Nonword repetition tasks were used to measure phonological short-term memory. The stimuli consisted of 12 English-like nonwords (*kog, buice, jat, dook, challoon, pookie, kuppy, bicken, bajapop, tellina, lolemas,* and *panaphone*) and 12 Spanish-like nonwords (*lan, trus, sen, pol, vato, meca, lesa, gache, gañeca, mullina, peballo,* and *calota*). These nonwords were constructed from real words taken from the MacArthur–Bates Communicative Development Inventory (CDI) (Fenson et al., 1993) for 16- to 30-month-olds and its Spanish version, the Inventario del Desarrollo de las Habilidades Comunicativas (IDHC) (Jackson-Maldonado et al., 2003). All of the sounds that occur in the real words also occur in the nonword stimuli in the same word positions, and the nonwords followed the same phonotactic frames and stress patterns as the real words from which they were derived. Thus, the nonwords were phonologically like the words children acquire at this age in each language. We excluded late-developing sounds, such as English /r/ and Spanish trilled /r/ (as have others, e.g., Shriberg et al., 2009), because we wanted to ensure that children's errors were based on repetition abilities rather than on articulation abilities to the degree possible. There were four one-syllable, four two-syllable, and four three-syllable nonwords in each language. The monosyllabic nonwords were constructed by interchanging the onsets and rhymes of the monosyllabic real words. The bisyllabic nonwords were formed by combining the onset of the first syllable of one real word with the rhyme and second syllable of another real word. The trisyllabic nonwords were a combination of the first, second, and third syllables of three different real words for English and a combination of the onset and nucleus of one real word with the second and third syllables of another real word for Spanish.

The procedure used to assess nonword repetition accuracy followed the procedure developed and validated by Hoff and colleagues (2008) to assess nonword repetition in children as young as 20 months. The nonwords were presented orally by an examiner who was a native speaker of the language that was the basis of the nonwords presented. The tasks using English- and Spanish-like stimuli were administered on different days. For 34 children the sessions occurred in the children's homes, and for 7 children they occurred in a laboratory playroom, depending on the caregivers' preferences. Stimuli were presented in a standard way, embedded in a toy play activity. The examiner's face was always visible to the children. The procedure was as follows: After a warm-up period, children were presented with nonwords one at a time. The nonwords were accompanied by toys representing animals or people. Participants were told that the nonwords were the names of these toys and were asked to repeat them back. For instance, children were told, "This guy is named *Kog.* Can you say *Kog*?" The session started with two training trials. After two successful repetitions, the test stimuli were presented. Children were provided up to three presentations if they did not repeat the first or second presentation. The first repetition children produced was scored. Children's productions were recorded for later transcription. If a child failed to repeat six consecutive stimuli, the session was terminated. Only children who attempted to repeat at least three nonwords in either of the languages were included.

The accuracy of nonword repetition was measured by calculating the percentage of consonants presented that were repeated correctly (PCC), which is the most widely used measure of repetition accuracy (Coady & Evans, 2008). Percentage correct was used rather than total number correct because of differences in the number of possible consonants presented that existed between the English- and Spanish-like stimuli and because not all stimuli were presented to children if they failed to repeat six consecutive stimuli. The scoring of repetition accuracy for English-like stimuli was done by an expert phonetician and a graduate student trained in phonetic transcription, both of whom were native English speakers. The scoring of repetition accuracy for Spanish-like stimuli was done by the expert phonetician, a fluent Spanish speaker, and two graduate students trained in phonetic transcription, both of whom were native speakers of Spanish. Disagreements were resolved by discussion until consensus was reached.

Language exposure

The percentages of the children's language exposure that were in English and Spanish were estimated by the primary caregivers using the Home Language Environment Questionnaire (HLEQ). The HLEQ is a 145-item interview protocol designed for this study based on an instrument developed by Marchman and colleagues (2004). As part of the larger study from which these data are drawn, caregivers' estimates of their children's language exposure were validated against language diary data; a total of 33 mothers kept language diaries in which they recorded the language their children were exposed to for each waking 30-min period of 7 days. The correlation between caregivers' estimates of the percentage of their children's language input that was in English and the number of hours per day of English exposure recorded in diary logs was high, $r(29) = .71$, $p < .001$. The diary data also revealed that English was more prevalent in children's language exposure outside the home than inside the home; thus, the estimates of home language exposure were underestimates of the proportion of the children's language exposure that was in English (Place & Hoff, 2010). Including out-of-home exposure, the children in the current sample heard more English than Spanish, on average. The caregivers' estimates of the relative amount of exposure do not, of course, capture all of the variability in these children's dual language experience. There was no measure of the absolute quantity of exposure to either language. However, the diary data suggest that these are valid estimates of relative exposure, and relative differences in exposure are likely to be related to differences in the quantity of exposure unless there are systematic differences in the amount of talk addressed to children related to the balance of English and Spanish addressed to children. We compared the levels of parental education among Spanish-dominant, balanced, and English-dominant households and found no difference. That finding argues against one potential confound between relative balance and absolute amount of child-directed speech.

Language development

Vocabulary and grammar in English and Spanish were assessed using caregiver report inventories, the CDI (Fenson et al., 1993), and the IDHC (Jackson-Maldonado et al., 2003). Vocabulary size was calculated from part I of the CDI and IDHC, "Words Children Use." This part contains 680 words of different lexical categories, including nouns, verbs, adjectives, prepositions, pronouns, and articles. Parents were asked to indicate the words they heard their children say.

The measure of grammatical development was calculated from part II of the CDI and IDHC, "Sentences and Grammar." In this section, parents are presented with 37 pairs of sentences. Each pair contains one sentence that is more complex than the other. Parents are asked to select the sentence that is more representative of the sentences their children use. The number of times they chose the more complex sentence was calculated.

Procedure

Recruitment was carried out through electronic advertisements and advertisements in local magazines for parents of young children, through word of mouth, and by contacting parents at library events and preschools. In exchange for their participation, children received a T-shirt and a toy and caregivers received a $25 gift card at each visit. The data for the current study were collected when the children were 22 and 25 months of age. At 22 months, the nonword repetition tasks in English and Spanish were administered on separate days within a week of each other. The primary caregivers were contacted later, when their children were 25 months of age, to complete the communicative development inventories. When possible, English and Spanish native speakers completed the English and Spanish versions, respectively; otherwise, caregivers who were proficient Spanish–English bilinguals completed both inventories.

Results

The means and standard deviations for the measures of the relative amount of English language exposure at home, nonword repetition accuracy for English- and Spanish-like stimuli at 22 months of age, and raw vocabulary and grammatical complexity scores in English and Spanish at 25 months of age are presented in Table 1. Almost exactly half of the children's language exposure at home was to English, on average, but recall that the language diary data available for a subset of these children indicated that language exposure outside the home is more dominated by English (Place & Hoff, 2010). Children's scores for measures of phonological memory, vocabulary, and grammar were significantly higher in English than in Spanish for nonword repetition accuracy, $t(40) = 2.07$, $p < .05$, for vocabulary size, $t(40) = 2.98$, $p < .01$, and for grammatical complexity of speech, $t(40) = 2.22$, $p < .05$ (all two-tailed). This pattern is consistent with the children's greater exposure to English than to Spanish outside the home suggested by the language diary data, but these findings should be interpreted cautiously because none of the instruments is calibrated to provide a basis for comparing the children's skill across languages. (There were no gender-related differences on any of these measures).

Relation of language exposure to phonological memory and language development

The percentage of children's home language exposure that was in English was positively related to their nonword repetition accuracy for English-like stimuli, $r(n = 41) = .26$, $p = .05$ (one-tailed), and unrelated to their nonword repetition accuracy for Spanish-like stimuli, $r(n = 41) = -.05$, $p = .37$ (one-tailed). Because repetition accuracy for English- and Spanish-like stimuli was not independent (see Table 3), a clearer test of the hypothesis that language exposure benefits the development of language-specific phonological memory skills is the correlation between language exposure and

Table 1
Means (and standard deviations) for bilingual children's English language exposure, nonword repetition accuracy, vocabulary size, and grammatical complexity in English and Spanish ($N = 41$).

Variable	Mean (SD)
Percentage of home language input in English	49.88 (29.12)
English nonword repetition accuracy at 22 months[a]	35.05 (25.92)
Spanish nonword repetition accuracy at 22 months[a]	29.86 (24.51)
English vocabulary at 25 months[b]	240.80 (159.78)
Spanish vocabulary at 25 months[c]	142.41 (112.07)
English grammatical complexity at 25 months[b]	7.19 (9.36)
Spanish grammatical complexity at 25 months[c]	3.02 (6.32)

[a] Percentage consonants correctly repeated (PCC).
[b] Raw scores on the CDI.
[c] Raw scores on the IDHC.

repetition accuracy in one language when the variance shared with repetition accuracy in the other language is held constant. Both were significant, $r(n = 41) = .50$, $p = .001$ (one-tailed), for English nonword repetition and $r(n = 41) = -.45$, $p = .004$ (one-tailed), for Spanish nonword repetition. These findings indicate that with the shared variance in these two tasks removed, relative language exposure accounted for a significant 25% of the variance in performance on English-like stimuli and a significant 20% of the variance in performance on Spanish-like stimuli.

Correlations between relative language exposure and the measures of vocabulary and grammatical development assessed at 25 months are presented in Table 2. English exposure showed a strong positive relation to English vocabulary and grammar and showed a strong negative relation to Spanish vocabulary and grammar.

Relations of phonological memory to language development

In Table 3, zero-order correlations among the phonological memory and oral language measures are presented in lines 1–6, and these same correlations with effects of the relative amount of exposure to English held constant are presented in lines 7–12. In the zero-order correlations, phonological memory skill for English-like stimuli was strongly and positively related to that for Spanish-like stimuli (line 1). Phonological memory skill for English-like stimuli was significantly related to English vocabulary and English grammar but not to Spanish vocabulary or grammar (line 1). Phonological memory skill for Spanish-like stimuli was significantly related to Spanish vocabulary and Spanish grammar but not to English vocabulary or grammar (line 2). English vocabulary was related to English grammar (line 3), and Spanish vocabulary was related to Spanish grammar (line 4). There was a significant negative cross-language correlation between English vocabulary and Spanish grammar (line 3). The cross-language correlation between Spanish vocabulary and English grammar was nonsignificant (line 4).

All of the zero-order correlations among measures of phonological memory and oral language development are influenced by the common effects of language exposure on those variables. Because exposure to English and Spanish were measured as proportions of input, these two measures are necessarily negatively related. Thus, to the degree that any of the other measures depend on input, the trade-off between the relative amount of exposure to English versus Spanish pushes within-language correlations in a positive direction and pushes across-language correlations in a negative direction. Marchman and colleagues (2004) argued that appropriate estimation of within- and across-language effects requires holding constant the effects of language exposure. In contrast to the pattern of language-specific effects seen in the zero-order correlations, the partial correlations observed in this study suggested both within- and across-language relations between phonological memory skill and language development.

The problem with these partial correlations, however, is that removing effects of language exposure in assessing relations between phonological memory and language removes exactly the language-specific variance in phonological memory skill that would be the basis of a language-specific effect of phonological memory on language development. We argue that a better test of the hypothesis that language exposure supports the development of language-specific phonological memory skills

Table 2
Correlations between percentage of language exposure in English at 22 months of age and vocabulary size and grammatical complexity in English and Spanish ($N = 41$).

Variable	r
1. English vocabulary at 25 months	.72***
2. Spanish vocabulary at 25 months	−.57***
3. English grammatical complexity at 25 months	.58***
4. Spanish grammatical complexity at 25 months	−.45**

** $p < .01$ (one-tailed).
*** $p < .001$ (one-tailed).

Table 3
Correlations among nonword repetition accuracy at 22 months of age and vocabulary and grammar at 25 months of age within and across languages ($N = 41$).

(A) Zero-order correlations

Variable	1	2	3	4	5	6
1. English nonword repetition	–	.80***	.54***	.23	.49***	.18
2. Spanish nonword repetition		–	.23	.39**	.22	.28**
3. English vocabulary			–	−.19	.84***	−.29*
4. Spanish vocabulary				–	−.17	.61***
5. English grammatical complexity					–	−.15
6. Spanish grammatical complexity						–

(B) Partial correlations holding constant relative language exposure

Variable	7	8	9	10	11	12
7. English nonword repetition	–	.84***	.52**	.47***	.43**	.34*
8. Spanish nonword repetition		–	.38**	.44**	.31*	.29*
9. English vocabulary			–	.38*	.75***	.06
10. Spanish vocabulary				–	.24	.48**
11. English grammatical complexity					–	.15
12. Spanish grammatical complexity						–

* $p < .05$ (one-tailed).
** $p < .01$ (one-tailed).
*** $p < .001$ (one-tailed).

that, in turn, support language development can be accomplished using hierarchical regression to first remove effects of phonological memory skill in the other language so as to estimate, in the second step, the variance accounted for by language-specific phonological memory skill. A third step provides estimates of the effects of input that are not mediated by language-specific phonological memory skill. The results of those regressions with English vocabulary and grammar and Spanish vocabulary and grammar as outcomes are presented in Tables 4 and 5. They suggest that after the shared variance with phonological memory skill for Spanish-like stimuli is removed, variance in phonological memory skill for English-like stimuli uniquely accounts for a significant 35% of the variance in English vocabulary and 27% of the variance in English grammar. Language exposure accounts for an additional significant 25% and 15% of the variance in these outcomes, respectively. (The percentage of language

Table 4
Hierarchical regression analyses predicting English vocabulary and grammar at 25 months of age ($N = 41$).

Predictor	R^2	ΔR^2
Outcome: English vocabulary at 25 months of age		
Step 1: Spanish nonword repetition at 22 months	.05	.05
Step 2: English nonword repetition at 22 months	.40	.35***
Step 3: Language exposure at 22 months	.65	.25***
Outcome: English grammar at 25 months of age		
Step 1: Spanish nonword repetition at 22 months	.05	.05
Step 2: English nonword repetition at 22 months	.32	.27***
Step 3: Language exposure at 22 months	.47	.15**

** $p < .01$.
*** $p < .001$.

Table 5
Hierarchical regression analyses predicting Spanish vocabulary and grammar at 25 months of age ($N = 41$).

Predictor	R^2	ΔR^2
Outcome: Spanish vocabulary at 25 months of age		
Step 1: English nonword repetition at 22 months	.05	.05
Step 2: Spanish nonword repetition at 22 months	.17	.12**
Step 3: Language exposure at 22 months	.48	.31***
Outcome: Spanish grammar at 25 months of age		
Step 1: English nonword repetition at 22 months	.03	.03
Step 2: Spanish nonword repetition at 22 months	.08	.05
Step 3: Language exposure at 22 months	.29	.21**

** $p < .01$.
*** $p < .001$.

exposure that is English is a positive predictor of English outcomes and a negative predictor of Spanish outcomes.) After the shared variance with phonological memory skill for English-like stimuli is removed, variance in phonological memory skill for Spanish-like stimuli uniquely accounts for a significant 12% of the variance in Spanish vocabulary; the relation to Spanish grammar was not significant. Language exposure accounts for an additional 31% and 21% of the variance in these outcomes, respectively.

Discussion

In this study, the relations among Spanish–English bilingually developing children's relative amount of exposure to each of their languages, their phonological memory skills in each language (measured at 22 months of age), and their productive vocabulary size and grammar in each language (measured at 25 months of age) were examined in a sample of children who had been exposed to both languages from birth. The study made use of variability in these children's relative exposure to their two languages to estimate the degree to which phonological memory skills depend on language experience and the degree to which the value of phonological memory to language acquisition might also be language specific.

There was evidence in the data that phonological memory skill is in part dependent on language experience. Relative exposure to English accounted for a significant 25% of the variance in children's phonological memory for English-like stimuli that was not shared with variance in phonological memory for Spanish-like stimuli, whereas relative exposure to Spanish accounted for 20% of the unique variance in phonological memory for Spanish-like stimuli. Because the stimuli were not real words but rather were sound sequences that conformed to the phonological properties of each language, we hypothesize that these relations reflect the effect of language exposure that resulted in the children's building mental representations of the phonemes and phonotactics of each language. These representations are the knowledge-based component of phonological memory skill. This finding and interpretation are consistent with evidence in the literature that children show more accurate nonword repetition for stimuli that are more word-like (Gathercole et al., 1991) and that adults and children (Thorn & Gathercole, 1999) show more accurate nonword repetition for their own language than for a foreign language (Service & Kohonen, 1995).

The strong positive correlation between phonological memory skill for English-like stimuli and that for Spanish-like stimuli (shared variance of 64%) suggests that the ability to repeat sequences of phonemes in these two languages is also dependent on a common underlying ability. This common underlying ability likely includes a general auditory memory capacity that does not make use of any particular knowledge base. The correlation between phonological memory for English-like stimuli and that for Spanish-like stimuli may also reflect the fact that there is substantial overlap between the phonemes of English and those of Spanish; thus, the knowledge base that supports phonological memory for English- and Spanish-like stimuli is in part a single knowledge base. The current data do not provide a way to partition the variance that is shared between English and Spanish phonological memory skills into that which depends on a general capacity and that which reflects phonological overlap. Research on bilingual children acquiring languages that differ more in their phonological properties may be able to address this question.

Despite the overlap between English and Spanish phonologies, there was evidence of language-specific relations between these children's phonological memory skills and their vocabulary and grammatical development in each language. That is, 35% of the variance in English vocabulary and 27% of the variance in English grammar were attributable to variance in phonological memory for English-like stimuli after the variance shared with memory for Spanish-like stimuli was removed, whereas 12% of the variance in Spanish vocabulary was attributable to variance in phonological memory for Spanish-like stimuli after the variance shared with memory for English-like stimuli was removed. Phonological memory for Spanish-like stimuli did not uniquely account for variance in Spanish grammar, but floor effects on the grammar measure limited its value. Language exposure made additional direct contributions to explaining variance in all outcomes. These findings are consistent with the hypothesis proposed by Hoff and colleagues (2008) that, in addition to direct influences of language exposure on language development, exposure has indirect influences mediated by phonological memory skill.

Although the relation of language exposure to phonological memory and the relation of phonological memory to vocabulary and grammar were the foci of this investigation, the current study also provided data on the relation of language exposure to vocabulary and grammar and data on the within- and across-language relations between vocabulary and grammar. The proportion of children's home language exposure that was English was a significant positive predictor of their English vocabulary and grammar and was a significant negative predictor of their Spanish vocabulary and grammar. These findings are consistent with the results of previous studies of bilingual children (Pearson et al., 1997), with other findings from the larger study from which this sample was drawn (Hoff et al., 2010), and with a large body of evidence from the study of monolingual children that the amount of language input children receive predicts the rate of their language development (Hoff, 2006).

The current data also showed strong correlations between vocabulary size and grammar within-languages but not across languages, replicating findings by Marchman and colleagues (2004) and Conboy and Thal (2006). The process underlying these correlations is a topic of some controversy but is likely to reflect both mutual influences between vocabulary and grammatical development and the influence of a common cognitive capacity on both (Conboy & Thal, 2006; Dionne, Dale, Boivin, & Plomin, 2003; Marchman et al., 2004; Naigles, Hoff, & Vear, 2009). Finally, the current data showed that with effects of language exposure held constant, children's vocabulary size in English was highly correlated with that in Spanish and that the grammatical complexity of children's English was unrelated to that of their Spanish. The positive relation between English and Spanish vocabularies suggests a common underlying capacity that serves vocabulary development in both languages, and the other findings from this study suggest that phonological memory is likely to be at least a component of that common underlying capacity. The implication of the nonsignificant correlation between English and Spanish grammar is less clear, but many children were at zero on this measure (particularly for Spanish) and that lack of variance may be the explanation for the null finding.

The current findings leave several questions unaddressed. The data are only correlational, and it may be that the influence between phonological and lexical development also operates in the direction of vocabulary growth, prompting phonological reorganization as some theories posit (Beckman & Edwards, 2000; Metsala & Walley, 1998). If so, then the relations among language exposure, the development of phonological memory skill, and the growth of vocabulary and grammar are spiraling mutual influences rather than unidirectional, but the language specificity of those relations still holds.

In sum, the current findings replicate in young bilingual first language learners the relation between phonological memory skill and language development that has been well demonstrated in monolingual development (Gathercole, 2006). This finding, in combination with the finding that children's phonological memory for English-like stimuli was related to their relative amount of English exposure, supports the hypothesis suggested by Hoff and colleagues (2008) that children's phonological memory skills develop in part as a result of their building phonological representations that support storage of newly encountered sound sequences that conform to the learned phonological system. The current findings that phonological memory for English-like stimuli uniquely accounted for variance in English language skill and that phonological memory for Spanish-like stimuli uniquely accounted for variance in Spanish language skill support the proposed function of phonological memory as temporary storage of individual exemplars of words and sentences as they are encountered, which in turn provides a database for the abstraction of lexical items and grammatical patterns (Gathercole, 2006; Speidel, 1993). Finally, the findings that language exposure showed language-specific relations to phonological memory and to language development and that phonological memory partially mediated the effect of exposure on development suggest that language exposure benefits language development both directly, as the source of the database on which learning depends, and indirectly, as an influence on the capacity to temporarily store that database.

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