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Nonword Repetition and Interactions Among Vocabulary, Phonotactic probability, and Phonological Awareness in Four Linguistic Groups

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Nonword Repetition Performance and Related Factors in Children Representing Four Linguistic Groups

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Abstract

The current study was designed to compare the English nonword repetition accuracy in 7-year-old monolingual English, Korean–English bilingual, Chinese–English bilingual, and Spanish–English bilingual children. The relationships among nonword repetition accuracy, vocabulary, phonological awareness, and phonotactic probability in each group of children were also examined. The results indicated significant differences among the groups' accuracy of consonants and vowels by syllable length. Different correlational patterns emerged among nonword repetition accuracy, vocabulary, and phonological awareness. Theoretical and clinical implications for the use of nonword repetition tasks for children from various linguistic backgrounds are discussed.

Keywords bilingual, Chinese, Korean, nonword repetition, phonological awareness, phonotactic probability, Spanish, vocabulary

Introduction

Investigations designed to enhance our understanding of children's phonological short-term memory (PSTM) skills have been of intense interest in recent years. PSTM is considered to be a limited-capacity storage buffer that is responsible for temporary maintenance of phonological information and related to a vast array of linguistic and academic skills. For example, research has indicated significant relationships between PSTM and vocabulary development (Edwards, Beckman, & Munson, 2004; Gathercole & Baddeley, 1990; Gathercole, Willis, Emslie, & Baddeley, 1992), morphosyntactic development (Adams & Gathercole, 1995; Thordardottir, 2008), and sentence comprehension (Montgomery, 1995). PSTM skills also appear to be significantly related to reading acquisition and comprehension (Gathercole et al., 1992). Some evidence suggests that performance on simple span tasks designed to tap PSTM is as predictive of reading and math skills as more complex span memory tasks (Bayliss, Baddeley, & Gunn, 2005).

Theoretical perspectives of PSTM

Numerous ideas exist about memory skills as related to how individuals process, store, and retrieve information (for a review, see Montgomery, Magimairaj, & Finney, 2010). While some evidence indicates that short-term memory and working memory are separate constructs (Engle, Tuholski, Laughlin, & Conway, 1999), the most widely recognized conceptualization of PSTM is based on the well-known model of working memory proposed by Baddeley and Hitch (1974), composed of a central executive and two subsystems, the phonological loop and the visuospatial sketchpad. Another subsystem, the episodic buffer, responsible for storing information as chunks, was later added to the model (Baddeley, 2000). The central executive is a limited-capacity system that is responsible for control and regulation of cognitive processes, including attention, inhibition, coordination of tasks, and retrieval from long-term memory. The phonological loop is currently the most thoroughly investigated component of their working memory model. The short-term storage function of the phonological loop is thought to be responsible for coding stable phonological representations, and these coding and storage abilities are believed to contribute to the aforementioned linguistic and academic skills.

Nonword repetition

Nonword repetition (NWR) appears to be the PSTM task of choice in language assessment research (e.g. Bishop, North, & Donlan, 1996; Botting & Conti-Ramsden, 2001; Dollaghan & Campbell, 1998; Ellis Weismer et al., 2000). In this task, children listen to a series of nonwords that are presented live by an examiner or via a digitized recording and are expected to repeat each nonword verbatim. Stimuli generally range from one to five syllables in length. Unsurprisingly, children tend to exhibit greater accuracy on shorter than longer nonwords (Archibald & Gathercole, 2006; Graf-Estes, Evans, & Else-Quest, 2007). Beyond that, tests vary in their inclusion of tense versus lax vowels, singleton versus clustered consonants, and stress patterns (Archibald & Gathercole, 2006). In a meta-analysis of 23 studies meeting quality guidelines, Graf-Estes et al. (2007) found that children with specific language impairment (SLI) displayed NWR skills an average of 1.27 standard deviations below the mean score of typically developing children. Moreover, some research indicates that NWR tasks are less culturally biased than many other language measures (Ellis Weismer & Evans, 2002; Engel, Santos, & Gathercole, 2008; Rodekohr & Haynes, 2001). Consequently, researchers have recommended including NWR tasks in the language assessment of children from diverse cultural backgrounds, which is resulting in their increased presence on standardized language assessments. However, further insight into how various linguistic backgrounds may influence NWR performance is needed, which was the primary motive for the current investigation.

NWR in bilinguals

The vast majority of studies investigating children's NWR performance have been conducted with monolingual English speakers. English ranks third after Mandarin and Spanish as the most spoken language in the world (Lewis, 2009). In the United States, approximately one in five children aged 5 years and older speaks a native language other than English; Spanish is the next most common language, with Chinese and Korean within the top seven (U.S. Bureau of the Census, 2006). Research with speakers of other languages has increased, particularly to explore relationships between NWR performance and English language development, yet continued investigation with children from diverse linguistic backgrounds is of interest.

A number of recent studies have examined the NWR performance of Spanish–English (SE) bilingual children. Kohnert, Windsor, and Yim (2006) compared the English NWR performance of English monolinguals with typical language, SE bilinguals with typical language, and English monolinguals with language impairment, all between 7 and 13 years of age. They found the highest accuracy in the English monolinguals with typical language, followed by the SE bilinguals and then the English monolinguals with language impairment, with insufficient overall diagnostic accuracy. Summers, Bohman, Gillam, Pena, and Bedore (2010) examined the NWR skills of Spanish-speaking English language learners between the ages of 4 and 6 and found higher performance on shorter Spanish and English nonwords than on longer nonwords, a finding consistent with other studies (Ebert, Kalanek, Cordero, & Kohnert, 2008; Girbau & Schwartz, 2008; Kohnert et al., 2006). The authors suggest that children who have more experience with languages, which contain numerous multisyllabic words, such as Spanish, may be more efficient at repeating longer nonwords regardless of the language upon which the nonwords are based. As children's language dominance shifts, however, their performance may change. Windsor, Kohnert, Lobitz, and Pham (2010) examined both English and Spanish NWR performance in typically developing English monolinguals and SE bilinguals, and also in English monolinguals and SE bilinguals with language impairment. Children ranged from 6 to 11 years of age with a mean age of 8 years. Results indicated a significant correlation between children's NWR performance in English and Spanish, with higher accuracy in their native language. English monolinguals, both those with typical language and those with impaired language, performed better on English nonwords containing one to three syllables than their bilingual peers.

Factors related to NWR performance

While NWR tasks have long been used to tap PSTM skills, more recent research indicates that NWR skills both tap into and are influenced by several factors such as vocabulary knowledge and phonological awareness (PA) (Coady & Evans, 2008; Edwards et al., 2004). Indeed, research has shown that the relationships between these skills appear to be quite complex (e.g., Gathercole, Willis, & Baddeley, 1991). Gillam and van Kleeck (1996), for example, provided compelling evidence of the association between NWR and PA even early in development. Specifically, they examined preschoolers over the course of an academic year and found that their phonological coding abilities, as measured by NWR, improved as a direct result of PA training.

Vocabulary skills are thought to support NWR because children may use the phonological templates of real words as analogies to support their recall of unfamiliar words (Snowling, Chiat, & Hulme, 1991). To probe the role of vocabulary in NWR performance further, several researchers have recently analyzed the association between vocabulary and repetition accuracy of nonwords as composed of high and low phonotactic probabilities. Edwards et al. (2004), for example, reported that English-speaking children more accurately produced nonwords with high phonotactic probability than nonwords with low probability. Moreover, this probability effect was even more robust in children with small vocabularies. Extending this study, Munson, Edeards, and Beckman (2005) found that, of several measures including articulation and speech perception skills, only vocabulary significantly predicted this probability effect in NWR performance. They proposed that children's ability to successfully repeat nonwords with low phonotactic probability may depend upon having a rich representational system as acquired through having a large vocabulary. In light of these findings, one may speculate that the English vocabulary skills of bilingual speakers will also have significant influence on their English NWR accuracy according to the phonotactic probability of the stimuli, a possibility that was examined in the current study.

Related factors in bilingual

In the field of second language acquisition, several researchers have examined the potential influence of NWR on children's vocabulary acquisition in their second language (L2). The results from numerous studies have suggested that children with stronger PSTM skills also achieve higher English (L2) skills than children with weaker PSTM skills (Cheung, 1996; Kormos & Safar, 2008; Masoura & Gathercole, 1999; Service, 1992). Cheung (1996) split his Cantonese-speaking sample and found that nonword span predicted English vocabulary learning for the low-English vocabulary group but not for the high-English group, suggesting that the role of PSTM in new word learning may decline as learners develop higher proficiency in and phonological knowledge of L2. Masoura and Gathercole (2005) found further support for this conclusion with Greek speakers. Kormos and Safar (2008), however, found that NWR and vocabulary were related in Hungarian students with higher English and but not in students with emerging English skills. They attributed these contrasting results to different learning processes, with more implicit learning in the higher English group and more explicit (e.g. memorization) learning in the lower group.

In research focusing on language and literacy development, between language and literacy, Gorman (in press) provides evidence for the significant interrelationships between PA, vocabulary, and working memory, including NWR skills, in SE bilingual children. Similar to what Gathercole et al. (1991) reported in English monolinguals, Gorman found dynamic relationships between these factors in bilinguals. Overall, the majority of research investigating the relationships between these factors has been conducted in English speakers. Relatively few studies have been conducted to help us understand contributors to NWR performance in children from various language backgrounds.

Purpose

Given the prevalent use of English NWR tasks in research and language assessments, there is a significant need for enhanced understanding of the performance on these tasks of children from various linguistic groups. Consequently, there were three primary objectives of the current study. The first was to evaluate whether there were any group differences between the English NWR performance of monolingual English, Korean–English (KE), Chinese–English (CE), and SE bilingual groups according to the composition of nonwords (i.e. consonants, vowels, syllable length, & phonotactic probability). The second objective was to examine the correlations between children's NWR, vocabulary, and PA skills in English to support interpretation of any performance differences across linguistic groups. As discussed previously, researchers have found that monolingual English children's vocabulary skills influenced their repetition accuracy on words containing high and low-probability sequences (Edwards et al., 2004; Munson et al., 2005). Due to our interest in understanding potential performance differences according to nonword composition, our third objective was to analyze whether the patterns of association between vocabulary skills and repetition accuracy of nonwords composed of high and low phonotactic probabilities were similar among monolingual and bilingual children. In addition, the findings from the current study may have important implications for using English NWR tasks with bilinguals, augment our understanding of factors that influence their performance on these tasks, and potentially, inform the composition of stimuli to enhance their utility for children from various linguistic backgrounds.

In line with past research, we anticipated observing some performance differences between linguistic groups. Group differences documented previously have been attributed to children's knowledge and experience with phonological characteristics that are salient in their respective languages (e.g. Gutierrez-Clellen & Simon-Cereijido, 2010; Summers et al., 2010). Consequently, to support interpretation of potential differences, a brief description of pertinent characteristics of the languages spoken by children in the current study follows.

Characteristics of the languages

English, Korean, Chinese, and Spanish have various similarities and differences in their phonological and orthographic systems, which are relevant to the variables under investigation. A summary of these systems is presented in Table 1. To describe a few key characteristics, relative to consonants, both English and Chinese have the same number of consonants and more than Korean and Spanish. In terms of vowels, English has a larger inventory of monophthongal vowels than Korean, Chinese, and Spanish, and the three latter languages do not have tense-lax distinctions such as /i / and /ɪ/. Chinese and Korean contain a larger number of diphthongs and triphthongs than English and Spanish. Then, predominant syllable shapes also vary by language, with a high frequency of monosyllabic words in English and Chinese, disyllable words in Korean, and multisyllabic words in Spanish.

Table 1. Linguistic characteristics of English, Korean, Chinese, and Spanish.

Language	No. of consonants	No. of vowels	Syllable structure	Dominant types of syllable in words	Writing system/ isomorphism
English	24	V:12, VV:5	$C_{(0-3)}V_{(1-2)}C_{(0-4)}$	Monosyllable	Roman alphabet, relatively weak 1 to 1 correspondence between sound and letter
Korean	19	V:7, VV:12	$C_{(0-2)}V_{(1-2)}C_{(0-1)}$	Disyllable	Korean alphabet (Hangul), strong 1 to 1 correspondence between sound and letter except for coda
Chinese	24	V:5, VV:9, VVV:4	$C_{(0-1)}V_{(1-3)}C_{(0-1)}$	Monosyllable	Logographic characters, no 1 to 1 correspondence between sound and letter; Pinyin system: strong isomorphism
Spanish	18	V:5,VV:6	$C_{(0-2)}V_{(1-2)}C_{(0-2)}$	Multisyllable	Roman alphabet, strong 1 to 1 correspondence between sound and letter

C = consonant;V = monophthong;VV = diphthong;VVV = triphthong.
Subscripts show range of elements by position.

In terms of phonotactic differences, English allows three-consonant clusters in word initial position, whereas Korean, Chinese, and Spanish allow two consonants. The second consonant in any clusters in Korean and Chinese is a glide. In word final position, English permits all consonants except /h/; Spanish allows six consonants (/d, j, l, n, r, s/); Korean allows stops (/p, t, k/), nasals (/m, n, ŋ/), and latera(/l/); and Chinese permits only nasals (/n, ŋ/).

In terms of the writing system, English, Korean, and Spanish are phoneme-based languages, while Chinese is a topographic language with no consonant or vowel symbols. Both Spanish and English use the Roman alphabet system, whereas Korean uses the Korean alphabet "*Hangul*." Spanish is considered to have a relatively transparent orthography because there is a nearly 1:1 correspondence between letters and sounds, with few exceptions. Korean has also strong sound and letter correspondence except for the coda. In contrast, English is considered to have an opaque, or deep, orthography because there is less consistency between sounds and letters. Since Chinese is a topographic language, it adopts the Roman alphabet to represent pronunciation in the system called "*pinyin*." Chinese students learn both Chinese characters and pinyin when they start to learn Chinese in China and the United States.

Method

Participants

A total of 57 children (15 monolingual English, 15 KE, 15 CE, 12 SE[1]bilingual children) living in the Midwestern United States participated in this study. All children were 7 years old and enrolled in first grade in public elementary schools with no speech, language, hearing, or other health problems based on parent and teacher report.

The monolingual English speakers had no previous intensive learning of any language other than English. Bilingual children acquired their home language first and began learning English upon entering English day care, preschool, or kindergarten settings. At the time of this study, they communicated primarily in English with siblings and peers at school and the native language (i.e. Korean, Chinese, or Spanish) with parents and grandparents. Table 2 shows the distributions of the number of bilingual children in each category of onset of English language exposure among the three groups. A *Kruskal–Willis* one-way ANOVA indicated no significant difference in the average onset of English language exposure age among the three bilingual groups (z = 0.271, df = 2, p = 0.873). We did not obtain exact information on individual participants' socioeconomic background (e.g. income or mother's educational level). However, the monolingual English, KE, and CE bilingual children attended schools located in neighborhoods of higher median household incomes than the SE bilingual participants.

Table 2. Number of bilingual children per each category of onset of English exposure.

Onset of English language exposure	No. of KEB children	No. of CEB children	No. of SEB children
Birth–before 3	1	2	3
After 3–before 5	7	8	3
After 5	7	5	6

KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English Bilingual.

Data collection procedures

Trained examiners tested children individually in their home, school, or church. Testing was completed during one session lasting approximately 1 hour. A short break was given as necessary. NWR, vocabulary, and PA tasks were administered in random order.

The NWR stimuli were composed of four different syllable lengths ranging from two to five syllables. These nonwords were adopted from two previous studies (i.e. Edwards et al., 2004; Gathercole, Willis, Baddeley, & Emslie, 1994). Edwards et al. (2004) developed a list of 22 two- and three-syllable nonwords pairs (a total of 44 words) designed specifically to contain high and low CV (consonant–vowel), VC, or CC phonotactic sequences. For example, the two-syllable–paired nonwords/bogib/and/jugoin/ were classified as having high and low CV phonotactic probability, respectively, because the underlined /gi/ occurs in high frequency while /goi/ occurs in low frequency in English. Beyond the target CV sequence, the remaining consonants in the nonword pairs were constructed similarly in terms of phonetic components, prosodic position, and age of acquisition. Edwards et al. reported an average word-likeness score of 2.79 out of 5 for their nonword set. In addition, to examine children's accuracy on longer nonwords, 20 nonwords containing four and five syllables from Gathercole et al. (1994) were also adopted. Although Gathercole et al. did not report a word-likeness score, they did indicate that their nonwords were constructed to correspond to the legal phonotactic and stress patterns in English. In total, 64 nonwords were used in the current study.

The adopted nonwords were produced by two native English speakers with a Midwest dialect[2] and recorded in random order using the Computerized Speech Lab system (CSL, model 4300, Kay Elemetrics). Prior to the formal assessment, the examiner presented two to three practice items using her live voice to each child. Participants were instructed to repeat the nonwords as accurately as possible. The targeted nonword stimuli were then presented once or twice per token over two external speakers from a laptop computer. Each participant's repetitions were recorded with a stand-mounted, omnidirectional dynamic microphone (Electro-Voice 635A/B), which was positioned on a table and connected to a digital recorder (Marantz Model PMD670).

English vocabulary skills were measured using the Peabody Picture Vocabulary Test–4 (PPVT-4; Dunn & Dunn, 2007). The PA section of the Emerging Literacy and Language Assessment (ELLA) (Wiig & Secord, 2006) was administered to examine PA. The seven subtests within PA included letter–sound identification, rhyming, initial sound identification, blending, segmenting, deletion, and substitution.

Standardized administration and scoring procedures as outlined in the test manuals were used for both tests.

Data analysis

The participants' nonword productions were stored in wave file format. For transcribing the nonword production, Adobe Audition waveform editor was used so that each nonword could be played as often as necessary. All responses were transcribed by native English speakers using the International Phonetic Alphabet (IPA). A second transcriber independently transcribed 20% of each participant's consonant or vowel productions for each syllable length. Phoneme-by-phoneme interrater reliability was calculated. The mean reliability was 89% for consonants and 87% for vowels. The reliability ranged from 77% (vowels in five-syllable nonwords in the SE bilingual group) to 98% (consonants in two-syllable nonwords in the CE group). All data were entered into the Logical International Phonetics Program (LIPP) (Oller & Delgado, 1990). The LIPP program was used to analyze the accuracy of consonant and vowel production in the four lengths of nonwords. The percentage of consonants correct (PCC) and the percentage of vowels correct (PVC) were calculated by dividing the number correct by the total number and multiplying the result by 100. Next, the percentages of consonants and vowels produced correctly in sequences representing high versus low phonotactic probabilities were calculated using the same formula.

Statistical design

An analysis of variance (ANOVA) was performed to address the first research objective of evaluating whether there were any group differences between the English NWR performances of monolingual English (ME), KE, CE, and SE bilingual groups according to the composition of nonwords. The PCC and PVC were the dependent variables. Language group (four levels: ME, KE, CE, and SE), syllable length (four levels: 2, 3, 4, and 5 syllable), and phoneme type (two levels: consonants and vowels) were the independent variables. Another ANOVA was conducted to compare NWR accuracy of high and low phonotactic probabilities among the four groups. The NWR accuracy of high and low sequences was the dependent variable, and phonotactic probability and language group were the independent variables. Pearson product-moment correlation analyses were conducted for each language group separately to address the second research objective of examining the relationship between children's NWR, vocabulary, and PA in English to assist with the interpretation of potential performance differences across groups. Although not a goal of this present study, per se, we also performed an ANOVA to compare vocabulary and PA skills across the four groups to enhance our understanding of the bilingual children's overall linguistic performance. Standard scores of the PPVT and ELLA were the dependent variables and language group was the independent variable. To address the third objective, correlations were computed to explore whether patterns of association between English vocabulary skills and repetition accuracy of nonwords composed of high and low phonotactic probabilities were similar among monolingual and bilingual groups.

Results

NWR among monolingual and bilingual groups

The mixed ANOVA indicated a significant main effect of syllable length (F (3, 159) = 65.53, p = 0.001, η2p = 0.55) but no significant main effect for language group (F (3, 53) = 2.28, p = 0.09, η^2_p = 0.11) or phoneme type (F (1, 159) = 2.93, p = 0.092, η^2_p = 0.05). Two-way interactions between language group ×

phoneme type (F (3, 159) = 6.46, p = 0.001, η^2_p = 0.26), language group × syllable length (F (3, 159) = 2.25, p < 0.001, η^2_p = 0.11), and phoneme type × syllable length (F (3, 159) = 3.65, p = 0.016, η^2_p = 0.06) and the three-way interaction among language group × phoneme type × syllable length (F (9, 159) = 2.24, p = 0.025, η^2_p = 0.11) were significant.

Figures 1 and 2 show the PCC and PVC for each syllable length among the four groups. For consonants, post hoc comparison (using α = 0.05) indicated no significant differences among the language groups in the consonant accuracy for two- and three-syllable nonwords. However, SE bilingual children displayed a lower PCC for four-syllable nonwords than the ME group (p = 0.047) and both KE and SE bilingual groups displayed a lower PCC for five-syllable nonwords than the ME (p = 0.022 for KE; p = 0.010 for SE) and CE groups (p = 0.01 for KE; p = 0.005 for SE). For vowels, a post hoc comparison (using α = 0.05) indicated no differences across language groups in vowel accuracy for two-syllable nonwords. However, KE and CE children displayed a lower PVC for three-syllable nonwords than SE children (p = 0.001 for KE; p = 0.004 for CE). For four-syllable nonwords, CE children displayed lower PVC than ME children (p = 0.04), whereas KE children displayed a lower PVC than ME (p = 0.004) and SE bilingual children (p = 0.045). Finally, for five-syllable nonwords, KE children displayed a lower PVC than ME children (p = 0.025). Overall, as compared to ME and CE children, the KE bilinguals demonstrated lower accuracy on consonants in four- and five-syllable nonwords, and SE bilinguals demonstrated lower accuracy on consonants in five-syllable nonwords. In terms of vowels, as compared to ME and SE children, the KE group demonstrated lower accuracy on three-, four-, and five-syllable nonwords, and the CE group demonstrated lower accuracy on three- and four-syllable nonwords.

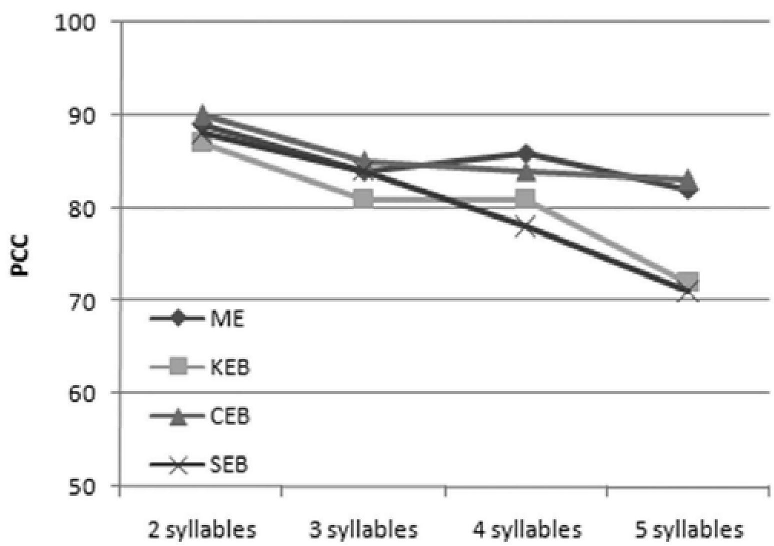

Figure 1. PCC in the four lengths of nonwords among the ME, KE, CE, and SE bilingual children.

PCC: percentage of consonants correct; ME: monolingual English; KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English bilingual.

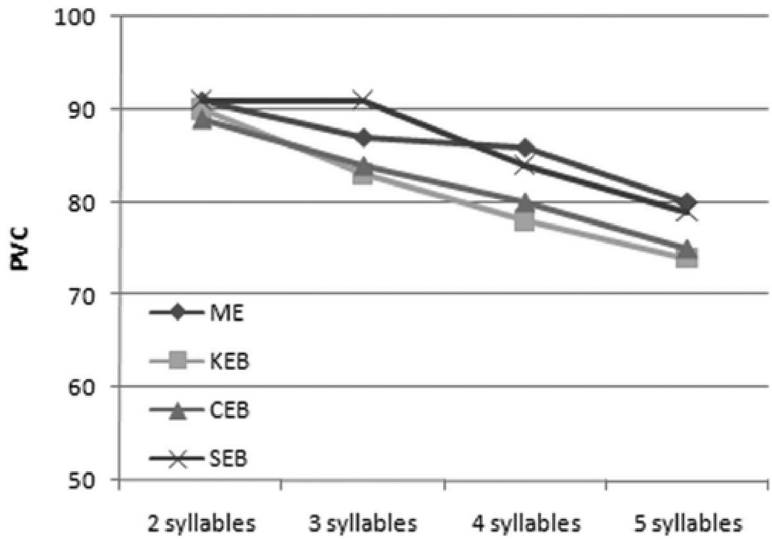

Figure 2. PVC in the four lengths of nonwords among the ME, KE, CE, and SE bilingual children.

PVC: percentage of vowels correct; ME: monolingual English; KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English bilingual.

Figure 3 shows the NWR accuracy for the high and low phonotactic probabilities for each of the four groups of children. A mixed ANOVA indicated a significant main effect for phonotactic probability (F (1, 53) = 101.17, $p < 0.001$, $\eta^2_p = 0.66$); however, no significant main effect for language group (F (3, 53) = 0.75, $p = 0.53$, $\eta^2_p = 0.04$) or significant interaction effect (F (3, 53) = 2.73, $p = 0.053$, $\eta^2_p = 0.13$) were found. Both monolingual and bilingual children produced high phonotactic probability with higher accuracy than low phonotactic probability.

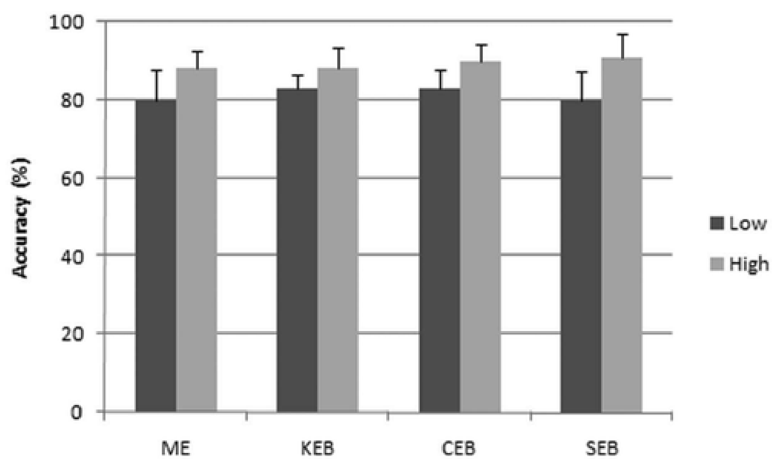

Figure 3. NWR accuracy of high and low phonotactic probabilities among the ME, KE, CE, and SE bilingual children.

NWR: nonword repetition; ME: monolingual English; KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English bilingual.

Related factors

Figure 4 shows standard scores of vocabulary as measured by the PPVT and of PA as measured by the ELLA for each of the four groups. A mixed ANOVA indicated a significant main effect for language group

($F(1, 53) = 4.88$, $p = 0.005$, $\eta^2_p = 0.21$) and a significant interaction between language group and task ($F(1, 53) = 3.25$, $p = 0.16$, $\eta^2_p = 0.05$). However, no main effect for task were found ($F(3, 53) = 0.018$, $p = 0.89$, $\eta^2_p = 0.00$). Post hoc comparisons indicated that the SE bilingual group's standard scores on the PPVT were significantly lower than the monolingual English ($p = 0.002$), KE ($p = 0.001$), and CE bilingual groups ($p = 0.023$). However, there were no significant differences in PA performance.

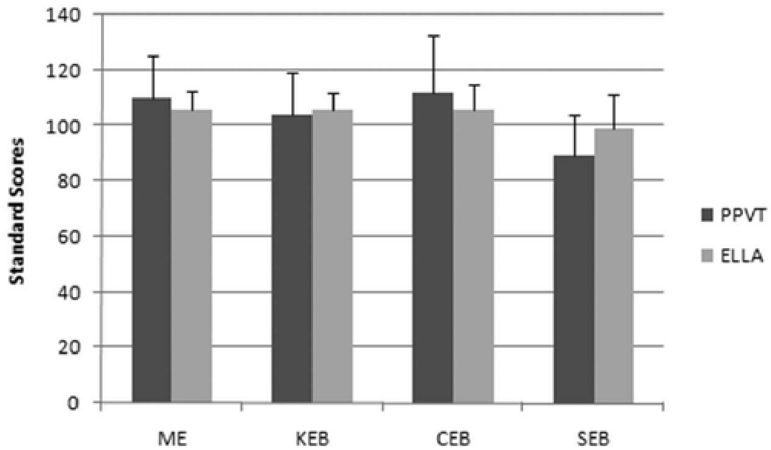

Figure 4. Standard scores of PPVT and ELLA among ME, KE, CE, and SE bilingual children.

PPVT: Peabody Picture Vocabulary Test; ELLA: Emerging Literacy and Language Assessment; ME: monolingual English; KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English bilingual.

Correlation analyses indicated various patterns of association among the four linguistic groups (see Table 3).Vocabulary and PA were significantly correlated with overall NWR accuracy in the ME, CE, and SE groups. Interestingly, there was no such relationship in the KE group.

Table 3. Correlations among overall NWR accuracy, vocabulary, and PA measured by PPVT and ELLA, respectively, for monolingual English (ME), KE, CE, and SE bilingual children.

	ME	KEB	CEB	SEB
PPVT	.722**	.007	.653**	.583*
ELLA	.600*	.120	.788**	.623*

NWR: nonword repetition; PA: phonological awareness; PPVT: Peabody Picture Vocabulary Test; ELLA: Emerging Literacy and Language Assessment; ME: monolingual English; KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English bilingual.
** $p < 0.001$, * $p < 0.05$.

Finally, there were significant relationships between vocabulary and repetition accuracy of high and low-probability sequences in the ME group, but these relationships were not significant in any bilingual group (see Table 4).

Table 4. Correlations among vocabulary and accuracy for high and low phonotactic probabilities for monolingual English (ME), KE, CE, and SE bilingual children.

	ME	KEB	CEB	SEB
High	.721**	−.077	.339	.143
Low	.762**	.217	.164	.501

ME: monolingual English; KEB: Korean–English bilingual; CEB: Chinese–English bilingual; SEB: Spanish–English bilingual.
** $p < 0.001$.

Discussion

In language assessment research, NWR appears to be the task of choice for measuring PSTM skills. In clinical practice, NWR tasks have been recommended as a component of less-biased child language assessment protocols (Ellis Weismer et al., 2000; Engel et al., 2008; Rodekohr & Haynes, 2001). The main goal of the current study was to analyze the potential influence of various linguistic backgrounds on children's English NWR performance. With this goal in mind, we compared the English NWR accuracy of children from four linguistic groups and analyzed whether there were group differences according to nonword composition.

NWR in monolingual and bilingual children

The first intriguing result was that the main effect for language group was not significant, indicating that the overall repetition accuracy across all 64 stimuli was similar among the four linguistic groups. This was unexpected, as previous research has indicated significant differences in NWR performance between monolingual and bilingual children (Kohnert et al., 2006; Windsor et al., 2010). The divergence in findings may reflect potential differences between the current and previous studies in nonword composition and/or the bilingual participants' English proficiency levels, with conceivably higher proficiency in our sample. The age at which the SE bilingual children examined by Windsor et al. (2010) began to learn English was not specified. They reported that the bilingual children performed lower than the monolingual English speakers on the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4), although within normal ranges. In the current study, the CELF-4 was not administered; rather, vocabulary and PA were measured using the PPVT-4 and ELLA, with results indicating equivalent PA skills across the four groups and lower vocabulary performance only in the SE group. It would appear that, regardless of any differences in English vocabulary knowledge, the bilinguals had developed sufficiently strong phonological representations to match the English NWR performance of the English monolinguals. These findings provide further support for Gorman's (in press) recommendation that, due to the complex interrelationships between vocabulary, PA, and NWR, all three variables are worthy of consideration in a comprehensive protocol when trying to enhance our understanding of bilingual children's skills. We would also underscore the importance of considering these factors when comparing and interpreting monolingual and bilingual children's NWR performance.

Despite similar scores across all NWR stimuli, results did indeed indicate significant differences in both consonant and vowel accuracy between groups according to syllable length. Specifically, both the SE and KE groups produced more consonantal errors than the ME group, but the CE and ME groups produced a similar number of consonantal errors. Therefore, bilinguals do not necessarily display lower accuracy on English nonwords than their monolingual peers. These performance patterns may be influenced by the consonant inventory of children's native language. As shown in Table 1, English and Chinese contain larger consonantal inventories than Korean and Spanish. In particular, a relatively large number of late-acquired consonants such as fricatives appear in English and Chinese. Thus, the results indicate that researchers and clinicians should be aware of children's L1 sound inventory when evaluating and interpreting bilingual children's performance on English nonwords and should be acutely aware when comparing their performance to English speakers.

To our knowledge, the current study is the first in which repetition accuracy of English vowels was specifically reported. Similar to consonants, there were significant differences in vowel accuracy, with both CE and KE groups displaying lower accuracy than the ME and SE groups. Despite the fact that vowel inventories among Korean, Chinese, and Spanish are similar (see Table 1), a more in-depth analysis indicated that KE and CE children produced more vowel errors specifically on four- and five-syllable nonwords, while the SE bilinguals appeared to display an advantage over the CE and KE speakers. Recall that Spanish is a language that contains numerous multisyllabic words as compared to Korean and Chinese. Consequently, it is possible that this advantage in the SE group may be attributed to their familiarity with Spanish, as suggested by Summers et al. (2010), despite the fact that the nonwords in the current study were based on English. Thus, the differences in performance on vowels within multisyllabic words may provide further support for the notion that knowledge and experience with specific characteristics that are salient in L1 may also support NWR performance in L2 (Gutierrez-Clellen & Simon-Cereijido, 2010).

Although consonant clusters and lax vowels were eliminated from the nonword stimuli in Windsor et al. (2010), the stimuli adopted in this study included consonant clusters, diphthongs, and lax vowels. Stimuli were also produced following the metrical stress patterns of English. Another possible explanation for the differences in vowel accuracy might be that both KE and CE have more difficulty following English stress patterns than the monolinguals and SE children, especially for longer items. Tremblay and Owens (2010) examined the acquisition of English (primary) word stress by native adult speakers of Canadian French using disyllabic and trisyllabic nonsense nouns. The results indicated that the L2 learners who failed to align the head of the trochaic foot with the heavy syllable realized stress with higher pitch. Conversely, the L2 learners who aligned the head of the trochaic foot with the heavy syllable realized noninitial stress by lengthening the syllable. The authors argued that L2 learners may have reached different prosodic grammars as a result of attending to distinct acoustic cues to English stress. If the KE and CE bilinguals had different prosodic grammars from the English monolingual and SE bilinguals, they may produce vowels somewhat differently. Future research may examine the performance of children from various linguistic backgrounds on tense versus lax vowels and words with various stress patterns in order to fully understand speech produced by bilingual children.

Factors related to NWR performance

We also examined children's vocabulary and PA skills, two additional factors that previous research has indicated to influence NWR (Coady & Evans, 2008). As mentioned earlier, there were weak relationships between vocabulary and NWR accuracy in the KE bilinguals, contrary to the ME, CE, and SE groups. With respect to the relationship between PA and overall NWR accuracy, findings with the former three groups were consistent with previous studies reporting strong relationships between these skills (Mann & Liberman, 1984; McDougall, Hulme, Ellis, & Monk, 1994). Results with the KE group, however, diverged from this pattern. It remains to be answered why similar correlations among these variables were not observed in the KE bilingual group. The weak correlation among these variables in KE bilinguals may be attributed to their performance patterns; recall that KE bilinguals produced more errors in consonants and vowels than the other groups of bilingual children. These findings also suggest that logographic characters in Chinese as opposed to the other three languages may not be the major factor affecting PA and NWR accuracy in English. Because the CE bilingual children also learned Chinese sounds using the "pinyin" system, it is possible that the phonological processing skills of the CE bilingual children develop similarly with children who learn languages based on a segmental alphabet.

NWR accuracy for high and low phonotactic probabilities

All four groups of children demonstrated similar performance for low and high phonotactic sequences, with greater accuracy on nonwords composed with high phonotactic probability sequences. This is consistent with the findings with English monolinguals of Edwards et al. (2004) and Munson et al. (2005). As mentioned previously, Munson et al. (2005) found that of several measures, including articulation and speech perception skills, only vocabulary significantly predicted this frequency effect, arguing that successfully repeating nonwords may depend upon having a rich representational system acquired through having a large vocabulary. In line with their research, we had anticipated finding a strong correlation between vocabulary and performance on low and high phonotactic sequences in bilingual children. However, English vocabulary skills did not appear to have the same effect on bilingual children's performance. It is uncertain why these patterns would be different, and thus, what factors may support bilingual children's repetition accuracy of English nonwords containing low-probability sequences. Among the 22 pairs of nonwords from Edwards' set, 9 nonwords for low phonotactic probability were composed of diphthongs, whereas the corresponding nonwords for high phonotactic sequences were not (e.g. /moipəd/vs./mæbɛp/). Although the sequence / moi / is less frequent than the sequence / mæ / in English, the diphthong vowel itself possesses production constraint (Lee, Davis, & MacNeilage, 2010). Thus, bilingual children's production accuracy may not be necessarily related with their mental representation as established through their vocabulary acquisition.

Theoretical implications

A large body of research has indicated that bilingual speakers display advantages in numerous cognitive processes such as control, attention, and regulation (Bialystok, 2008). Therefore, interpreting results within the framework of the aforementioned working memory model, one might speculate that bilinguals in the current study could compensate for nonnative English experience to match monolinguals' performance due to enhanced central executive skills, which support strong storage and coding of stable English phonological representations. That no consistent advantage in overall English NWR performance was apparent for any bilingual group may support the benefits to working memory of a bilingual experience in general, as opposed to experience with a particular native language. These ideas are speculative and require further examination.

Clinical implications

Our data indicate that, even in bilingual children with relatively strong English skills, NWR tasks do not eliminate the role of linguistic experience. While NWR tasks are often used to tap PSTM, there are clearly language-specific effects not only in terms of production accuracy but also seemingly of the underlying processes that influence performance. Therefore, while linguistic bias was not evidenced in children's overall performance across the stimuli combined, providing some evidence that this corpus may be used with children from the targeted linguistic groups, we recommend using it with bilinguals with significant caution.

One might conclude that, based on our results indicating no group differences in the number of consonant errors for the two- and three-syllable nonwords, reduced nonword length as well as analysis of consonants rather than vowels results in less linguistic bias. However, it should be noted that research with English speakers has shown that shorter nonwords do not differentiate typical language from impaired language as well as longer nonwords (e.g. Graf-Estes et al., 2007). Therefore, considering results as a whole, which show significant influences of language experience on repetition accuracy, children's performance would ideally be compared to the performance of their peers with similar language experience. If that is not feasible, administration of a wide corpus of nonwords, which are diversely composed, such as the set in the current study, may help spread out linguistic effects and reduce the potential advantage of a particular linguistic group.

Limitations and future directions

This study adopted nonwords from two sources, one specifically designed to examine children's performance on two- and three-syllable nonwords composed of high and low-probability sequences (i.e. Edwards et al., 2004) and the other designed to contain four and five syllables (Gathercole et al., 1994). Because these words were constructed somewhat differently, this may pose a challenge in interpreting results relative to syllable length. In Figures 1 and 2, an overall decline from two-syllable words to five-syllable words is visible, indicating that children produced more consonant and vowel errors as syllable length increased. However, the decline is less steady from the three-syllable words to the four-syllable words, specifically, suggesting a possible difference in nonword difficulty or word-likeness. Recall that Edwards et al. reported a word-likeness score and Gathercole et al. did not. Thus, based on our finding of a significant negative correlation between the length of syllable and accuracy of consonants and vowels ($r^2 = -0.375$ for consonants and $r^2 = -0.553$ for vowels), it appears that children's accuracy was affected by syllable length to a greater extent than word-likeness. It is likely, however, that the prosodic and morphological structure of nonwords may influence children's performance, and thus, should be examined systematically in future research.

Another potential limitation is that other nonlinguistic factors such as socioeconomic status (SES) were not controlled. Therefore, it is unknown if the lower vocabulary score of the SE group was related to proficiency, SES, or both. Interestingly, however, PA performance was equivalent across groups. Future studies should carefully consider these factors for obtaining a more comprehensive understanding of bilingual children's performance. Furthermore, the sample size in the current study was relatively small. Consequently, replication with a larger sample may provide additional insight into our research questions. Finally, examination of other potential factors such as speech perception and articulation, which have also been found to be related to NWR (Coady & Evans, 2008; Edwards et al., 2004), may be warranted to more fully understand the processes involved in children's NWR performance.

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Notes

1. Initially, 15 Spanish–English bilingual children were recruited. Twelve of the 15 Spanish–English bilingual children acquired Spanish as their first language and then learned English as they were enrolled in English-speaking schools, while 3 of Spanish–English bilingual children had attended a Spanish immersion school to learn Spanish language after they acquired English as their first language. Thus, the three children whose first language was English were eliminated from the analyses.
2. Some vowels for the nonword stimuli were produced differently from transcriptions shown in the previous studies. For example, /jugoin/as transcribed from the Edwards, Beckman, and

Munson (2004) was produced as [jƱgɔɪn] because the diphthong /ju/and /oi/are produced as [jƱ] and [ɔɪ], respectively, in Southern Wisconsin dialect.

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