Published in final edited form as:

Int J Lang Commun Disord. 2014 ; 49(5): 631–636. doi:10.1111/1460-6984.12090.

The Role of Auditory Nonverbal Working Memory in Sentence Repetition for Bilingual Children with Primary Language Impairment

Kerry Danahy Ebert

Rush University, Department of Communication Disorders & Sciences, 1016 D, Armour Academic Center, 600 S. Paulina St. Chicago, IL 60612, Tel: 312-563-6034, Fax: 312-942-7211

Abstract

Background—Sentence repetition performance is attracting increasing interest as a valuable clinical marker for Primary (or Specific) Language Impairment (LI) in both monolingual and bilingual populations. Multiple aspects of memory appear to contribute to sentence repetition performance, but nonverbal memory has not yet been considered.

Aims—The purpose of this study was to explore the relationship between a measure of nonverbal auditory working memory (NVWM) and sentence repetition performance in a sample of bilingual children with LI.

Methods & Procedures—Forty-seven school-aged Spanish-English bilingual children with LI completed sentence repetition and nonword repetition tasks in both Spanish and English as well as an NVWM task. Hierarchical multiple linear regression was used to predict sentence repetition in each language using age, nonword repetition, and NVWM.

Outcomes & Results—NVWM predicted unique variance in sentence repetition performance in both languages after accounting for chronological age and language-specific phonological memory, as measured by nonword repetition.

Conclusions & Implications—Domain-general memory resources play a unique role in sentence repetition performance in children with LI. Nonverbal working memory weaknesses may contribute to the poor performance of children with LI on sentence repetition tasks.

Keywords

working memory; bilingualism; specific language impairment; developmental language impairment; nonlinguistic processing; school-aged children

Sentence repetition (also known as sentence imitation or sentence recall) is a relatively simple task in which a child is asked to verbally imitate sentences presented aloud. Despite its apparent simplicity, sentence repetition appears to tap multiple underlying skills. The exact nature of these skills is of particular interest to researchers and clinicians working with children with Primary (or Specific) Language Impairment (LI) because sentence repetition has been identified as one of the most promising clinical markers for the disorder (Archibald & Joanisse 2009; Conti-Ramsden, Botting & Faragher 2001). Children with LI have long been identified on the basis of exclusionary criteria (i.e., poor language skills in the absence

of a host of other conditions), but the validation of effective clinical markers could transform the identification of LI. Furthermore, clinical markers may provide insight into the nature of the disorder itself. In other words, the skills that drive sentence repetition performance are likely to be key areas of weakness for children with LI.

Among monolingual English-speaking children, sentence repetition effectively identifies the presence of LI. Two separate studies (Archibald & Joanisse 2009; Conti-Ramsden et al. 2001) have compared the sensitivity and specificity of the task to other candidates for a clinical marker, including nonsense word repetition and grammatical tense marking. Both studies concluded that sentence repetition was the most promising candidate; Conti-Ramsden et al. (2001) reported sensitivity and specificity values of 90% and 85%, respectively, in a sample of 160 eleven-year old children, whereas Archibald and Joanisse (2009) found sensitivity of 85% and specificity of 90% in a group of 90 five- to nine-year old children living in Canada.

A true clinical marker should identify LI in children from a variety of linguistic backgrounds – i.e., those who speak languages other than English, are learning more than one language, or both. To some extent, the promise of sentence repetition for identifying LI extends to children from linguistically diverse backgrounds (e.g., Ziethe, Eysholdt & Doellinger 2013). For example, sentence repetition accurately separates Cantonese-speaking children with LI from their typically developing peers (Stokes, Wong, Fletcher & Leonard 2006).

Among French-English bilingual children, Thordardottir and Brandeker (2013) found high sensitivity for sentence repetition in identifying LI. However, specificity was substantially lower in this same study (57%), suggesting that typically developing bilingual children may be falsely identified as having LI when only sentence repetition is used. Lower specificity may be related to the role of language-specific exposure in sentence repetition for bilingual children. Thordardottir and Brandeker (2013) also found a clear relationship between the percentage of time a child spent using each language and his or her sentence repetition performance in that language. In addition, Swedish-Finnish bilingual children with both typical and impaired language skills scored below their Swedish-only monolingual peers on a sentence repetition measure in Swedish (Westman, Korkman, Mickos & Byring 2008), suggesting that reduced experience in Swedish negatively affected performance.

It is thus very likely that both experience and ability play some role in children's performance on sentence repetition tasks. Several investigations have attempted to deconstruct the “ability” component of sentence repetition in order to determine what the task truly measures. Results have revealed the importance of varying types of memory: long-term memory for linguistic representations (also called language knowledge), verbal working memory, and phonological short-term memory have all been found to play significant roles in the task (Alloway & Gathercole 2005; Poll et al. 2013; Riches 2012). Riches (2012) investigated components of sentence repetition performance in a group of 23 children with LI, along with age and language-matched controls. Linguistic representational knowledge, as assessed by a syntactic priming task, was the best predictor of sentence repetition performance for children with LI, though assessments of verbal working memory (backwards color span and listening span) and of phonological short-term memory (nonword

repetition) also explained significant amounts of variance. Riches (2012) concluded that long-term memory for language, specifically grammatical knowledge, is the primary component of sentence repetition performance in children with LI. Additionally, phonological short-term memory plays a larger role in sentence repetition for children with LI than for typically developing children. Hesketh and Conti-Ramsden (2013), after studying a sample of 11 year old children with and without histories of LI, reach a similar conclusion: both linguistic representational knowledge (as assessed by a morphological production task) and nonword repetition performance predicted sentence repetition in children with a history of LI, whereas only linguistic knowledge predicted sentence repetition in the group of children without LI. Finally, Poll and colleagues (Poll et al. 2013) found verbal working memory to play a strong role in sentence repetition performance for children with a wide range of language abilities.

Although several types of memory have been shown to predict sentence repetition performance, all of them have been aspects of verbal memory. Working memory and short-term memory have typically been contrasted with long-term memory for language, yet the measures of working memory and short-term memory that have been investigated – namely nonword repetition, listening span, and color span – all use linguistic stimuli and thus overlap with long-term memory for language. One recent study (Poll et al. 2013) linked nonverbal cognitive skills to sentence repetition performance in children with LI; however, only processing speed was considered in the nonverbal domain in this work, with working memory measured using linguistic stimuli. Thus, the possibility that nonverbal memory skills play a role in sentence repetition performance has not yet been explored. Furthermore, some results have pointed to nonverbal working memory weaknesses in the LI population (e.g., Hoffman & Gillam 2004), suggesting a need to consider this skill.

The purpose of the present study was to explore the contribution of nonverbal working memory to sentence repetition performance among a group of bilingual children with LI. Because participants were bilingual, nonverbal working memory could be related to sentence repetition in both languages, providing a stronger test of the hypothesis that nonverbal memory will contribute to sentence repetition performance. In this study, nonverbal working memory was measured in the auditory modality, using a tonal pattern matching task. Though many assessments of nonverbal working memory employ visuospatial stimuli (e.g., Hoffman & Gillam 2004), auditory stimuli were preferred here to match the modality of the sentence repetition task.

Participants

Participants were 47 Spanish-English sequential bilingual children with LI, aged 5;6-11;2. All children were participating in a treatment study for bilingual children with LI (Ebert, Kohnert, Pham, Rentmeester Disher & Payesteh 2013). Data in the present study originated from testing conducted when participants entered the treatment study (i.e., prior to any treatment). All children came from homes that used primarily Spanish and attended schools that used primarily English. Participants had previously qualified for special education services for language disorder through their school district. Initial testing for the study confirmed depressed performance on both Spanish and English language tests (i.e., scores at

least 1.25 standard deviations below the mean on Core Language composite of the *Clinical Evaluation of Language Fundamentals – 4th Edition*, in English, CELF-4E, Semel, Wiig & Secord 2003, and in Spanish, CELF-4S, Wiig, Secord & Semel 2006), alongside typical hearing and average nonverbal intelligence. Group mean Core Language composites were 50.6 (SD = 9.7) for English and 62.7 (SD = 11.6) for Spanish (note that composites are not directly comparable across languages due to differences in the normative samples for the CELF-4E and CELF-4S). See also Ebert, Pham, and Kohnert (in press) for additional information on this sample.

Measures

Three measures were employed in the current study. The first two are language measures that were administered in both Spanish and English. The sentence repetition measure was the Recalling Sentences (RS) subtest from the CELF-4E and CELF-4S. Children repeat sentences that increase from 6 to 19 words. The score for each item ranges from 0-3, depending on the number of deviations from the original stimulus. In this study, task administration followed standard procedures for the CELF-4, including the use of starting points and test ceilings. Raw scores were translated to scaled scores using the published normative tables, and scaled scores were used in all analyses. As noted above, the normative samples for the RS subtest in English and Spanish differ. However, scaled scores are preferred to raw scores here because the number of items administered differs across age groups (rendering raw score comparisons across different ages invalid).

The second language measure, nonword repetition (NWR), was also administered in both languages. English stimuli (Dollaghan & Campbell 1998) consisted of 16 words ranging from 1 to 4 syllables and conforming to the phonotactic properties of English, including word-final consonants. Spanish stimuli (Ebert, Kalanek, Cordero & Kohnert 2007) consisted of 20 words ranging from 1 to 5 syllables and conforming to the phonotactic properties of Spanish, including only consonant-vowel syllables. All nonword stimuli were recorded by a native speaker of the target language and administered to children via recording. Children's productions were recorded and later scored on a phoneme-by-phoneme basis, following the procedures in Dollaghan and Campbell (1998), resulting in a Percent Phonemes Correct (PPC) score for each language. Scores reported in this study are PPC for the longest word length in each language (4 syllable words for English and 5 syllable words for Spanish), as longer words proved to be more sensitive dependent variables in this sample.

The third measure was a tonal pattern matching task, designed to assess auditory working memory using nonverbal stimuli (nonverbal working memory; NVWM). On each trial participants listened to a pair of tone sequences and determined whether the sequences were the same or different. The task assesses working memory because participants were required to store one sequence of tones while processing the second, and to complete deeper processing than simple recall. Fifteen trials were presented at each of four sequence lengths: 2, 3, 4, and 5 tones per sequence. Tones were 250, 500, 1000, 2000, or 3000 Hertz. Participants received a score corresponding to the most difficult level at which they could accurately match at least 11 of 15 trials (73 percent; see Ebert et al. 2013, for additional

details). For children who could not accurately respond to at least 73 percent of the easiest trials (those with 2-tone sequences), a score of 0 was assigned.

Descriptive statistics for the three experimental measures are reported in Table 1.

Analyses

Correlation analyses were first performed to examine relations among study variables. The effects of age were partialled out of these correlations as NWR and NVWM scores were expected to increase with age. Correction for multiple comparisons was achieved by setting the False Discovery Rate at 0.05, following Benjamini and Hochberg (1995).

In order to examine the contributors to sentence repetition performance, we then conducted two hierarchical multiple regressions, one for English sentence repetition and one for Spanish sentence repetition. In each language, predictors were entered in a planned order: age first, followed by NWR for that language, followed by NVWM scores. This procedure allowed us to consider the unique contributions of nonverbal memory after controlling for the effects of age and language-specific phonological short-term memory.

Results

Results of the correlation analysis appear in Table 2. Age was positively correlated with NVWM ($r = 0.39, p = 0.007$) and with both English measures (NWR-E, $r = 0.35, p = 0.017$; RS-E, $r = 0.43, p = 0.002$). The result indicates that *standardized* English test scores improve with age in this bilingual sample (see also Ebert et al. in press). After controlling for the effects of age, NVWM was significantly correlated with sentence repetition scores in English ($r = .33, p = .026$) and in Spanish ($r = .41, p = .005$). NWR correlated significantly with sentence repetition for English ($r = 0.38, p = .01$) and for Spanish ($r = 0.35, p = .017$). The NVWM measure did not correlate significantly with NWR in either language.

Next, regressions were conducted to predict sentence repetition scores in each language. In Spanish, the regression model predicting sentence repetition performance using age, Spanish NWR, and nonverbal auditory working memory was significant, $F(3, 46) = 6.99, p < .001$, and accounted for 32.8% of the variance in sentence repetition scores. Nonverbal auditory working memory made a significant contribution after accounting for age and Spanish NWR, $R^2 = .124, p = .007$. Standardized beta coefficients and R^2 change values are shown in Table 3 for each model predicting Spanish sentence repetition.

The regression model predicting English sentence repetition performance using age, English NWR, and nonverbal auditory working memory was significant, $F(3, 46) = 8.31, p < .001$, and accounted for 36.7% of the variance in English sentence repetition performance. The contribution of nonverbal auditory working memory, after age and English NWR were entered, was significant ($R^2 = .067, p = .039$). Standardized beta coefficients and R^2 change values are shown in Table 4 for each model predicting English sentence repetition.

Discussion

The results of this study indicate that a measure of auditory NVWM is significantly associated with sentence repetition scores in both languages for a group of bilingual children with LI. Furthermore, auditory NVWM predicts unique variance in sentence repetition, after accounting for the contributions of development and phonological short-term memory. The NVWM measure in this study predicted 12.4% of variance in Spanish sentence repetition performance and 6.7% of variance in English sentence repetition performance. These results support the role of domain general memory abilities in sentence repetition performance for children with LI. Thus, while long-term linguistic representations may be strongly related to sentence repetition performance (Riches 2012), it appears unlikely that sentence repetition performance can be completely captured without involving nonverbal resources as well. The current results are consistent with previous findings of nonverbal working memory weakness in LI (Hoffman & Gillam 2004), and suggest these weaknesses may contribute to the markedly poor performance of children with LI on sentence repetition tasks.

Several variables may have influenced the results of this exploratory work. First, we were not able to account for the role of long-term memory for linguistic representations in our analyses because our dataset did not include a straightforward measure of this skill. It is likely that the inclusion of a measure of grammatical comprehension or production (as are commonly used to assess linguistic representational knowledge) could have increased the proportion of variance accounted for by the regression models. However, it is unlikely that such a measure could completely eliminate the relationship between NVWM and sentence repetition that was established here, given the clear distinction between these domains. Instead, it is more likely that a grammatical measure would account for some portion of the unexplained variance in the regression models presented here.

The stimuli used in sentence repetition tasks may also influence results. This study adopted the stimuli and scoring of the Recalling Sentences subtest of the CELF, consistent with several previous studies of sentence repetition (Conti-Ramsden et al. 2001; Hesketh & Conti-Ramsden 2013; Poll et al 2013). Other studies have designed sentence repetition stimuli that manipulate grammatical structures (e.g., complex vs. simple sentences, Riches 2012); it is possible that the relative contributions of linguistic representations and working memory may vary depending on qualities of the stimuli.

Thirdly, the NVWM task in this study used tonal stimuli to assess nonverbal abilities within the auditory modality. Children with LI have difficulty with a variety of tasks employing tonal stimuli, a result which has been attributed to auditory processing difficulty (e.g., McArthur & Bishop 2004). In the current study, the NVWM task was considered to be primarily a measure of memory as the tones were neither particularly rapid (at 100ms) nor difficult to discriminate (with at least 250 Hz separating tones). Rather, children had increasing difficulty with longer tone sequences, pointing to the memory demands of the task. However, the possibility exists that the poor performance of children with LI on tonal tasks, such as the one used here, may ultimately stem from a combination of auditory processing difficulty and cognitive skill weakness.

The current work is thus a complement to existing literature on the components of sentence repetition performance in LI. Future work should explore a host of factors, including both verbal and nonverbal aspects of memory, grammatical knowledge, and linguistic experience to more fully understand the components of this valuable clinical marker.

References

- Alloway TP, Gathercole SE. The role of sentence recall in reading and language skills of children with learning difficulties. *Learning and Individual Differences*. 2005; 15:271–282.
- Archibald LMD, Joanisse MF. On the sensitivity and specificity of nonword repetition and sentence recall to language and memory impairments in children. *Journal of Speech, Language, and Hearing Research*. 2009; 52:899–914.
- Benjamini Y, Hochberg Y. Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*. 1995; 57:289–300.
- Conti-Ramsden G, Botting N, Faragher B. Psycholinguistic markers for specific language impairment (SLI). *Journal of Child Psychology and Psychiatry*. 2001; 42:741–748. [PubMed: 11583246]
- Dollaghan C, Campbell T. Nonword repetition and child language impairment. *Journal of Speech, Language, and Hearing Research*. 1998; 41:1136–1146.
- Ebert KD, Kalanek J, Cordero KN, Kohnert K. Spanish nonword repetition: Stimuli development and preliminary results. *Communication Disorders Quarterly*. 2008; 29:67–74.
- Ebert KD, Kohnert K, Pham G, Rentmeester Disher J, Payesteh B. Three treatments for bilingual children with primary language impairment: Examining cross-linguistic and cross-domain effects. *Journal of Speech, Language, and Hearing Research*. 2013 E-Publication ahead of print.
- Ebert KD, Pham G, Kohnert K. Lexical profiles of bilingual children with primary language impairment. *Bilingualism: Language and Cognition*. in press.
- Hesketh A, Conti-Ramsden G. Memory and language in middle childhood in individuals with a history of Specific Language Impairment. *PLoS One*. 2013; 8:e56314. [PubMed: 23409172]
- Hoffman LM, Gillam RB. Verbal and spatial information processing constraints in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*. 2004; 47:114–125.
- Mcarthur GM, Bishop DVM. Which people with specific language impairment have auditory processing deficits? *Cognitive Neuropsychology*. 2004; 21:79–94. [PubMed: 21038192]
- Poll GH, Miller CA, Mainela-Arnold E, Adams KD, Misra M, Park JS. Effects of children's working memory capacity and processing speed on their sentence imitation performance. *International Journal of Language and Communication Disorders*. 2013; 48:329–382. [PubMed: 23650889]
- Riches NG. Sentence repetition in children with specific language impairment: An investigation of underlying mechanisms. *International Journal of Language and Communication Disorders*. 2012; 47:499–510. [PubMed: 22938061]
- Semel, E.; Wiig, EH.; Secord, WA. *Clinical evaluation of language fundamentals*. 4th. San Antonio, TX: The Psychological Corporation; 2003.
- Stokes SF, Wong AMY, Fletcher P, Leonard LB. Nonword repetition and sentence repetition as clinical markers of specific language impairment: The case of Cantonese. *Journal of Speech, Language, and Hearing Research*. 2006; 49:219–236.
- Thordardottir E, Brandeker M. The effect of bilingual exposure versus language impairment on nonword repetition and sentence imitation scores. *Journal of Communication Disorders*. 2013; 46:1–16. [PubMed: 23021785]
- Wiig, EH.; Secord, WA.; Semel, E. *Clinical evaluation of language fundamentals*. 4th., Spanish. San Antonio, TX: The Psychological Corporation; 2006.
- Ziethe A, Eysholdt U, Doellinger M. Sentence repetition and digit span: Potential markers of bilingual children with suspected SLI? *Logopedics Phoniatrics Vocology*. 2013; 38:1–10.

What this paper adds**What is already known on this subject?**

Sentence repetition performance effectively distinguishes children with Primary Language Impairment (LI) from typically developing peers. Established components of sentence repetition performance include language experience, long-term language knowledge, and linguistic short-term and working memory.

What this study adds

This study considered whether nonverbal working memory also contributes to sentence repetition performance within a group of bilingual children with LI. Results indicated nonverbal working memory predicted unique variance in sentence repetition in both languages and suggested that domain-general memory resources play a significant role in this task.

Table 1
Performance on Experimental Measures

Variable	Mean	SD	Range
Age	8;6	1;5	5;6-11;2
RS-E	1.79	1.14	1-5
RS-S	3.77	1.75	1-8
NWR-E	57.4%	12.6%	27.8%-86.1%
NWR-S	73.2%	16.5%	15.0-97.5%
NVWM	2.17	1.56	0-4

Note. Sample consisted of 47 participants. Age is reported as year; month. Scaled scores are reported for the *Recalling Sentences* subtest of the CELF-4 in English (RS-E) and in Spanish (RS-S). Nonword repetition scores in English (NWR-E) and in Spanish (NWR-S) are reported as percent phonemes correct. Nonverbal working memory task performance (NVWM) was scored by task difficulty level, from 0-4.

Table 2

Partial Correlations Among Variables (Age Removed)

	NVWM	RS-S	NWR-S	RS-E	NWR-E
Age	0.39*	-0.31	0.31	0.43*	0.35*
NVWM	--				
RS-S	0.41*	--			
NWR-S	0.11	0.35*	--		
RS-E	0.33*	0.31	0.11	--	
NWR-E	0.11	0.31	.044*	0.38*	--

Note. Bivariate correlations between age and all variables are reported in the top row of the table. Subsequent rows report partial correlations between variables controlling for age.

* significant after controlling for false discovery rate at 0.05 (Benjamini & Hochberg, 1995)

Table 3

Standardized beta coefficients and R^2 change from hierarchical regression to predict sentence repetition scores in Spanish.

Variable	Model 1	Model 2	Model 3
Age	-.31	-.41	-.55
NWR-S		.35	.31
NVWM			.38
R^2 change	.09	.11	.12
F for R^2 change	4.61*	6.14*	7.91**

Table 4

Standardized beta coefficients and R^2 change from hierarchical regression to predict sentence repetition scores in English.

Variable	Model 1	Model 2	Model 3
Age	.43	.31	.21
NWR-E		.36	.33
NVWM			.28
R^2 change	.19	.11	.07
F for R^2 change	10.26**	7.19*	4.54*