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Research Note

Working Memory and Linguistic Performance of Dual Language Learners With and Without Developmental Language Disorders

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Purpose: This research note describes the use of working memory measures as potential indicators of developmental language disorders (DLD) in preschool-age dual language learners from Spanish-speaking backgrounds. This report is an extension of early work, completed by the same authors that described the diagnostic accuracy of a Spanish nonword repetition task.
Method: One hundred thirty Spanish-speaking families with preschool-age children participated; 37 children had DLD, and 93 were typically developing. Families were recruited from early childhood programs in three states in the western region of the United States. Working memory and linguistic measures were collected from the children; parents completed a vocabulary checklist and reported on their child's longest utterances.
Results: Nonverbal working memory was not associated with other measures, but verbal working memory was associated with linguistic measures. Although there were no group differences on nonverbal working memory, group differences (DLD vs. typical development) were detected on verbal working memory and linguistic measures. Verbal working memory combined with vocabulary scores resulted in 79% of cases correctly classified.
Conclusions: Working memory tasks yielded different results depending on the type of task (verbal vs. nonverbal). Outcomes from this study showed that a nonverbal working memory task (hand movement) was not useful in distinguishing preschool-age dual language children with DLD from typical peers, but a verbal working memory task (nonword repetition) may be useful if combined with other more robust linguistic measures.

Language learning is complex, placing demands on various cognitive processes, each of which could constrain the learning process. Working memory, a critical aspect of cognition, is the portion of the memory system responsible for simultaneously processing and storing incoming information (Gray et al., 2017). Although there are several differing models describing working memory and its role in language learning (Baddeley, 2003; Cowan, 2001), a recent modeling study with school-age children identified the most viable components of existent models and proposed a *combined model* (Gray et al., 2017). This combined model includes a phonological loop that handles verbal and acoustic information, an attention/visuospatial sketchpad that manages visual information, and a central executive system responsible for maintaining activated memory representations while simultaneously processing incoming information.

Our understanding of the relationship between working memory and language learning may be further expanded through the study of unique language learners, including bilingual children and/or those with developmental language disorders (DLDs). There is limited research on bilingual children available, but there is emerging evidence documenting bilingual children's working memory skills as compared to monolingual peers. For example, a study that compared monolingual to bilingual Turkish- and Dutch-speaking young school-age children found that bilingual children had stronger nonverbal working memory skills than monolingual peers and that higher language skill across languages was

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related to better verbal working memory skills (Blom et al., 2014). Similarly, a study that compared the nonverbal working memory performance of monolingual English-speaking children to a linguistically heterogeneous bilingual sample of young school-age children found that bilingual children outperformed monolingual children on nonverbal working memory tasks, especially when additional executive control demands were added to the tasks (Morales et al., 2013).

Contributing to our understanding of the relationship between verbal working memory and nonverbal working memory are studies examining performance among children with DLD (e.g., Baddeley, 2003; Montgomery et al., 2010; Vugs et al., 2013). In a study of Dutch preschool-age children, the investigators found that children with DLD had deficits in all components of working memory (verbal and nonverbal) with strong diagnostic accuracy obtained from a composite working memory measure (sensitivity = .88, specificity = .90; Vugs et al., 2014). Verbal working memory deficits have also been found in dual language learners with DLD (Ebert, 2014; Ebert & Pham, 2019). Although there is limited research that has looked at nonverbal working memory in dual language learners, Ebert and Pham (2019) found that nonverbal working memory had promising classification accuracy in school-age children, especially in younger school-age children (6-year-olds).

Viewed together, findings from studies of unique language learners indicate that it may be useful to further investigate working memory tasks as a potential diagnostic marker of DLD. To our knowledge, there is no research available that describes the verbal and nonverbal working memory skills of preschool-age Spanish-speaking children with and without DLD. Performance on working memory tasks could contribute to the accurate identification of DLD in young dual language learners. Furthermore, easy-to-administer, accessible, and relatively natural working memory tasks may be especially appealing and clinically useful to practitioners.

In this research note, the authors report an exploratory analysis from a data set that includes information gathered from earlier studies and data not previously reported. Two simple working memory tasks are tested, nonword repetition (NWR) and a hand movement task. The purpose of this study was to (a) describe the association between working memory tasks and linguistic measures in dual language learners; (b) identify differences between typical and DLD groups on a linear combination of working memory (verbal and nonverbal) and linguistic measures; and (c) describe the classification accuracy of working memory, linguistic, and combined measures.

Method

Participants

Internal review board institutional approval was granted for this study by the University of Wyoming. One hundred thirty preschool-age children (ages 3;0–5;10 [years; months]) participated in this study (M_{age} = 4;6, SD = 9.29 months). Data reported here include children (n = 44) from a previous study that described NWR (Guiberson & Rodríguez, 2013), children (n = 53) from an earlier study describing children's performance on morphosyntactic measures (Checa-García & Guiberson, 2019), and children (n = 33) that have not been reported previously. Families were recruited from early childhood programs in three states in the western region of the United States. Inclusionary criteria included that children had normal hearing, no known neurological impairment, and absence of severe phonological impairment. Only dual language learners who were predominately Spanish speaking (spoke Spanish 80% of the time or more according to parent report) were included.[1] Children who did not meet these criteria were not included in the study.

Triangulation of three sources of information was used to establish DLD status; sources included (a) identification of DLD by a bilingual speech-language pathologist (SLP), (b) report of parent concerns about child's language development, and (c) Expressive Language scores on the Spanish Preschool Language Scale–Fourth Edition (SPLS-4) ≤ 77 (1.5s SD below the mean). Parent concern data on child's language development were obtained verbally, over the phone, or in person when study visits were scheduled. Earlier studies with kindergarten to primary-grade bilingual children have shown that parent report of concern and/or family history of language learning difficulties is a good source of information, when combined with other sources, in predicting language impairment in Spanish-speaking children (Restrepo, 1998). The DLD group included 37 children (18 girls and 19 boys). Children in the typically developing (TD) group had not been previously diagnosed as having DLD; parents did not report concerns about language development, and all TD children had SPLS-4 Expressive Language scores ≥ 77. The TD group included 93 children (44 girls and 49 boys). There were no significant group differences in the children's age (t = −1.22), children's percentage of Spanish use (t = 1.40), or caregivers' percentage of Spanish use (t = 0.73).

Measures

Verbal Working Memory Task

A Spanish NWR task to examine verbal working memory consisting of 20 nonword stimuli that follow Spanish phonotactic constraints and phoneme frequency patterns was used (Ebert et al., 2008). The NWR stimuli were developed based on the consonant–vowel syllable structure that is common in Spanish. The nonwords also maintained the Spanish pattern of stress on the penultimate syllable. The nonwords gradually increased in syllable length (from one to five syllables), with four items for each syllable length presented. Because item-level scoring of these stimuli has been shown to yield better psychometric qualities, this scoring approach was applied (Guiberson &

[1]The term *dual language learner* will be used to refer to this sample for the remainder of this article.

Rodríguez, 2013). Data scoring and reliability procedures described by Guiberson and Rodríguez were applied to the larger database, and three to five syllable items were selected because they had the best classification accuracy measures in the earlier study.

Nonverbal Working Memory Task

Hand Movements, a task from the Kaufmann Assessment Battery for Children–Second Edition (Kaufman & Kaufman, 2004), was given as a nonverbal measure of working memory and sequential processing. The Kaufmann Assessment Battery for Children–Second Edition authors describe Hand Movement as a working memory task, and it is considered part of the tool's model of measuring *narrow abilities* of cognition to arrive at a child's general ability. For the Hand Movements task, children were asked to imitate a random sequence of hand movements (e.g., palm down, fist, and side down) of increasing length (two to five movements). This task was similar to the NWR task in that an imitation response was required and an all-or-nothing (plus or minus) scoring approach was applied. Scaled scores were obtained for this measure.

SPLS-4

The Spanish version of the Preschool Language Scales–Fourth Edition, an assessment developed from a Spanish-language model, includes a Receptive and Expressive Language subtest (Zimmerman, et al., 2002). The Expressive subtest of the SPLS-4 has strong sensitivity (.92) and less-than-adequate specificity (.68). To strengthen specificity in our sample, triangulation was used that included diagnosis of DLD by an SLP and parent report of concern of language development. Standard scores were obtained for the Expressive Language subtest.

Parent Report Measures

Two parent report measures were used to gather language development information. First, a parent checklist of 100 preschool-level vocabulary items was collected. This tool was previously found to have acceptable psychometrics for classifying TD and DLD in dual language learners (sensitivity = .82, positive likelihood ratio [LR+] = 4.25 [1.88, 9.58], specificity = .81, negative likelihood ratio [LR−] = 0.22 [0.09, 0.55]; Guiberson & Rodríguez, 2010). Recall that LR+ values of 3–9 are moderately positive and suggestive but insufficient alone in indicating disorder, whereas LR+ values of 10 or greater are very positive and likely to be accurate indicators of disorder (Dollaghan, 2007). Furthermore, LR− that are 0.30–0.11 are moderately negative and suggestive but insufficient alone to rule out disorder and LR− values of 0.10 or less are thought to be extremely negative and very likely to be accurate in ruling out a disorder, (Dollaghan, 2007). Vocabulary scores could range from 0 to 100; raw scores were obtained. Second, parent report of their child's longest three utterances in words (M3L-W) was collected. M3L-W was calculated by adding the number of words for each of the three utterances provided and then dividing by three. In earlier studies with toddlers (Guiberson et al., 2011) and preschool-age children (Guiberson et al., 2015), M3L-W was moderately and significantly associated with standardized language measures.

Procedure

All study visits were conducted in either a parent education room or a child assessment room at the collaborating preschool centers. During the study visits, a guardian accompanied their child while a bilingual SLP administered the SPLS-4, NWR, and Hand Movements tasks. All testing was completed in Spanish, and the order of task administration was counterbalanced. Parents were provided with the parent report measures in advance of the study visit, but in the cases where the forms were incomplete at time of visit, parents were given additional time to complete them and assistance was offered.

Results

Associations between working memory tasks and linguistic measures. To adjust for the multiple correlations completed, a Bonferroni correction was applied before analysis of significance; $p = \leq .01$ was determined to be an acceptable criterion for significance. Table 1 presents Pearson correlation values between working memory and linguistic measures. Of the working memory measures, performance on the Hand Movements task was not associated with performance on the NWR or the linguistic measures. However, correlations between NWR performance, SPLS-4 Expressive Language standard scores, as well as M3L-W and vocabulary measures were positive and significant. Positive and significant correlations between all of the linguistic measures were also observed.

Group comparisons of working memory and linguistic performance. Table 2 presents group performance on working memory and linguistic measures. To explore group differences on these measures, a multivariate analysis of variance entering all measures simultaneously as dependent variables was completed, with partial eta squared (η^2) used as an estimate of effect size. There was a significant overall effect of group, with the children with DLD performing

Table 1. Pearson correlations between working memory and linguistic measures.

Measures	1	2	3	4	5
1. NWR	—				
2. Hand Movements	.13	—			
3. SPLS-4	.55*	.09	—		
4. M3L-W	.47*	−.04	.48*	—	
5. Vocabulary	.53*	−.07	.43*	.54*	—

Note. $N = 130$. NWR = nonword repetition; SPLS-4 = Spanish Preschool Language Scale–Fourth Edition; M3L-W = parent report of their child's longest three utterances in words.

*$p \leq .01$.

Table 2. Group means, standard deviations, and multivariate analyses of variance results for working memory and linguistic measures.

Measures	DLD group *N* = 37		TD group *N* = 93			
	M	*SD*	*M*	*SD*	*F*	η^2
Working Memory						
NWR	3.30	2.85	7.13	3.30	$F(1, 128) = 38.38^*$	.23
Hand Movement	8.95	1.72	9.05	2.26	$F(1, 128) = 0.07$	.001
Linguistic						
M3L-W	3.92	2.10	6.41	2.30	$F(1, 128) = 32.28^*$	.20
Vocabulary	35.97	26.99	63.78	23.82	$F(1, 128) = 33.42^*$	.21

Note. DLD = developmental language disorders; TD = typically developing; NWR = nonword repetition; SPLS-4 = Spanish Preschool Language Scale–Fourth Edition; M3L-W = parent report of their child's longest three utterances in words.

$^*p \leq .01$.

less well than the typical children, Wilks's lambda (λ) = .68, $F(63, 125) = 15.03$, $p < .001$, $\eta^2 = .33$. The next set of multivariate analyses of variance tested for group differences across the two working memory and two linguistic tasks. Although the groups did not differ in terms of nonverbal working memory (hand movement), $F(1, 128) = 0.07$, $\eta^2 = .001$, children with DLD performed less well on verbal working memory (NWR), $F(1, 128) = 38.38$, $\eta^2 = .23$, and had lower M3L-W, $F(1, 128) = 32.28$, $\eta = .20$, and reported vocabulary scores, $F(1, 128) = 33.42$, $\eta^2 = .21$.

Classification accuracy. Given that group differences were not detected on the nonverbal working memory task, this task was excluded from classification accuracy analysis. As a first step, logistic regression was completed to identify if working memory (NWR) combined with linguistic measures (M3L-W + vocabulary) predicted DLD status. All three variables were entered together, but M3L-W was dropped from the model because of collinearity. When vocabulary and NWR were considered together, they significantly predicted children's DLD status, $\chi^2 = 49.49$, $df = 3$, $N = 130$, $p < .001$. The variables in the model accounted for 45% of variance in DLD status. Next, the individual classification accuracy of NWR, M3L-W, and vocabulary was calculated (see Table 3). Diagnostic evidence values and descriptors from Dollaghan (2007) are applied to the coefficients reported below. Although NWR accounted for the greatest area under the curve, vocabulary was the only measure that had sensitivity (.76) and specificity (.72) values above .7. Even so, all three measures alone had LR+ and LR− in the neutral range, indicating these measures would be inadequate alone in classifying children as DLD or typical. As a final step, the classification accuracy of verbal working memory (NWR) combined with individual linguistic variables (M3L-W and vocabulary) was calculated. Table 4 shows that NWR + M3L-W yielded a .72 overall classification accuracy and NWR + vocabulary yielded a .79 overall classification accuracy. Although the two combinations had moderately LR+ values, both combinations had neutral LRs−, indicating that positive results (+ DLD) would be suggestive from the combined measures but negative results (-DLD) would be uninformative for ruling out the disorder. In summary, these measures and measure combinations were inadequate for diagnosis purposes.

Conclusions

Associations between working memory tasks and linguistic measures. The verbal working memory task (NWR) was significantly associated with the linguistic measures, vocabulary, and M3L-W. The nonverbal working memory task (hand movement) was not associated with the verbal working memory or other linguistic measures. These results differ from earlier studies that have found a general working memory deficit in bilingual preschool-age children with DLD (Vugs et al., 2014) and significantly lower nonverbal memory working skills in bilingual school-age children with DLD (Ebert & Pham, 2019). This is somewhat perplexing because the NWR and hand movement tasks were similar in that they required immediate imitation of a

Table 3. Classification accuracy of individual measures.

Measures	AUC	Sensitivity	Specificity	LR+ (95% CI)	LR− (95% CI)
NWR	.81*	.70	.72	2.51 [1.71, 3.70]	.41 [.25, .69]
M3L-W	.80*	.73	.68	2.26 [1.59, 3.22]	.40 [.23, .69]
Vocabulary	.78*	.76	.72	2.70 [1.86, 3.93]	.34 [.19, .60]

Note. AUC = area under the curve; LR+ = positive likelihood ratio; LR− = negative likelihood ratio; CI = confidence interval; NWR = nonword repetition; M3L-W = parent report of their child's longest three utterances in words.

$^*p \leq .01$.

Table 4. Classification accuracy of combined variables.

Variable	Overall correct classification	Sensitivity	Specificity	LR+ (95% CI)	LR– (95% CI)
NWR + M3L-W	.72	.70	.77	3.11 [2.02, 4.79]	.38 [.23, .64]
NWR + Vocabulary	.79	.73	.77	3.23 [2.11, 4.94]	.35 [.20, .60]

Note. LR+ = positive likelihood ratio; CI = confidence interval; LR– = negative likelihood ratio; NWR = nonword repetition; M3L-W = parent report of their child's longest three utterances in words.

sequence of items (hand movement or production of phonemes) and they were of similar length (up to five units in length). These results may indicate that nonverbal working memory is distinct and untethered from verbal working memory at this stage in development, providing preliminary support for a phonological loop deficit in young children with DLD that is not at work in visually based working memory tasks. Furthermore, when considered in light of the combined model (Gray et al., 2017), these results may show that, for young children, the attention/visuospatial sketchpad and the central executive systems may be still developing or emergent and there may not be enough variability to detect group differences on an imitation-based hand movement working memory task.

Another possible explanation for the contrasting results is that the task selected to measure nonverbal working memory (hand movements) may tap into different aspects of nonverbal working memory. For example, the nonverbal working memory task that Ebert and Pham selected for use with school-age children was auditory pattern matching, which required the processing of tone sequencing. However, the Vugs et al. study included tasks that required visuospatial storage (e.g., "point to the where the dot was, recreate a pathway through a maze") or attention tasks (e.g., "point the correct stimuli in the correct order," "point to the positions of a series of stimuli in the correct order"). This variability in nonverbal working memory tasks may contribute to different profiles of performance and may require additional attentional and or executive function resources, consistent with the combined model. The nonverbal working memory task applied in the current study, Hand Movements, is unencumbered by complex instructions, required no objects, and involved the use of movement. Hand movement is a simple task when compared to some of the other tasks described that involve the use of technology and recalling the location of a figure on a screen.

Group differences on working memory and linguistic measures. There were significant group differences on the verbal working memory performance, M3L-W, and vocabulary with large effect sizes observed.

Classification accuracy of working memory measures, linguistic measures, and combined measures. None of the measures (NWR, M3L, vocabulary) or the combinations of measures (NWR+ vocabulary or NWR+ M3L) were adequate to classify preschool-age dual language learners as DLD. Even with significant group differences, these particular tasks do not provide adequate diagnostic information and other sources of diagnostic information would be needed to make a definitive determination of DLD or typical status.

Limitations. There are several limitations to the current study. First, the SPLS-4 lacks the psychometric qualities that would allow it to be used alone and without triangulation of data to establish DLD or typical status. Another limitation is that the hand movement measure is not as innovative as some of the experimental nonverbal working measures that other researchers have used. It is, however, a practical measure and one that is part of a commonly used cognitive assessment for children.

Implications. This study has important implications for the use of working memory measures with preschool-age dual language learners. Earlier studies documented the potential usefulness of nonverbal working memory tasks in identifying DLD; however, results from the current study with preschool-age dual language learners showed that children with DLD did not differ from their TD peers in hand movement performance. To better understand this finding, more research is needed that includes a number of nonverbal working memory tasks that will tap into different aspects of this construct. Conversely, verbal working memory, as measured through NWR, had significant group differences with a small effect size observed, but inadequate classification accuracy. Based on this work and earlier studies with preschool-age dual language learners, a verbal working memory task such as NWR, when used in combination with other sources of information, may be useful but only if combined with other diagnostic measures.

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