Copyright

by

Maria Nicole Mitidieri

2015

The Thesis Committee for Maria Nicole Mitidieri
Certifies that this is the approved version of the following thesis:

The Role of Vocabulary Knowledge for Tongue Twister Repetition in Bilingual Children with and without Language Impairment

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: _____

Lisa M. Bedore

_____

Elizabeth D. Peña

The Role of Vocabulary Knowledge for Tongue Twister Repetition in Bilingual Children with and without Language Impairment

by

Maria Nicole Mitidieri, B.A.

Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Arts

The University of Texas at Austin

May 2015

Dedication

To my Mom and Dad, for your never-failing love, support, and encouragement, to Chris and Erin, for your empowering counsel and advice, to Allyson, for your constancy, unflinching determination, and timely humor, and to Susanna, for your contagious smiles and giggles: in unique ways, you all have inspired me to persevere and reach my goals. With sincere love and gratitude, I dedicate this thesis to you.

Acknowledgements

I would like to credit all of those who assisted my endeavors to complete this thesis. Primarily, I express my gratitude to Dr. Lisa M. Bedore for her diligent guidance throughout the course of my research and technical writing. I am thankful for her time, dedication, and constructive feedback that have made the completion of my project possible. I would also like to thank Dr. Elizabeth D. Peña for offering her input during the final editing phase. Completing this thesis has enlightened me to the difficult process, yet valuable role, of conducting research. I therefore admire the determined work and passion of both of my supervisors to continue to contribute evidence-based information to this field, and thank them for supporting my efforts to do the same.

I also extend my thanks to the students and staff of the HABLA lab. Particularly, I would like to recognize Daniel Ibarra for his instruction that guided the initial course of this study's data analysis, Jennifer Briseño, Barbara Hidalgo-Sotelo, and Haydeé Becerril for providing resources that enabled me to contextualize and appropriately evaluate the original study's data and procedures, and Cristina Rincón and San Juanita Millán for their efforts to help complete this study's final data transcriptions. Finally, I thank LaKesha Henry for her unhesitating assistance throughout my time working in the lab.

Lastly, I would like to acknowledge my fellow graduate cohort members. I deeply appreciate their friendship and shared "team" mentality that allowed us to support each other through this challenging process.

Abstract

The Role of Vocabulary Knowledge for Tongue Twister Repetition in Bilingual Children with and without Language Impairment

Maria Nicole Mitidieri, M.A.

The University of Texas at Austin, 2015

Supervisor: Lisa M. Bedore

This study evaluates the relationship between semantic and phonological representations via the comparison of vocabulary knowledge and tongue twister performance in 34 bilingual Spanish-English children with and without language impairment (LI). In Spanish and English, scores and error analyses for eight four-word tongue twisters were compared to their vocabulary scores on the *Expressive One-Word Picture Vocabulary Test (EOWPVT*). Results indicated the typically developing (TD) group outperformed the group with LI in all areas. Positive significant correlations occurred between vocabulary knowledge and tongue twister performance in both languages and negative significant correlations between vocabulary knowledge and specific tongue twister error types demonstrated cross-language and cross-group discrepancies. These results imply that semantic knowledge and language experience and exposure influence bilingual children's performance on tongue twisters repetition tasks.

Table of Contents

List of Tables

Introduction

A Foundation Relating Phonological Skills and Vocabulary Knowledge

Phonological skills and vocabulary knowledge share a mutual, interactive relationship during the early stages of development, which promotes language learning. Studies of nonword repetition (NWR) tasks show that short-term memory facilitates quick and immediate storage and reproduction of novel phonological forms, which represent the skills necessary for learning new words (Gathercole, 2006). For example, Gathercole and Baddeley (1989) initially demonstrated strong correlation between NWR and vocabulary knowledge at four different points as children developed between four and eight years of age. NWR tasks remove access of learned semantic representations, allowing the assessment of short-term phonological memory; thus, studies examining the correlation between NWR and vocabulary knowledge emphasize phonological short-term memory as the underlying predictive mechanism of lexical learning.

At the same time, children's language experience and vocabulary knowledge can help refine their phonological representations. As language experience and vocabulary knowledge grow, the relationship between the two variables becomes more interactive (Edwards, Beckman, & Munson, 2004; Gathercole & Baddeley, 1989; Munson, Kurtz, and Windsor, 2005). Specifically, as vocabulary knowledge increases, children link phonological and semantic representations across known words to apply to new words, which in turn, promotes further phonological and vocabulary development. To better understand this process it is necessary to explore the relationships between vocabulary knowledge and phonological learning tasks that incorporate semantic knowledge.

Tongue twisters denote such a task given their sequence of real words that introduce the opportunity to develop semantic associations with the stimuli. Thus, the incorporation of real words in tongue twister repetition tasks requires the separation and storage of interfering semantic connotations with their corresponding phonological representations, whose similar forms challenge their unique distinction during repeated production.

Primarily, this study will review previous works focusing on NWR tasks that provide insights into the relationship between lexical and phonological learning. This analysis will guide areas to consider when testing these factors for tongue twister tasks. The goal of the current study is to build our understanding of the role of lexical knowledge in phonological learning in the context of real word stimuli. Furthermore, this study will consider how tongue twister repetition and the specific errors the task induces contribute to our understanding of the relationship between phonological representation and vocabulary knowledge.

THE THEORETICAL FRAMEWORK AND LIMITATIONS OF NWR

Gupta and MacWhinney (1997) stated that NWR tasks require the maintenance and recall of phonological forms, or short-term phonological working memory skills. The absence of recognizable phonological forms presents distinct challenges because the stimuli undergo rapid decay, impairing phonological memory's storage and recovery abilities for recall. According to Gathercole (2006), given NWs' isolation from phonologies of known lexicon, NWR tasks reveal word-learning skills by demonstrating superior abilities to retain and recall unfamiliar phonological forms (i.e. "new words").

However, Edwards et al. (2004) and Munson et al. (2005) demonstrated how word-learning skills might not solely rely on the ability to store and recall new phonological forms, but also depend on developing vocabulary knowledge. For example, Edwards et al. (2004) analyzed TD children between ages 3;2 and 8;10 on their performance on a continuum of NWR stimuli. Specifically, they compared the repetition of NWs with low phonotactic probabilities compared to the performance on matched NWs with high phonotactic probabilities.[1] Participants with high expressive vocabulary scores outperformed those with low expressive vocabulary scores on NWR, regardless of phonotactic probability level. Munson et al. (2005) found similar results in their study that included a group of TD children who were age-matched with a group of children with LI, and a younger group of children matched for vocabulary size with the LI group. For all NWR tasks, the group with LI performed no differently compared to the younger group of TD children. The outcomes from both of these studies suggest that older children and those with higher expressive vocabulary skills demonstrate superior abilities to accurately repeat all NWs. In addition to short-term phonological memory, semantic knowledge also appears to influence the ability to store, recall, and repeat phonological sequences.

Edwards et al. (2004) and Munson et al. (2005) accounted for their findings by explaining that children with rich vocabularies are exposed to a greater variety of phonological forms, which provides more opportunities for phonological patterns to

[1] Phonotactic probability refers to a NW's degree of phonological similarity to those of real words in the target language. NWs with low phonotactic probability are highly dissimilar to real word phonological forms and NWs with high phonotactic probability are highly similar to real word phonological forms.

generalize across multiple contexts. Beckman and Edwards (2000) similarly theorized that the acquisition of phonological representations occurs through experience over time through the constant restructuring of phonological forms; the exposure to, and knowledge of, a large number of words promotes the abstraction of these phonological forms across contexts for the building and organization of an extensive phonological repertoire for future word learning. In turn, developing such deep phonological representations refines skills to assign meaning to new phonological forms in new words for encoding and future recall (Beckman & Edwards, 2000).

Gray (2004) verified these principles by examining novel word learning abilities in children with LI, who demonstrated poor word learning skills, in comparison to their age-matched TD peers. The primary predictor for the children's capacity to acquire, comprehend, and produce new word stimuli were standardized vocabulary scores. Therefore, evidence that children with large vocabularies can more accurately access and utilize a larger selection of phonological patterns for word learning supports the phenomenon that children with larger vocabularies excel in repetition tasks in comparison to children with lower vocabulary sets; because of their familiarity to diverse word forms, TD children with larger vocabularies than their age-matched peers with LI more efficiently store, recall, and apply known semantic and phonological forms for the repetition of new stimuli.

The evidence that vocabulary influences phonological storage and recall, which are inherent skills of the word learning process, suggests that real word repetition tasks might provide additional perspective in the evaluation of children's word learning

abilities. NWs lack semantic content, thus the presentation of real words, which contain both semantic content and plausible phonological patterns, would theoretically require the simultaneous processing of these two systems for accurate storage and repetition of stimuli.

Real Word Repetition to Measure Phonological-Semantic Relations

The evidence that word learning relies on prior semantic knowledge in order to efficiently store, access, and refine meaning of words' phonologies suggests that providing access to semantic knowledge during repetition tasks would influence performance. On one hand, according to Gupta and MacWhinney (1997) the introduction of real words during phrase repetition tasks provides more meaningful foundations of phonological forms, which supports retention of stimuli and increases accuracy of real word rehearsals. However, Gupta and MacWhinney (1997) recognized that for real word phrases, the changing semantic connotations of phonological forms induce specific types of errors, particularly for phrases that include a similar and complex string of related phonological forms. For example, if a series of words incorporate similar phonological segments, the repetition task requires efficient distinction and assignment of each segment that derives from the same phonological representation. Maintaining the fact that the organization of phonological representations descends from word knowledge, accurate repetition of real word phrases with similar phonological segments would therefore demand the simultaneous distinction of meaning from related phonological forms to accurately distinguish each unique word. A related application of this phenomenon is the study by Demke, Graham, and Siakaluk (2002), which demonstrated

that the lexical-phonological representations of learned words facilitated activation of subsequently presented stimuli with related phonological representations in young children.

Gupta and MacWhinney (1997) asserted however, that when similar phonological patterns occur across and at different points in a real word phrase, this high level task of synchronizing semantic-phonological activations may not occur in correspondence to the phrase's phonological sequence, resulting in production errors. Thus, unlike in NWR, errors during real-word repetition manifest from the competition of phonological forms in the words, whose semantic and phonological representations simultaneously interact (Gupta & MacWhinney, 1997). Therefore, related real words in repetition tasks may indicate the depth of semantic development based on error performance; errors indicate less experience with (weaker representations of) meaningful phonological forms, which thus inhibits their efficient activation during recall.

Overall, bridging the theoretical frameworks for the repetition of NWs and real words, repetition tasks appear to verify the complex and interactive relationship between phonological and semantic representations. Highly developed vocabularies promote the generalization of phonological forms across contexts, allowing the association of phonological patterns with meaningful words and thus enhancing abilities to repeat phonological sequences. However, the repetition of real words with similar phonological representations is unique from NWR. This task for similar-sounding real words not only requires the knowledge of sound patterns to distinguish related phonological arrangements, but also the vocabulary knowledge to be able to recognize the meaning in

each of those forms, which convey unique connotations according to their precise combination. Therefore, in comparison to NWR tasks, the use of real words incorporating complex phonological sequences during phrase repetition tasks may supplement the analysis of phonological and semantic abilities.

CURRENT RESEARCH ANALYZING TONGUE TWISTER-SEMANTIC RELATIONSHIPS

Tongue twister phrases may serve as phonologically related real-word stimuli for repetition tasks examining the relationship between phonological representations and word knowledge. Specifically, tongue twister phrases merge meaningful connotations and similar phonological forms in their presentation of real words, thus requiring the simultaneous access, interaction, and distinction of phonological representations and their associated meanings. Therefore, given the context of real word stimuli, accurate rehearsals of tongue twister phrases require not only strong phonological memory and familiarity to learned phonological forms (as are found in NWR), but also the semantic depth to simultaneously decipher and assign precise productions of related phonological forms that compete across words with distinct meanings in the phrase (Gupta & MacWhinney, 1997).

Unfortunately, limited research incorporates the analysis of tongue twister repetition tasks, especially with young children. A study by Wilshire (1998) examined monolingual adults' comparative performances on NWR and tongue twister repetition. Results confirmed that specific errors, which constituted the assimilation of phonological forms in the initial position across words, occurred only on the tongue twister task. In addition, phonological errors on tongue twister repetitions commonly resulted in the

formation of real words. Likewise, Wilshire (1999) also found that word initial phonological errors appeared to represent forms present not just in the initial positions of previously uttered words, but also those in upcoming words. The findings collectively demonstrate how these particular phonological errors occurred as a result of lexical planning that influenced phonological recovery (Wilshire, 1998, 1999).

These results parallel the theories found in Gupta and MacWhinney (1997), which attribute such errors on real-word repetition tasks as the misselection of phonological forms based on the competition of similar phonological, but distinct semantic, representations. As a result, the strength of lexical representations, and thus, their phonological forms, appears to contribute to specific error patterns in the context of repeated attempts to differentiate unique real words with highly similar phonological segments.

Exploring tongue twister repetition in bilingual adult speakers, Gollan and Goldrick (2012) compared the performance of NWR and tongue twister repetition tasks (similar to Wilshire (1998)). Their analysis showed, like in previous studies, that Spanish-English bilingual speakers produced more errors with NWR tasks than with the tongue twisters, and also produced more errors on tongue twister phrases containing a greater degree of phonological similarity across words than those with more dissimilar phonological forms across words. Like the outcomes in Wilshire (1998, 1999), these overall findings suggest that real word phrase stimuli provide greater lexical and corresponding phonological contexts to support the recall of familiar phonological forms, but that similar phonological forms inherent of tongue twisters induce an increased

number of errors. Therefore, these results verify how like in studies including TD adult monolingual speakers, TD adult bilingual speakers demonstrate the complex interaction between real words' meaningful contexts and corresponding phonological patterns, which requires increased familiarity to lexicon, and thus corresponding semantic and phonological segments, to accurately repeat tongue twister phrases.

THE CURRENT STUDY

Overall, merging the theories of Gupta and MacWhinney (1997) and Beckman and Edwards (2000), larger vocabulary sizes not only provide meaningful support of phonological forms, but also allow the generalization and expansion of sound patterns across multiple contexts, which promote phrase repetition. Interestingly however, tongue twister phrases as real-word stimuli introduce distinct challenges for phrase repetition, namely, the interference between the words' semantic connotations and phonological forms degrades the ability to separate their similar phonological representations to distinguish each independent word. Thus, tongue twister repetition clearly exhibits the dynamic and interactive relationship between vocabulary depth and phonological skills that NWR fails to address in its inability to access semantic representations.

Tongue twister performance may indicate the emergence of interactive skills inherent of language development, namely in the areas of vocabulary and phonological knowledge. The current study intends to analyze the tongue twister framework with bilingual children with and without LI. Given the fact that language development in bilingual children is multifactorial, and vocabulary acquisition depends on variables such as conceptual knowledge, variation of exposure and use of each language, and the ability

to separate two distinct phonological systems (Sheng et al., 2012; Summers et al., 2010), tongue twister repetition tasks may reveal unique patterns in this population. Moreover, because of the study's inclusion of bilingual children with LI, who exhibit limited language learning abilities and distinct patterns of linguistic development, tongue twisters may serve to reveal further performance distinctions between them and their TD peers. Therefore, this study intends to address the following questions:

1.) To what extend does vocabulary knowledge support phonological skills during tongue twister repetition tasks in bilingual children with and without LI?

2.) What patterns exist between levels of vocabulary knowledge and the nature of errors that tongue twister repetition induces in bilingual children with LI versus in their TD bilingual peers?

Methods

PARTICIPANTS

Thirty-four participants were chosen for the current study from a group of 360 students enrolled in a large longitudinal study analyzing change in language performance in Spanish-English bilingual children between kindergarten and fifth grade. The parent study recruited students from school districts in central Texas that served a large number of bilingual Hispanic students. The participants qualified for the study if parent report indicated at least 20% exposure and use of Spanish at home and school settings and receiving their first exposure to English by kindergarten. Participants were excluded from the study if they received a score below 70 on the *Universal Nonverbal Intelligence Test* (Bracken & McCallum, 1998) at the time of recruitment or if their parents indicated history of brain injury, severe social-emotional problems, intellectual disability, autism spectrum disorder, or hearing loss.

As part of the parent study, the children were systematically classified into LI, low normal, and TD groups based on objective language testing. Participants completed the *Bilingual English Spanish Oral Screener (BESOS)* in Spanish and English.[2] A year later, the children completed the *Bilingual English Spanish Assessment* (*BESA*) (Peña et al., 2014) in Spanish and English and the *Test of Narrative Language (TNL)* (Gillam and Pearson, 2004) in English with a corresponding experimental equivalent in Spanish. At this time, the participants' parents and teachers also completed the *ITALK* questionnaire from the *BESA* (Peña et al., 2014) to classify the children's language abilities.

[2] With a cut-off of -1 SD below the mean across all four subtests, the *BESOS* demonstrates a 90% accuracy rate (Lugo-Neris et al., in press).

Results on each of these measures were converted into indicator scores and combined for a comprehensive analysis of the children's abilities. Participants received a high individual indicator score (1) on the formal language measures if their composite scores were 1 SD below the mean, and received a low individual indicator score (0) if their composite scores were 1 SD above the mean. On the *ITALK*, children who received a parent or teacher rating of 4.2 or below (out of 5) were assigned an indicator score of 1 while children who scored 4.8 or higher received an indicator score of 0. The individual indicator scores were summed and used to classify children with LI (indicator totals of 4 and above, constituting 3 or more positive LI indicators) or as TD (indicator totals between 0-1.5, signifying no more than 1 LI indicator).

Based on group classifications, participants were matched for cross-group comparisons of their performance during the study's testing phase. Criteria for controlled matching included being of the same sex, within three months of age at the time of testing, within 12 months of age at the time when they were first exposed to English, within 33% difference in the time of daily English exposure between school and home settings, and receiving scores falling within one point on the Hollingshead scale to classify their mother's education level as a measurement of socio-economic status.

Of the participants from the original study, a total of 34 bilingual children were selected for the current study. Primarily, children with LI were selected for this analysis if they had completed both the Expressive One-Word Picture Vocabulary Test: Spanish-Bilingual Edition (*EOWPVT: SBE*) (Brownell, 2001) and the Expressive One-Word Picture Vocabulary Test-3rd Edition (*EOWPVT-3*) (Brownell, 2000), and the tongue

twister task portions of the original study's testing measures in either the first, second, or third grades. These children with LI remained in the current study only if they were matched with a TD language peer (versus with a low normal language peer), who had completed the same vocabulary and tongue twister tasks to enable cross-group comparisons. Seventeen of the chosen participants meeting these criteria were classified with LI, two who were in first grade, seven in second grade, and eight in third grade. The remaining participants represented their 17 grade and age-matched TD peers. Tables 1 and 2 present a summary of the current study's participants based on testing performance and descriptive data at the time of entry into the parent study.

Table 1. Average Test Performances Classifying LI and TD Groups

Measurement	LI (*n*=17)	TD (*n*=17)
BESOS		
Standard Score	75.9 (55.8-95.9)	106.7 (76.0-123.3)
Indicator Score	0.85 (0.5-1.0)	0.12 (0-1.0)
BESA Semantics		
Standard Score	79.7 (53.6-112.9)	108.9 (59.6-130.8)
Indicator Score	0.76 (0-1.0)	0.15 (0-1.0)
BESA Morphosyntax		
Standard Score	63.2 (17.6-106.3)	106.9 (80.2- 124.6)
Indicator Score	0.82 (0-1.0)	0.15 (0-1.0)
TNL		
Indicator Score	0.82 (0.5-1.0)	0
Parent-Teacher Concern		
Indicator Score	0.91 (0.5-1.0)	0.32 (0-1.0)
Total Classification Score		
Indicator Score	4.94 (4-6)	0.74 (0-1.5)

Note. *BESOS* refers to the *Bilingual English Spanish Oral Screener*; *BESA* refers to the *Bilingual English Spanish Assessment*; *TNL* refers to the *Test of Narrative Language*. Data presented as means (and ranges in parentheses).

Table 2. Characteristics of Participants by Group for Initial LI-TD Matching

Matching Criteria	LI (*n*=17)	TD (*n*=17)	Combined (*n*=34)
Sex			
Male	11	6	17
Female	6	11	17
Age	86.9 (68.0-100)	89.7 (67.0-101)	88.3 (67.0-101)
Daily English exposure	36.9 (7.69-67.0)	31.6 (10.4-51.2)	34.1 (7.69-67.0)
Age of first English exposure	39.0 (0-60.0)	43.4 (0-66.0)	41.2 (0-66.0)
Mother's education level	2.53 (1.0-5.0)	2.53 (1.0-6.0)	2.53 (1.0-6.0)

Note. Objective data are presented as means (and ranges in parentheses).
Age is recorded in months; daily English exposure is recorded in the average percentage that parents reported their child hearing and using English; age of first English exposure is recorded in months; mother's education level is a score based on the Hollingshead scale.

STIMULI

The focus of this analysis was based on 32 tongue twister phrases in both Spanish and English that were created for the parent study. Each tongue twister phrase comprised four words that represented comparable phonological patterns in the initial word position. Each set of eight tongue twisters included tongue twister phrases with a variety of single phoneme and cluster repetitions to observe the anticipatory and assimilation error patterns they induce. Each set incorporated different tongue twisters, but the phonological patterns represented were consistent across sets. In English most words were monosyllabic while in Spanish most words were multisyllabic. Appendix A presents a list of the tongue twister sets administered to the participants selected for the current study.

Based on a balanced Latin square formula, participants were randomly assigned tongue twister sets in each language for the repetition task. To control for participant development and stimulus learning, participants never received the same tongue twister set in consecutive years in the original longitudinal study. Therefore, despite their potential familiarity with the tongue twister task and procedures from previous years of enrollment in the parent study, the tongue twister sets analyzed for the participants in the current study still represented novel stimuli for them at the time of administration.

PROCEDURE

At the time of testing for the original study, bilingual Spanish-English examiners administered the Spanish and English versions of the *EOWPVT* to the participants. To distinguish vocabulary depth in each language, the raw scores of the *EOWPVT: BSE* represented the participants' Spanish vocabulary knowledge and the raw scores of the *EOWPVT-3* represented their English vocabulary knowledge. In addition, the testers administered the tongue twister task using a computer-based program, which presented one set of eight tongue twister phrases in each language. The examiners monitored the children's attention to the task and ensured that the data was audio recorded.

For the tongue twister task, the computer program initially modeled two tongue twister phrases to introduce the format of the task to the participants, and then guided them through their assigned set of eight four-word tongue twister phrases in both Spanish and English. For each tongue twister phrase of the set, the child heard an initial demonstration opportunity and practice trial of the phrase, and then heard five subsequent test trials of the phrase.

During the demonstration and practice trial, an owl animation appeared to recite the four-word tongue twister phrase, twice consecutively, paired with timed visual and auditory cues. After this first demonstration, the program paused and asked the participants to repeat what they heard. The examiners either confirmed or corrected the children's production one time, then allowed the program to continue. The owl animation then disappeared and a rabbit animation appeared, which indicated the children's turn to practice the same tongue twister, twice in succession, under the same timed and cued conditions as the owl's initial demonstration. The examiner corrected and coached the participants through this step, if necessary. This demonstration and practice trial modeled the task sequence exactly as expected for the subsequent five recorded test trials for that tongue twister phrase; however for the five test trials, the participants received no corrections or guidance from the examiner and were timed and cued at a faster rate in comparison with the demonstration and practice trial.[3] Appendix B provides a detailed description of a single trial's presentation sequence for a tongue twister phrase.

The participants thus completed a sample sequence of the slow, guided practice trial followed by five faster and unguided test trials, eight times for each new tongue twister phrase in both Spanish and English. Therefore, all participants produced 80 total tongue twister trials (16 novel tongue twister phrases across languages X 5 recorded trials for each tongue twister phrase = 80 recorded tongue twister trials). Given each trial consisted of two successive recitations of the tongue twister phrases, the participants

[3] Older participants received faster cue rates during the test trials than younger participants.

ultimately repeated Spanish and English tongue twisters 160 total times (80 tongue twister trials X 2 successive recitations of each tongue twister phrase per trial = 160 total tongue twister recitations across languages), all of which were recorded for off-line phonetic analysis.

ANALYSIS

The current study consisted of the transcription, scoring, and analysis of the Spanish and English tongue twister tasks and the raw scores of the Spanish and English *EOWPVT* for the 34 participants chosen from the parent study. Specifically, this constituted the comparison of each participant's Spanish tongue twister score with their Spanish *EOWPVT: SBE* raw score, their English tongue twister score with their English *EOWPVT-3* raw score, and an additional analysis of the error types they demonstrated on the tongue twister tasks.

A bilingual graduate and two bilingual undergraduate students trained in phonetic transcription and blinded to participants' language ability classification phonetically transcribed the recorded tongue twister phrases for each participant. The same graduate student scored the transcriptions for phonological accuracy, based on actual tongue twister productions compared to the target stimuli. Full credit for a single trial constituted a score of eight points, which represented the number of words recited for a correct repetition of a four-word tongue twister phrase (recited twice). Scoring focused on the complete production of all words in the correct order. Participants received partial credit depending on the number of changes they made in comparison to the target, including modifications to the phonetic form of words that altered target meaning,

transpositions of words, word additions and omissions, and word repetitions and mazes. Appendix C presents the scoring rules and error classifications applied for all individual trial scores.

For each language, the scores of all the individual trials for all eight tongue twister phrases were combined to yield a composite score of 320 (potential score of 8 points per trial X 5 trials per tongue twister phrase X 8 tongue twister phrases = 320 points). Each participant received two composite scores, which represented their tongue twister performances in Spanish and English. In addition, based on the number of errors deducted from each participant's composite scores, a follow-up analysis was conducted to classify specific types of errors and quantify how frequently each type occurred. The error analysis included the number and frequency of:

1.) Word omissions—words deleted from the phrase (e.g. "Grecia gana * *" for "Grecia gana guerras grandes")
2.) Assimilation errors—errors resulting in nonword productions, whose phonological forms appeared related to patterns in the tongue twister phrase (e.g. "Francia ***fr****abica* ***fr****autas* francesas" for "Francia fabrica flautas francesas")
3.) Phonological semantic errors (PSE)—errors resulting in real words, whose phonological forms appeared related to patterns in the tongue twister phrase (e.g. "fleas ***flight*** frantic ***flags***" for "fleas fight frantic flies")
4.) Non-phonological semantic errors (NPSE)—errors resulting in real words, whose phonological forms appeared unrelated to patterns in the tongue twister

phrase (e.g. “Brad bakes ***grass stinks***” for “Brad bakes blue bread” and “luego locos leones ***pelean***” for “luego locos leones luchan”)

a. NPSE accuracy—the percentage of NPSE that demonstrated appropriate semantic changes according to the meaning of the rest of the tongue twister phrase (e.g. of the NPSE above, the former example (“grass stinks”) represents inappropriate semantic substitutions in relation to the meaning of the phrase, whereas the latter example (“leones pelean”) demonstrates a semantic substitution corresponding to the meaning of the phrase)

In addition, a numeric rating (1-5) was assigned to describe the overall consistency of tongue twister repetitions for each phrase. See Appendix D for detailed explanations of error classification criteria with examples of each error type.

Results

VOCABULARY PERFORMANCE

Raw scores on the *EOWPVT: SBE* and *EOWPVT*-3 indicated that vocabulary scores were higher in Spanish than in English for all participants (M=55, SD=14.4 in Spanish, M=45, SD=22.8 in English). The TD group demonstrated similar cross-language differences, scoring higher on the Spanish subtest (M=65, SD=11.1) than on the English subtest (M=47, SD=26.7). However, children with LI showed relatively similar scores across Spanish and English vocabulary subtests (M=45, SD=10.1 in Spanish, M=43, SD=20.1 in English). Overall, the TD group outperformed the group with LI on subtests in each language, but there was greater group discrepancy on the Spanish scores (20-point mean difference, F=28.5, df=1, 32, p<.001) than on the English scores (4-point mean difference, F=0.295, df=1, 32, p=NS). Table 3 depicts the mean scores and standard deviations of the vocabulary scores for the combined and individual groups in each language.

Table 3. Means and Standard Deviations of the Tongue Twister Tasks and *EOWPVT* by Group and Language

	Tongue Twister Task		*EOWPVT*	
Groups	Spanish *M (SD)*	English *M (SD)*	Spanish *M (SD)*	English *M (SD)*
LI (n=17)	148.5 (52.6)	148.4 (76.0)	45.4 (10.1)	43.1 (20.1)
TD (n=17)	255.5 (28.0)	196.6 (56.7)	64.9 (11.1)	47.4 (25.7)
Combined (n=34)	202.0 (68.4)	172.5 (70.4)	55.1 (14.4)	45.2 (22.8)

Note. *EOWPVT* refers to the *Expressive One-Word Picture Vocabulary Test*. The Spanish scores are based on the *Expressive One-Word Picture Vocabulary Test: Bilingual-Spanish Edition* and the English scores are based on the *Expressive One-Word Picture Vocabulary Test-3*.

TONGUE TWISTER TASK PERFORMANCE

Mean Scores

The highest possible score on the tongue twister task in both languages was 320. Scores on the tongue twister task were higher in Spanish (M=202, 63%, SD=68.4) than in English (M=173, 54%, SD=70.4) overall. Consistent with the combined group pattern, the TD group achieved higher scores on the Spanish tongue twister task (M=256, 80%, SD=28.0) compared to the English tongue twister task (M=197, 61%, SD=56.7). The LI group diverged from these patterns, achieving near similar score distributions on the Spanish and English tasks (M=148, 46%, SD=52.6 for Spanish and M=148, 46%, SD=76.0 for English). In general, the TD group achieved elevated scores compared to the group with LI, but a wider degree of performance was observed between groups in Spanish (108-point mean score difference) over English (49-point mean score difference). A one-way mixed variance ANOVA analysis demonstrated a statistically significant difference between TD and LI children for tongue twister scores in Spanish F=54.9, df=1, 32, p<.001 and in English F=4.39, df=1, 32, p<.05. Table 3 depicts the mean scores and standard deviations of the tongue twister task scores for the combined and individual groups in each language.

Error Similarities Across TD and LI Groups

An in-depth error analysis generally demonstrated similarities regarding the types and frequency of errors portrayed by each group. Primarily, on the tongue twister task in both languages, the participants' phonological semantic errors (PSE), or changes of target words to other real words whose sound patterns related to those in the target, were relatively consistent. Overall, Spanish PSE constituted 6.9% of all errors for the TD group and 6.8% of all errors for the group with LI, and English PSE represented 18.8% of

all errors for the TD group and 16.2% of all errors for the group with LI. Across languages, each group also showed similar frequency patterns of non-phonological semantic errors (NPSE), or changes of target words to other real words whose sound patterns differed from those in the target phrase (of all errors in Spanish, M=5.8% for TD children and M=9.5% for children with LI and of all errors in English, TD=8.8% and LI=8.7%).

In English, the TD and LI groups performed relatively consistently in their frequency of word omissions (TD M=8.9% and LI M=8.8% of all errors), as well as assimilation errors, or changes of target words to nonwords that adopted phonologies in surrounding words (TD M=13.8% of all errors and LI M=10.1% of all errors).

Error Differences Across TD and LI Groups

The error measure demonstrating the greatest performance discrepancy across groups was the degree of semantic appropriateness of NPSE in both Spanish and English. In Spanish, only 46.8% of the LI group's NPSE demonstrated semantic appropriateness to the tongue twister phrase but for the TD group, NPSE corresponded to the meaning of the tongue twister phrase 84.9% of the time. There was a statistically significant difference for NPSE accuracy by group, F=5.35, df=1, 23, p<.04. This group disparity for semantic appropriateness of NPSE also appeared in English; the group with LI demonstrated 54.4% NPSE semantic accuracy versus the TD group, who demonstrated 68.6% NPSE semantic accuracy. However, variance testing demonstrated no statistical difference for this error type in English, F=1.21, df=1, 29, p=NS. Furthermore, for both languages the group with LI received low error consistency scores (2.7 in Spanish and 2.8 in English out of 5) in comparison to the TD group (4.3 in Spanish and 3.6 in English out

of 5). Lastly, for only Spanish tongue twisters, the group with LI showed a greater proportion of word omission errors (17.8%) as opposed to the TD group (10.6%).

The only error type that the TD group produced in greater proportion than the group with LI across languages was assimilation errors (changes of target words to nonwords that adopted surrounding phonology). Out of the TD group's total errors in Spanish, an average of 24.1% of them represented these contextual sound errors as opposed to the group with LI, whose assimilation errors constituted only an average of 10.8% of their errors. In English, the percentage gap was not as large as in Spanish, however on average, the TD group still produced more assimilation errors than the group with LI (TD M=13.8% and LI M=10.1%). Error frequencies across groups and languages are reported in Table 4.

Table 4. Average Frequencies of Error Types for LI-TD Groups Across Languages

Error Type	LI (*n*=17)	TD (*n*=17)
Spanish		
Errors	53.6	20.2
Omissions	17.8	10.6
Assimilation	10.8	24.1
PSE	6.8	6.9
NPSE	9.5	5.8
NPSE accuracy	46.8	84.9
Consistency rate	2.7	4.3
English		
Errors	53.7	38.6
Omissions	8.8	8.9
Assimilation	10.1	13.8
PSE	16.2	18.8
NPSE	8.7	8.8
NPSE accuracy	54.4	68.6
Consistency rate	2.8	3.6

Note. All errors are recorded as percentages except for consistency rate, which represents a score on a scale from 1-5 points. Errors=average percent of words erred out of 320 possible error opportunities; Omissions=average percent of errors that demonstrated failed word attempts; Assimilation=average percent of errors that were nonword productions that maintained surrounding phonological forms in the initial position; PSE=average percent of errors that were phonological semantic errors; NPSE=average percent of errors that were non-phonological semantic errors; NPSE accuracy=average percent of non-phonological semantic errors that demonstrated semantically accurate productions; Consistency rate=average score quantitatively describing the consistency of tongue twister trials.

TONGUE TWISTER TASK AND VOCABULARY CORRELATIONS

Tongue Twister Raw Scores and Vocabulary Raw Scores

A correlation analysis examined the relationship between tongue twister task scores and the *EOWPVT* raw scores for the LI and TD groups in each language. Combined group analysis demonstrated large correlations between vocabulary and tongue twisters in Spanish, r=.71, p<.01, and English, r=.75, p<.01.

Tongue Twister Error Types and Vocabulary Raw Scores

In both languages, PSE showed statistical significance with each respective language's tongue twister and vocabulary scores. Large correlations were observed between Spanish PSE and tongue twisters (r=-.70, p<.01) as well as Spanish PSE and vocabulary (r=-.69, p<.01); for PSE in English, correlations were more moderate, but still significant at p<.01 with tongue twisters, r=-.49, and with vocabulary, r=-.49. There was a very large significant correlation with the participants' consistency rates on the tongue twisters in Spanish, r=.95, p<.01, with their tongue twister scores, as well as with their vocabulary scores, r=.66, p<.01. Similarly in English, large correlations of r=.94 and r=.77 when p<.01 were evident with tongue twister and vocabulary scores, respectively. In both languages, statistically significant tongue twister correlations were evident with NPSE (r=-.50, p<.01 in Spanish and r=-.76, p<.01 in English) and with omission errors

(r=-.59, p<.01 in Spanish and r=-.49, p<.01 in English). In Spanish, omission errors were moderately correlated with vocabulary scores (r=-.47, p<.01). But for English, NPSE moderately correlated with vocabulary (r=-.56, p<.01). Tables 5 and 6 present correlation data for the Spanish and English tongue twister task and vocabulary scores.

Table 5. Correlations Between Spanish Tongue Twisters and *EOWPVT: BSE*

Spanish Measures	Tongue Twister	*EOWPVT: BSE*	PSE	NPSE	Omissions	Consistency
Tongue Twister	1.00					
EOWPVT: BSE	.711*	1.00				
PSE	-.704*	-.686*	1.00			
NPSE	-.504*	-.302	.217	1.00		
Omissions	-.592*	-.469*	.311	.131	1.00	
Consistency	.946*	.659*	-.634*	-.553*	-.495*	1.00

Note. The *EOWPVT: BSE* refers to the *Expressive One-Word Picture Vocabulary Test: Bilingual-Spanish Edition*. PSE=phonological semantic errors; NPSE=non-phonological semantic errors.
*p<.01

Table 6. Correlations Between English Tongue Twisters and *EOWPVT-3*

English Measures	Tongue Twister	*EOWPVT-3*	PSE	NPSE	Omissions	Consistency
Tongue Twister	1.00					
EOWPVT-3	.747*	1.00				
PSE	-.486*	-.494*	1.00			
NPSE	-.758*	-.557*	.056	1.00		
Omissions	-.474*	-.272	.130	.265	1.00	
Consistency	.944*	.767*	-.502*	-.705*	-.442*	1.00

Note. The *EOWPVT-3* refers to the *Expressive One-Word Picture Vocabulary Test-3*.
PSE=phonological semantic errors; NPSE=non-phonological semantic errors.
*p<.01

Discussion

This study examined the relationship between the phonological and semantic representations of bilingual children with and without LI via the comparison of their Spanish and English tongue twister performances and expressive vocabulary scores. Accurately reciting tongue twister phrases requires the distinction of complex sequences of related phonological forms while simultaneously sorting their semantic connotations; this suggests that superior levels of language development, namely stronger phonological and semantic representations, promote the ability to store and repeat tongue twisters. Given the unique patterns of cross-linguistic language development and word learning in bilingual children according to age and patterns of language status (LI versus TD), use, and exposure (Sheng et al., 2012), this study addresses the relationship of bilingual children's varying degrees of language knowledge and their ability to recite tongue twisters in each language. This study also considered the types of errors the tongue twisters induced, as well as the distinctions in the types of errors produced by bilingual children with LI in comparison with their TD peers.

For all participants across languages, findings demonstrated that vocabulary scores strongly correlated with tongue twister scores and consistency rates. Vocabulary scores also correlated with specific tongue twister error types; across both languages, strong correlations with vocabulary occurred with PSE, but only occurred in English with NPSE and in Spanish with omission errors. Cross-group performances demonstrated that in Spanish, omission errors represented the majority of LI group's errors and assimilation errors characterized the majority of the TD group's errors. In comparison to their

Spanish performances, the groups' English performances appeared to converge; both groups demonstrated PSE to occur most frequently in their English tongue twisters. Lastly, comparative accuracy rates of NPSE across groups confirmed that the TD group maintains robust and profound semantic representations in comparison to the group with LI.

Addressing the question concerning the relationship between phonological and semantic representations in bilingual children, tongue twister performance appears to correspond with vocabulary knowledge given the strong correlations between tongue twister scores and consistency rates with *EOWPVT* scores. This conclusion persists across languages despite the Spanish-English performance gaps on both the tongue twister tasks and vocabulary tests. The greater influence of vocabulary depth on the ability to repeat novel phonological forms in monolingual children (Edwards et al., 2004) prompts the prediction that the language with greater vocabulary skills in bilingual children would demonstrate stronger correlations with the repetition of recognizable phonological forms compared to the language with less semantic depth. However, the current study found that the strong correlation between Spanish vocabulary and tongue twisters was equally consistent between English vocabulary and tongue twisters. Therefore, these outcomes deviate from predictions that Spanish correlations would be stronger than English correlations, based on evidence that greater vocabulary development and experience promotes phonological storage and representations.

Possible explanations for these comparable cross-language correlations are the participants' levels of language experience and use. The average age of first exposure to

English was 3;4, with a group range of 0-5;5. Additionally, at the time of entry into the original study the participants' average language exposure patterns were reported as 34.1% English (65.9% Spanish) and English exposure levels ranged from 7.69%-67.0% (33.0%-92.3% Spanish). According to Sheng et al. (2012) lexical-semantic learning critically relies on language experience and exposure. Therefore, the broad arrays representing the cumulative cross-language experiences of all participants may have influenced elevated or truncated vocabulary scores relative to age-expected performances. Indeed, although the participants were originally matched on criteria including age and degree of language exposure, these variables (of evidently wide ranges) could have been randomly distributed across grade levels, potentially resulting in matched LI-TD pairs whose bilingual language experiences likened their language development patterns with matched pairs of different ages. Therefore, for this bilingual group, who represent distinct vocabulary knowledge in each language and who range across different grade levels (and thus different stages of language development), their varying levels of bilingual language exposure may explain the near-equal tongue twister-vocabulary correlations across languages.

Regarding the second question to the current study, tongue twister errors across languages evidently emphasize the relationship between phonological-semantic representations. For example, similar to the monolingual adults in Wilshire (1998, 1999), the bilingual children in this study appeared to encounter challenges to simultaneously organize semantic and phonological patterns during tongue twister tasks. However, this pattern appears to have a highly correlated function with vocabulary because across

languages and participants, vocabulary scores demonstrated strong negative correlations with PSE. Such errors signify that with weaker vocabulary scores, the errors the participants produced were increasingly prone to represent real words whose phonological forms were similar to those of the target. As vocabulary scores increased, the participants' word knowledge was more likely to repair these types of errors. Therefore, the correlation with PSE and vocabulary scores suggests that tongue twister performance is influenced by semantic knowledge, which triggers lexical planning and the likelihood of lexical-phonological interference, impairing phrase production.

Across all participants, vocabulary also correlated in a negative direction with NPSE on the English tongue twister task. NPSE constitute real word substitution errors, but have no phonological relation to the target. Therefore, decreased vocabulary knowledge in English seemed to have increased the likelihood that the participants produce real word errors that failed to bridge semantic-phonological associations to substitute words with phonology that was relevant to the stimuli. Therefore, NPSE would indicate that decreased word knowledge demonstrates weaker representations of meaningful phonological forms, which are therefore more difficult to store for recall.

Considering that participants in both the LI and TD groups demonstrated lower vocabulary and tongue twister scores in English relative to their respective scores in Spanish, the negative correlation between vocabulary and NPSE in English might be the result of limited word knowledge in their developing second language of less input and experience. Such phenomenon would further explain the PSE correlation that was stronger across groups in Spanish (r=-.686) than in English (r=-.494); although both

correlations were significant at $p<.01$ level, stronger word knowledge across groups in Spanish supported semantic-phonological processing on Spanish tongue twisters on a greater scale than in English, the language of less exposure and experience and whose cross-group vocabulary scores were lower.

In addition, level of language experience and exposure may also reflect overall correlation patterns between vocabulary and omission errors across languages. According to Sheng, et al. (2012), omission of words in expressive tasks indicates weak semantic representations that impair the ability to recognize the target words in their meaningful or phonological contexts. Therefore, a strong correlation was expected across languages to demonstrate that when vocabulary knowledge decreased, there was a high likelihood of omissions in the errors the participants committed. This study demonstrated however, that correlations between vocabulary and omission errors were significant in Spanish ($r=-.469$, $p<.01$) but not significant in English ($r=-.272$, p=NS).

Examining cross-group performances explains this phenomenon: although the TD group outperformed the group with LI on all tasks across languages, performance gaps on both vocabulary and tongue twister tasks were narrower between ability groups in English than in Spanish; this was most likely due to general patterns of unequal language exposure and experience favoring Spanish across participants. Therefore, TD groups' tongue twister errors closely aligned with the LI groups' errors in English; out of all the errors each group produced in English, an average of 8.8% of the LI group's and 8.9% of the TD group's represented omission errors. In Spanish, a near-significant difference constituted the comparative frequencies of omission errors across groups where an

average of 17.8% of the LI group's and 10.6% of the TD group's errors were omissions, F=3.58, p<.07. Therefore, despite higher English vocabulary scores of the TD participants over the participants with LI, small performance gaps across tasks in English influenced the TD group's errors to approximate those of the group with LI, which weakened the overall association between English vocabulary and omission errors. Therefore, cross-language differences evidently had some influence on the types of errors produced during tongue twister repetition based on the varying degrees of support that word knowledge provided to recognize stimuli in Spanish relative to English.

Further group distinctions demonstrated again, that both groups' error patterns were more similar in English than in Spanish. For example, of all errors, PSE represented the error type that occurred most often across groups in English (16.2% for the group with LI and 18.8% for the TD group), again establishing the distinct role of semantic knowledge in tongue twister tasks that allows access to relevant phonological forms and causes interference in the semantic-phonological sorting process. However in Spanish, participants achieved overall higher scores than in English and revealed large performance gaps across groups. These distinctions appeared to influence more omission errors in the group with LI and more phonological assimilation errors in the TD group. Omission errors that appeared in greater frequency in the group with LI corroborate the patterns in previous studies of children with LI, whose lack of familiarity to grammatical and semantic forms induced their exclusion in repetition and naming tasks (Boyle & Gerken, 1997; Sheng et al., 2012). Therefore, apparently weaker representations of the

semantic-phonological forms of the group with LI as compared to the TD group in the Spanish tongue twister task resulted in their inability to store them for attempted recall.

Interestingly, among their total number of errors, the error type emerging most frequently in the TD group was assimilation errors. Wilshire (1998, 1999) indicated that tongue twisters entail high demands on the articulatory system, which cause a greater likelihood of errors that adopt the parallel phonetic nuances of neighboring words as a result of lexical planning. Given the TD group's greater semantic experience and vocabulary scores in Spanish, their high patterns of assimilation errors are not unexpected, as higher vocabulary knowledge would predict increased levels of lexical planning abilities.

The last noteworthy finding from this study that demonstrates tongue twisters' clear ability to represent the varying levels of semantic knowledge across groups is evident from each group's NPSE patterns. In Spanish for example, on average, a greater percentage of the LI group's errors were NPSE (M=9.5%) than the TD group's errors (5.8%). Although these differences were statistically insignificant (F=1.05, p=NS), the LI group still appeared to rely on this error type more often than the TD group. However, only 47% of the LI group's NPSE were accurate according to the semantic context of the phrase, whereas 85% of the TD group's NPSE were semantically appropriate. This demonstrated a statistically significant group difference, F=5.35, p<.04. Compared to in Spanish, the LI and TD group frequencies of NPSE out of their total English errors converged (M=8.8% and M=8.9% respectively), yet greater degrees of NPSE accuracy were still evident in the TD group (69%) over the group with LI (54%). Although these

English NPSE accuracy rates demonstrated no statistically significant difference across groups (F=1.21, p=NS), they pointed to the TD group's increased abilities to more efficiently access semantic knowledge in their errors than the group with LI. Therefore, despite the lower degrees of exposure and experience in English across groups, the TD group nevertheless showed superior abilities to draw semantic associations during tongue twister repetition tasks than the group with LI. These cross-group patterns of NPSE assignments in Spanish and English are consistent with the comparative vocabulary performances of the bilingual LI and TD children in Sheng et al. (2012).

Overall, these patterns maintain the principle that children with greater semantic knowledge are able to demonstrate logical word associations than those with lower levels of semantic knowledge. Even though NPSE constitute errors that fail to represent phonological similarity to the target tongue twister phrase, the TD group revealed how their NPSE were more likely to promote real word productions that at least attempted to enhance the meaning of the phrase. Conversely, the LI group's NPSE were not only phonologically unrelated to the target, but were also void of any associative meaning with the target, which essentially classified their NPSE as completely irrelevant to the stimuli.

FUTURE TONGUE TWISTER RESEARCH

Future studies including bilingual children's repetition of tongue twisters may investigate purely nonword phonetic errors in greater depth. Given the LI group's higher ratio of inaccurate NPSE compared to the TD group, analysis of the groups' nonword errors that were also phonologically unrelated to the tongue twister phrase would predictably occur in higher frequency in the LI group as well.

Furthermore, an additional informative measure for future research might include assimilation errors that activate the phonological-lexical loop. Goldrick and Blumstein (2006) enhanced this idea by describing a "cascading" effect in their study of tongue twister repetition tasks in adult speakers. Namely, they demonstrated that the tongue twisters' initial activation of the lexical-phonological systems promote phonological errors consistent with surrounding word forms or may instigate future production errors that assimilate the phonological forms of the original error. The current study specifically excluded the measurement of voicing articulatory errors that led the investigation by Goldrick and Blumstein (2006) (voicing errors that produced real words were credited as PSE). However, future analysis of bilingual children's tongue twister productions may consider integrating the analysis of voicing errors to observe how their activation of phonological errors influence additional phonological and semantic errors during subsequent repetitions.[4]

[4] A trial particularly representative of this phenomenon is an LI child's English voiced assimilation error that resulted in the subsequent production of /m/ errors for /b/ targets when a real word was produced from an initial /m/ substitution: "brad **makes mu mr**ed" from the target "brad **bakes blue br**ed".

Conclusion

The results from this study provide validation that more advanced vocabulary skills facilitate performance on tongue twister tasks in bilingual children with and without LI. Emphasizing this model are strong positive correlations between standardized vocabulary scores and tongue twister performances. Despite the known principle that language exposure and experience influence vocabulary knowledge, and in turn, predict phonological skills, this relationship was unclear in this study given the parallel correlations between vocabulary and tongue twister performance across languages. This finding is a suspected result of varying levels of English exposure across children of different ages. However, strong negative correlations between vocabulary scores and particular tongue twister error types still emphasize the fundamental relationship between semantic and phonological representations that specifically emerge during tongue twister repetition tasks. Furthermore, the comparative performances of LI and TD groups' errors in each language highlight how TD children maintain greater semantic knowledge in comparison to children with LI.

The outcomes of this study thus indicate that tongue twisters reveal the interactive tendencies of vocabulary and phonology. Overall, superior vocabulary scores correlated with higher tongue twister repetition scores; thus, strong levels of word knowledge allow the development of stronger semantic associations with phonological forms, enabling the generalization and refinement of those forms' meanings across different words. As a result, the rich semantic context of phonological forms promote the ability to recognize, store, and sort the similar phonological forms inherent in tongue twister phrases for their

repeated production. Therefore, the meaningful and phonologically challenging characteristics of tongue twisters apparently constitute appropriate stimuli for analyzing the interactive language abilities on bilingual children, who represent unique patterns of vocabulary and overall language development.

Appendices

APPENDIX A: TONGUE TWISTER SETS ADMINISTERED IN SPANISH AND ENGLISH

Set	Spanish	English
1	Grecia gana guerras grandes	Slimy snakes strike slippers
	Brenda abrió libritos breves	Bright blue baby bracelets
	Tengo tres tortugas terribles	Flo found fresh flowers
	Rita reparte gorras ridículas	Quiet kids clap quickly
	Clara compra cristales claros	Ghosts grow glowing gardens
	Paco aprecia plata pura	People prefer playful pets
	Frecuentes fiestas festeja Francisco	Dogs drink dripping dough
	Jesús jala juguetes geniales	Twelve tricky turkeys twirl
2	Graciosas gallinas gordas gruñen	Blue birds bring blossoms
	Pepe aplasta planos pasteles	Fred felt flat frogs
	Brinca Bianca blandos brincos	Proper petted ponies prance
	Cuatro clases quieren cuadernos	Creepy cobras can't crawl
	María mira muchos marineros	Shelly's sister smells sugar
	Francia fabrica flautas francesas	Tweety tries two Twinkies
	Tres tigres temen trampas	Greedy goats gobble grass
	Lanza lejos largas latas	Dog drawers drain dimes
3	Grandes gallos guardan granos	Brad bakes blue bread
	Paty pronuncia aprisa poemas	Cream colored clowns cry
	Brenda busca blusas brillantes	Fleas fight frantic flies
	Cuatro caballos crecen curiosos	Seven sleepy sailors settled
	Luego locos leones luchan	Grumpy gorillas glow green
	Francisco firma famosas frases	Pretty plucky playful pretzels
	Tres tazas tapa Trinidad	Timmy thinks trees text
	Sonia siempre sugiere sopa	Damp drab dragon dash

APPENDIX B: PRESENTATION SEQUENCE FOR A SINGLE TONGUE TWISTER TRIAL

Initiation of a new tongue twister trial began with the initial priming of the target phrase, then subsequent prompts for the child's repetition of the same phrase. The participants would thus see and hear on the computer screen:

1. The paired appearance of the owl animation and a visual "3-2-1" countdown
2. The paired presentation of the sound of a single bell ring and four dots appearing across the screen, which cued the owl to begin reciting the tongue twister phrase
3. The successive blinking of each dot across the screen from left to right, pacing the owl to state the four words in the phrase in time with each blink
4. The sound of a second bell ring, signaling the end of the phrase's first recitation and transition to its second recitation
5. The successive blinking of each dot across the screen from left to right, pacing the owl to state the four words in the phrase in time with each blink for a second time
6. The simultaneous disappearance of the owl, and paired appearance of the rabbit animation and a visual "3-2-1" countdown, which cued the participants to take their turn to recite the tongue twister the owl modeled

To complete the tongue twister, the repetition of visual and auditory cues from steps two through five (the rabbit animation timing and signaling the participants to recite two successive repetitions of the tongue twister phrase) continued until the participants finished reciting the tongue twister, exactly like the owl, for five complete trials.

APPENDIX C: SCORING CRITERIA FOR TONGUE TWISTER TRIALS

Error Criteria	Exceptions	Examples
Phonetic Errors: Maximum of one point per word containing a consonant or vowel error that changes the meaning or understanding of the target word or phrase	Consonant or vowel errors that represent dialectically acceptable patterns, standard pronunciation differences due to bilingual language learning, or changes in voicing quality, as long as these errors do not represent intrusions from surrounding phonological forms in the phrase or semantic changes	• Target: rita repaɾte goras riðikulas Actual: **gɾita repueɾte** goras **reðikulas** 2-point deduction for the consonant and vowel errors in the first two words, given they alter the meaning and comprehensibility of the targets; No deduction for the vowel error in the last word since it does not alter the meaning or comprehensibility of the target • Target: bɹæd beɪks blu bɹɛd Actual: bɹæd beɪks **bəlu** bɹɛd; bɹæd beɪks **bu pɹɛd** bɹɛd 2-point deduction for consonant and devoicing errors, given they alter the meaning and comprehensibility of the targets; No point deduction for the vowel addition in the third word, given it does not alter the meaning or comprehensibility of the target
Maze and Repetition Errors: Maximum of one point per word or phoneme addition or repetition to the target phrase	Beginning a trial's first repetition of the tongue twister phrase with the correct phoneme/s and/or word/s before correctly restarting the phrase	• Target: rita repaɾte goras riðikulas; rita repaɾte goras riðikulas Actual: **ri** rita repaɾte goras riðikulas; **ri** rita repaɾte goras riðikulas 1-point deduction for the addition of /ri/ in the second recitation of the phrase; no deduction for the addition of /ri/ at the beginning of the first recitation

Error Criteria	Exceptions	Examples
Word Order Errors: Maximum of one point per word produced out of order in comparison to the target phrase	—	• Target: kwaɪət kɪdz klæp kwɪkli Actual: **klæp kɪdz kwaɪət** kwɪkli 3-point deduction for the transposition of the first three words
Word Omission Errors: Maximum of one point per absent word or lack of attempt Maximum of one point per absent or erred word due to coughing, yawning, etc., when the same words were also erred or inconsistently produced in surrounding trials	Absent words due to coughing, yawning, etc. that were correct in surrounding trials	• Target: gɾesja gana geras gɾandes Actual: gɾesja gana * *; gɾesja gana * gɾandes 3-point deduction for each absent word • Target: twɛlv tɹɪki tʌɹkiz twʌɹl Actual: twɛlv tɹɪki tʌɹkiz **twɛlv**; twɛlv tɹɪki tʌɹkiz **t—** **(recording cut out)**; twɛlv tɹɪki tʌɹkiz **tɹiəʃ** 1-point deduction for the cut-off word given the word's inconsistent production in surrounding trials • Target: bɹaɪt blu beɪbi bɹɛɪsləts Actual: **bɹaɪt** blu beɪbi bɹɛɪsləts; **bɹʌ** blu beɪbi bɹɛɪsləts **(coughed on first word)**; **bɹaɪt** blu beɪbi bɹɛɪsləts No point deductions for mispronouncing the choked word, given the evidence of correctly producing the word in surrounding trials

APPENDIX D: TONGUE TWISTER ERROR CLASSIFICATION EXAMPLES

Error Type	Example
Assimilation Errors in the Initial Position of Words: 1 point per each error that results in non-words that maintain initial position phonological patterns present in the phrase	• Target: francia fabrica flautas francesas Actual: fransja **fraβika frautas** fransesas; **flaunsja fraβika** flautas **flambesas** 5 points for each word that inappropriately adopts the initial position /fɾ/ or /fl/ blends based on the presence of those phonological patterns in surrounding target words
Phonological Semantic Changes (PSE): 1 point per each error that results in real-word utterances and maintains other initial position phonological patterns in the phrase	• Target: fliz faɪt fɹæntɪk flaɪz Actual: fliz **flaɪt** fɹentɪs **flægs**; li faɪts fɹentɪd **fɹends** 3 points for each real-word substitution that adopts relevant initial position phonological forms that appear in the target phrase
Non-Phonological Semantic Changes (NPSE): 1 point per each error that results in real-word utterances and deviates from the phonological patterns of the phrase	• Target: bɹæd beɪks blu bɹɛd Actual: bɹaɪt blu **gɹæs** bɹɛd; bɹæn blu bɹɛns **stɪŋks** 2 points for the real-word substitutions “grass” for “blue” and “stinks” for “bread”; although the new words phonological forms are unrelated to the target words, they still convey meaning (unlike assimilation errors); No NPSE credit for the real-word substitution “bright” for “brad” because its phonological forms are influenced by the target word “Brad” (PSE) • Target: lweɣo lokos leones luchan Actual: lweɣo lokos leones **pelejan** 1 point for the real-word substitution “pelean” for “luchan”; although the new word’s phonological forms are unrelated to the target, it still conveys meaning

Error Type	Example
Semantically Appropriate Non-Phonological Semantic Changes (NPSE): 1 point per each error that results in real-word utterances that deviate from the phonological patterns of the phrase, but still relate to the meaning of the phrase or surrounding words	Based on the above NPSE examples: No credit for the real-word substitutions "grass" for "blue" and "stinks" for "bread" because the new words have no relation to the targets' phonological forms and do not enhance or relate to the meaning of the target words or phrase 1 point for the real-word substitution "pelean" for "luchan"; although the new word's phonological forms differ from the target, the new word maintains the semantic connotations of the target
Word Omission Errors: 1 point per each deleted word from the target phrase	• Target: ɡɾesja ɡana ɡeras ɡɾandes; ɡɾesja ɡana ɡeras ɡɾandes Actual: ɡɾesja ɡana * *; ɡɾesja ɡana * ɡɾandes 3 points for the three deleted words from the target phrase

Error Type	Example
Consistency rates for each tongue twister phrase across trials: 1-5 point rating scale 1=Inconsistent and random errors marked across trials; high number of overall errors 2=Errors are inconsistent and increase, decreasing accuracy across trials 3=The number and types of errors remain consistent across trials 4=Errors are consistent and decrease, increasing accuracy across trials 5=Consistently accurate repetitions across all trials; low number of overall errors	• Target: pɹɑpəɹ pɛtəd poʊniz pɹæns Actual: **pɹɛpər podin pʊtɪts pɛnst; pɛpər pʊdɪn punɪts pɛst** 1 point for multiple random and inconsistent errors across all trials • Target: dɑg dɹɔɪz dɹeɪn daɪmz Actual: dɑg ʤeɹz **dɹɪm** daɪmz; **dɑm ʤeɹmz dɹɪm daɪkz** 2 points for errors that increase and are inconsistent between the first and last trials • Target: pipəl pɹəfʌɹ pleɪfəl pɛts Actual: pipəl **pifoɹ pleɪ** pɛts 3 points for two-three errors consistently repeating across all trials • Target: sonja sjempɾe suxjeɾe sopa Actual: **sjempɾe suu xjeɾe ropa** sopa; sonja sjempɾe suxjeɾe sopa 4 points for errors that decrease; productions become consistently more accurate between first and last trials • Target: kwatɾo klases kjeɾen kwaðeɾnos Actual: kwatɾo klases kjeɾen **kwaðerðos** 5 points for none or only one error consistently repeating across all trials

References

Beckman, M. E., & Edwards, J. (2000). The ontogeny of phonological categories and the primacy of lexical learning in linguistic development. *Child Development*, *71*(1), 240.

Boyle, M. K., & Gerken, L. (1997). The influence of lexical familiarity on children's function morpheme omissions: A nonmetrical effect?. *Journal Of Memory And Language*, *36*(1), 117-128. doi:10.1006/jmla.1996.2478

Bracken, B., & McCallum, S. (1998). *Universal Nonverbal Intelligence Test*. Itasca, IL: Riverside.

Brownell, R. (2001). *Expressive One-Word Picture Vocabulary Test: Spanish-Bilingual Edition*. Novato, CA: Academic Therapy Publications.

Brownell, R. (2000). *Expressive One-Word Picture Vocabulary Test* (3rd ed.). Novato, CA: Academic Therapy Publications.

Demke, T. L., Graham, S. A., & Siakaluk, P. D. (2002). The influence of exposure to phonological neighbours on preschoolers' novel word production. *Journal Of Child Language*, *29*(2), 379-392. doi:10.1017/S0305000902005081

Edwards, J., Beckman, M. E., & Munson, B. (2004). The interaction between vocabulary size and phonotactic probability effects on children's production accuracy and fluency in nonword repetition. *Journal Of Speech, Language & Hearing Research*, *47*(2), 421-436. doi:10.1044/1092-4388(2004/034)

Gathercole, S. E. (2006). Non-word repetition and word learning: The nature of the relationship. *Applied Psycholinguistics*, *27*(4), 513-543. doi: 10.1017.S0142716406060383

Gathercole, S. E., & Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. *Journal of Memory and Language, 28*, 200–213.

Gillam, R. B., & Pearson, N. A. (2004). *Test of Narrative Language*. Austin, TX: Pro-Ed.

Goldrick, M., & Blumstein, S. (2006). Cascading activation from phonological planning to articulatory processes: Evidence from tongue twisters. *Language & Cognitive Processes*, *21*(6), 1. doi:10.1080/01690960500181332

Gollan, T. H., & Goldrick, M. (2012). Does bilingualism twist your tongue?. *Cognition*, *125*(3), 491-497. doi:10.1016/j.cognition.2012.08.002

Gray, S. (2004). Word learning by preschoolers with specific language impairment: Predictors and poor learners. *Journal Of Speech, Language & Hearing Research*, *47*(5), 1117-1132. doi:10.1044/1092-4388(2004/083)

Gupta, P., & MacWhinney, B. (1997). Vocabulary acquisition and verbal short-term memory: Computational and neural bases. *Brain And Language*, *59*(2), 267-333. doi:10.1006/brln.1997.1819

Lugo-Neris, M. J., Peña, E. D., Bedore, L. M., Gillam, R. B. (2015). Utility of a language screening measure for predicting risk for language impairment in bilinguals. *American Journal of Speech-Language Pathology*. doi: 10.1044/2015-AJSLP-14-0061

Munson, B., Kurtz, B. A., & Windsor, J., 2005. The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetition of children with and without specific language impairment. *Journal of Speech, Language and Hearing Research, 48*, 1022–1047.

Peña, E. D., Gutiérrez-Clellen, V. F., Iglesias, A., Goldstein, B. A., & Bedore, L. M. (2014). *BESA: Bilingual English-Spanish Assessment*. San Rafael, CA: AR-Clinical Publications.

Sheng, L., Peña, E. D., Bedore, L. M., & Fiestas, C. E. (2012). Semantic deficits in Spanish-English bilingual children with language impairment. *Journal Of Speech, Language & Hearing Research*, *55*(1), 1-15. doi:10.1044/1092-4388(2011/10-0254)

Summers, C., Bohman, T. M., Gillam, R. B., Peña, E. D., & Bedore, L. M. (2010). Bilingual performance on nonword repetition in Spanish and English. *International Journal Of Language & Communication Disorders*, *45*(4), 480-493. doi:10.3109/13682820903198058

Wilshire, C. E. (1999). The "tongue twister" paradigm as a technique for studying phonological encoding. *Language & Speech*, *42*(1), 57-82.

Wilshire, C. E. (1998). Serial order in phonological encoding: An exploration of the 'word onset effect' using laboratory-induced errors. *Cognition*, *68*(2), 143-166. doi:10.1016/S0010-0277(98)00045-6

Vita

Maria Nicole Mitidieri was born in southern New Jersey in November of 1990. In May 2009 she graduated from Cherry Hill High School West in Cherry Hill, New Jersey. In May 2013, she graduated with honors from Loyola University Maryland, where she earned a double Bachelor of Arts degree in Speech-Language Pathology and Spanish. She began her studies in the Communication Sciences and Disorders department at the University of Texas at Austin in August 2013. She received her Master of Arts degree in Speech-Language Pathology in May 2015.

Email address: mnmitidieri@utexas.edu

This thesis was typed by the author.