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# Lexical Access in the Second Year:
# A Cross-linguistic Study of Monolingual and Bilingual Vocabulary Development

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## 1   Introduction

Previous research documents a significant increase in vocabulary size and speed of word recognition in monolinguals throughout the 2nd year of life. Moreover, there is a relation between these measures across English- and Spanish-speaking monolinguals, such that children with larger vocabularies demonstrate faster word recognition than children with smaller vocabularies (Hurtado, Marchman, & Fernald, 2007; Fernald, Perfors, & Marchman, 2006). What's more, this relation becomes more robust from 18 to 24 months (Fernald, Marchman, & Weisleder, 2013). However, few studies have examined the development of speed in word processing in young bilinguals and whether improvements in word processing are related to vocabulary growth in both languages (Marchman, Fernald, & Hurtado, 2011). The present investigation compares the developmental changes in spoken word processing and vocabulary growth between monolingual English, Spanish, and bilingual English-Spanish learners during the 2nd year.

The study of speed of word processing in bilinguals offers both applied and theoretical implications. From an applied perspective, it has been shown that both vocabulary size and speed of word processing predict later language development within *monolingual* populations (Marchman & Fernald, 2008). Despite our rich understanding of the development of monolingual word processing and comprehension, it is estimated that a large majority of the world's population is speaks more than one language, and this population is rapidly growing within the US (US Census Bureau, 2011). Therefore an understanding of language differences that result from culturally and linguistically diverse environments is essential to the practice of SLPs who serve an increasingly diverse population (American Speech-Language-Hearing Association, 2007). To this end, researchers must first establish normative data about the rate of development of early bilingual vocabulary knowledge and speed of processing in order to appropriately identify atypical deviations within the multilingual population. Further, it is important to establish whether our understanding of monolingual language acquisition also applies to multilingual learners.

Although monolingual children demonstrate strong relations between vocabulary knowledge and speed of word recognition (Fernald, Perfors, & Marchman, 2006; Fernald, Swingley, & Pinto, 2001; Hendrickson, Mitsven, Poulin-Dubois, Zesiger, & Friend, 2015; Hurtado, Marchman, & Fernald, 2007; Zangl, Klarman, Thal, Fernald, & Bates, 2005), the nature and specificity of this relation is not well understood. One possible explanation is that the relation between word knowledge and word processing is based on experience within a language. In the case of bilinguals, this means that processing speed and vocabulary knowledge are dissociable

across languages, such that processing speed in one language is related to within- and *not* cross-language vocabulary knowledge. Alternatively, it is possible that the relation between word processing and word knowledge does not rely on experience within a language, but instead, general language experience. From this view, processing speed and word knowledge in bilinguals are related both within and across languages. A final possibility is that the association between vocabulary knowledge and word processing speed is not mediated by language experience but instead by general cognitive efficiency. That is, the speed with which auditory information (not specific to language) is processed influences the rate of vocabulary development. Thus, from a theoretical perspective, the study of lexical processing within bilinguals affords the opportunity to examine whether improvements in word processing are dissociable across languages within a single language learner.

Although bilinguals offer a way to tease apart these possibilities, most studies of bilinguals to date have focused on the relation between vocabulary and speed of word processing within, as opposed to between, languages. From this work it has been shown that processing speed and vocabulary size are related within the non-dominant language at 18 months and 22 months, and within the dominant language at 22 months in French-English bilinguals (Legacy, Zesiger, Friend, & Poulin-Dubois, 2015; Legacy, Zesiger, Friend, & Poulin-Dubois, in review). By 30 months, English-Spanish bilinguals show significant correlations between speed of word processing and vocabulary size within each language, but not across languages (Marchman, Fernald, & Hurtado, 2011). Thus, increases in word processing speed may be dissociable across languages. However, Marchman et al., (2011) reported marginal associations between total conceptual vocabulary and processing speed in each language, suggesting shared variance between languages within bilinguals. Nevertheless, the nature of this shared variance remains unclear and presents a critical gap in our understanding of the cross-linguistic associations between processing speed and vocabulary size.

The study of *cross-linguistic* associations between speed of word processing and word knowledge in early bilingual language acquisition presents two critical questions of interest in the present study. First, it is unknown how cross-linguistic associations develop *over time* in early language acquisition, and in particular at a time when young children are beginning to negotiate the semantic organization of words from two languages (i.e., 16 to 24 months; Arias-Trejo & Plunkett, 2009; 2013; Plunkett & Styles, 2009; von Koss Torkildsen et al., 2006; Willits, Wojcik, Seidenberg, & Saffran, 2013). Indeed, findings suggest that lexical-semantic organization follows a developmentally incremental process, such that 24- but not 18-month-old monolinguals, demonstrate semantic priming between words with related word meanings (e.g., Arias-Trejo & Plunkett, 2009). Thus, cross-linguistic lexical-semantic associations in bilinguals may demonstrate a similar developmental shift over the second year of life.

Second, if cross-linguistic associations exist, it is important to evaluate the influence of language dominance. Prominent models of adult bilingual language organization posit differential effects of language dominance on processing (e.g., Kroll & Stewart, 1994). For example, the Revised Hierarchical Model suggests that differences in language dominance (due to language proficiency and age of acquisition) can impact the connections between lexicons and the conceptual store (for a review see Kroll, van Hell, Tokowicz, & Green, 2010). This leads to differences in translation production from L2 to L1 and from L1 back to L2. Recent evidence suggests that this may extend to young toddlers, as Mandarin-English bilinguals exhibit lexical priming from the dominant to the non-dominant language, but not from the non-dominant to the dominant language (Singh, 2014). Together these findings suggest that cross-linguistic associations between processing speed and vocabulary size may also be modulated by language

dominance. It is possible lexical processing may differ within the dominant and non-dominant language in early development similar to findings in adults.

Third, there is a dearth of literature on how word processing in bilinguals compares to the monolinguals case across the 2nd year of life. In the only studies to compare lexical access across monolingual and bilingual toddlers, French-English bilinguals in Canada showed comparable speed of processing for words in both of their languages at 16 and 22 months of age, as well as comparable speed of processing relative to their French monolingual counterparts in Switzerland (Legacy et al., 2015; Legacy et al., in review). However, adult findings indicate differences in lexical processing in bilinguals versus monolinguals (Ivanova & Costa, 2008; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ransdell & Fischler, 1987). The present study addresses these limitations by evaluating cross-linguistic relations between speed of processing and vocabulary size, the effect of language dominance on these relations, and by contrasting bilingual and monolingual toddlers across languages, within the same geographic location and sociolinguistic strata, and on the same task longitudinally.

## 1.1    Study aims and hypotheses

The overall purpose of the present study is to compare speed of word processing and vocabulary within bilinguals and monolinguals longitudinally throughout the 2nd year of life. Importantly, in an approach unique to this paper, bilingual speed of processing and vocabulary size will be compared to two monolingual samples (one for each of the bilingual sample's languages). The first aim is to evaluate changes in speed of word processing from 16 to 22 months within the dominant and non-dominant languages in bilinguals and compare this to monolinguals over the same period. We expect speed of processing to improve over time across all language groups, consistent with monolingual and bilingual findings (Hurtado, Marchman, & Fernald, 2007; Fernald, Perfors, & Marchman, 2006; Legacy et al., 2015; Legacy et al., in review). Of particular interest is a) how dominance influences speed of word processing and b) how speed of processing changes within bilinguals between 16 and 22 months.

The second aim is to examine the relation between speed of word processing and vocabulary development in bilinguals in comparison to monolinguals. Following previous research, we hypothesize that within-language correlations are present in each language at both 16- and 22-months of age. However, within bilinguals, we expect that cross-language associations between speed of word recognition and vocabulary size are not evinced after controlling for within-language vocabulary. This hypothesis is consistent with a strong within-language correspondence between lexical processing and vocabulary size. Further, we hypothesized that language dominance would modulate associations between processing speed and vocabulary size consistent with previous cross-linguistic findings (e.g, Singh, 2014), such that the relation between word recognition and vocabulary would be strongest in the dominant language relative to the non-dominant language at both 16 and 22 months.

## 2    Method

## 2.1    Participants

Participants were drawn from a larger longitudinal project assessing language comprehension in the 2nd year of life. Participants were obtained through a database of parent volunteers recruited through birth records, internet resources, and community events in a large metropolitan area. All participants were full-term and had no diagnosed impairments in hearing, vision, language, and

cognition. A final sample of 187 children was then divided into three groups based on language exposure as assessed on the Language Exposure Assessment Tool (LEAT, DeAnda, Bosch, Poulin-Dubois, Zesiger, & Friend, in press): English monolingual, Spanish monolingual, and Spanish-English bilingual toddlers. The LEAT provides estimates of daily language exposure derived from parent reports of the number of hours of language input by parents, relatives and other caregivers in contact with the child. Trained experimenters followed the LEAT manual to interview parents on the number of speakers who interacted with the child and the number of hours of exposure to each speaker over the course of the child's life. Relative language exposure was estimated by calculating the proportion of time that the child heard English or Spanish relative to other language input. This calculation was then used to categorize the three groups. English and Spanish monolinguals were those children with >80% exposure to English or Spanish, respectively. Bilinguals were those with ≤ 80% to the dominant language (English or Spanish) and at least 20% exposure to their non-dominant language (English or Spanish). This 80% cutoff is often the limit for inclusion of bilingual participants in a sample (Pearson et al., 1997; Byers-Heinlein, 2015). On average, bilinguals had 63% exposure to their dominant language, and 37% to the non-dominant language. All but one child had exposure to a third language, but exposure was less than 12%.

The final sample included 79 monolingual English-hearing toddlers (41 females, 38 males), 64 monolingual Spanish-hearing toddlers (31 female, 33 male), and 44 bilingual English-Spanish hearing toddlers (17 females, 28 males). Each participant was tested at 16-months (English: $M =$ 16;20, range = 15;15 − 18;2; Spanish: $M = 17;3$, range = 15;15 − 20;21; Bilingual: $M = 17;23$, range = 14;23 − 19;21), and 22-months (English: $M = 23;2$, range = 21;6 − 25;12; Spanish: $M =$ 23;21; range = 21;0 − 21;15; Bilingual: $M = 24;15$; range = 21;3 − 26;18). The average maternal education for the English monolinguals was approximately completion of a 4-year college degree ($M = 15.45$ years, $SD = 2.08$, range = 12 − 18). Average maternal education for Spanish monolinguals and bilinguals was at some college completed (Spanish: $M = 13.05$ years, $SD =$ 3.35, range = 12 − 18; Bilinguals: $M = 14.62$, $SD = 2.32$, range = 8 − 18). An ANOVA revealed that maternal education differed significantly across language groups ($F(3, 460) = 20.95$, $p <$ .001). Therefore, we evaluated the effect of maternal education on latency in our analyses.

## 2.2 Apparatus

The study was conducted in a sound attenuated room. Stimuli were presented on a 51 cm 3M SCT3250EX touch capacitive wall-mounted monitor. An HD video camera was mounted above and behind the touch monitor to capture haptic response to the visual stimuli. Two audio speakers were positioned to the right and left of the touch monitor for the presentation of auditory reinforcers which aided in maintaining interest and compliance.

## 2.3 Procedure and measures

Toddlers were seated on their caregiver's lap centered at approximately 30 cm from the touch sensitive monitor with the experimenter seated just to the right. Parents wore blackout glasses and noise-cancelling headphones to mitigate parental influence during the task. The assessment followed the protocol for the Spanish and English adaptations of the Computerized Comprehension Task (CCT; Friend & Keplinger, 2003; 2008; Hendrickson & Friend, 2013; Hendrickson, Mitsven, Poulin-Dobois, Zesiger, & Friend, 2015; DeAnda, Arias-Trejo, Poulin-Dubois, Zeisger, & Friend, 2015). The CCT is a behavioral measure that captures children' haptic response to assess early decontextualized receptive vocabulary. The CCT demonstrates strong

internal consistency, converges with parent report, and predicts subsequent language production (Friend et al., 2012). Additionally, responses on the CCT are nonrandom (Friend & Keplinger, 2008) and this finding replicates across languages (Friend & Zesiger, 2011) and across monolinguals and bilinguals (Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013).

Participants are prompted to touch images on the monitor (e.g., "Where's the *dog?* Touch *dog!"*). A correct touch to the target image (e.g., the dog) elicits a reinforcing sound (e.g., the sound of a dog barking). The CCT presents 4 training trials and 41 test trials in a two-alternative forced-choice procedure. For each trial, two images (a target and distractor image) appeared simultaneously on the right and left side of the touch monitor. The side on which the target image appeared was presented in pseudo-random order across trials such that target images could not appear on the same side on more than two consecutive trials, and the target was presented with equal frequency on both sides of the screen (Hirsh-Pasek & Golinkoff, 1996). All image pairs presented during training, testing, and reliability were matched for word difficulty (easy, medium, hard) based on Macarthur-Bates Communicative Development Inventory norms (Dale & Fenson, 1996), part of speech (noun, adjective, verb), category (animal, human, object), and visual salience (color, size, luminance).

The CCT begins with a training phase to insure participants understand the nature of the task. During the training phase, participants were presented with early-acquired noun pairs (known by at least 80% of 16-month-olds; Dale & Fenson, 1996) and prompted by the experimenter to touch the target. If the child failed to touch the screen after repeated prompts, the experimenter touched the target image for them. If a participant failed to touch during all four training trials, the training trials were repeated once. Only participants who executed at least one correct touch during the training phase proceeded to the testing phase. All of the participants proceeded to the testing phase.

Each test trial ended when the child touched the screen or until seven seconds elapsed. When the child gaze was directed toward the touch monitor, the experimenter delivered the prompt in infant-directed speech and advanced each trial. The experimenter presented each pair of images as she uttered the target word in the first sentence prompt such that the onset of the target word occurred just prior to the onset of the visual stimuli.

*Noun Prompts*
      *Where is the _____? Touch _____.*
      *Donde esta el/la _____? Toca _____.*
*Verb Prompts*
      *Who is _____? Touch _____.*
      *Quien esta _____? Toca _____.*
*Adjective Prompts*
      *Which one is _____? Touch _____.*
      *Cual es_____? Toca _____.*

Participants completed testing at 16 months, and 6 months later at 22 months of age. Testing procedures were identical at both ages. English and Spanish monolingual participants were tested using the English or Spanish CCT, respectively. Spanish-English bilingual participants completed testing in both English and Spanish on separate days, approximately one week apart. The order in which each language was tested was counterbalanced.

**2.4     Coding**

A waveform of the experimenter's prompts was extracted from the video recording (see Hendrickson et al., 2015 for a similar coding procedure). Subsequently the video of participant's haptic responses and the waveform of the experiment's prompts were synced and used to code the onset of the visual stimuli, the onset and offset of the target word, and the frame in which the participant touched the screen for each trial using Eudico Linguistics Annotator (ELAN) (<http://tla.mpi.nl/tools/tla-tools/elan/>, Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands; Lausberg & Sloetjes, 2009). Only trials in which the participant touched the prompted word (e.g., target) were included in the analyses of haptic reaction time. Haptic responses were coded over the course of the entire trial (7 seconds). Coding for the haptic reaction time (RT) began at image onset, roughly 238 ms after target word onset, and prior to target word offset in the first sentence prompt. Inter-rater reliability coding was conducted for a random sample of 20% of the data for each sample (Monolingual English, Monolingual Spanish, Bilingual).

Coders completed extensive training to identify the characteristics of speech sounds within a waveform, both in isolation and in the presence of coarticulation. Because a finite set of target words always followed the same carrier phrases (e.g., "Where is the _____", "Who is ___", or "Which one is _____"?), training included identifying different vowel and consonant onsets after the words "the" and "is". Coders were also trained to demarcate the onset of vowel-initial and nasal-initial words after a vowel-final word in continuous speech, which can be difficult using acoustic waveforms in isolation. Additionally, coders were required to practice on a set of files previously coded by the first author with supervision and then to code one video independently until correspondence with previously coded data was reached.

Trials with short latencies (< 400 ms) likely reflect haptic behavior that was planned prior to hearing the target word (Bailey & Plunkett, 2002; Ballem & Plunkett, 2005; Fernald, Zangl, Portillo, & Marchman, 2008; Poulin-Dubois, Bialystock, Blaye, Polonia, & Yott, 2013). For this reason trials were included in subsequent analyses if the participant touch the screen with a latency > 400 ms. A total of 22 trials were removed with latencies <400 ms.

**3     Results**

Haptic RT was used as a measure of word processing speed (Poulin-Dubois et al., 2012; Legacy et al., 2015; Legacy et al., in review), and the number of target touches executed during the task was used as the measure of vocabulary knowledge (Friend & Keplinger, 2003; 2008; Hendrickson & Friend, 2013; Hendrickson, Mitsven, Poulin-Dubois, Zesiger, & Friend, 2015; DeAnda, Arias-Trejo, Poulin-Dubois, Zesiger, & Friend, 2015). Recall that vocabulary knowledge on the CCT converges with parent report on the MCDI and predicts subsequent language production (Friend et al., 2012). Language dominance was determined based on the dominant and non-dominant language of exposure as measured on the LEAT. Table 1 provides descriptive statistics across these two measures for all three groups of participants. To begin, an omnibus ANCOVA with haptic RT as the dependent variable was run to evaluate effects of maternal education and sex. Results revealed no effects of maternal education and sex (all n.s. $p >$ .3). These variables were therefore dropped from subsequent analyses.

**Table 1.** Descriptives for vocabulary size and haptic RT across groups at 16 and 22 months of age.

| | Vocabulary Size | | Reaction Time (ms) | |
|---|---|---|---|---|
| | 16 months | 22 months | 16 months | 22 months |
| | *M (SD)* | | | |
| Bilingual Dominant | 9.35 (5.82) | 18.42 (10.98) | 3479.34 (914.79) | 2736.27 (989.49) |
| Bilingual Non-dominant | 10.05(5.67) | 20.07 (8.52) | 3318.01 (812.09) | 2631.95 (664.77) |
| English Monolingual | 11.9 (7.36) | 26.82 (7.81) | 3450.29 (905.70) | 2605.44 (603.60) |
| Spanish Monolingual | 9.19 (5.02) | 17.54 (8.41) | 3413.55 (737.89) | 2853.37 (852.11) |

### 3.1 Development of speed of word processing

Our first aim was to evaluate changes in speed of word processing from 16 to 22 months within the dominant and non-dominant languages in bilinguals and compare this to monolinguals over the same period. Haptic RT's were the dependent measure in a 2 X 4 mixed-design ANOVA with one within-subjects variable, Age (16 or 22-months), and one between-subjects variable, Language Group (monolingual Spanish, monolingual English, bilingual dominant language, and bilingual non-dominant language). Results revealed a significant main effect of Age ($F(3, 368) = 72.77$, $p < .001$), but no significant main effect of language group, or significant Age x Language Group interaction (all n.s. $p > .5$), demonstrating that children show faster word processing between 16 and 22 months of age across all groups. These results are presented in Figure 1.
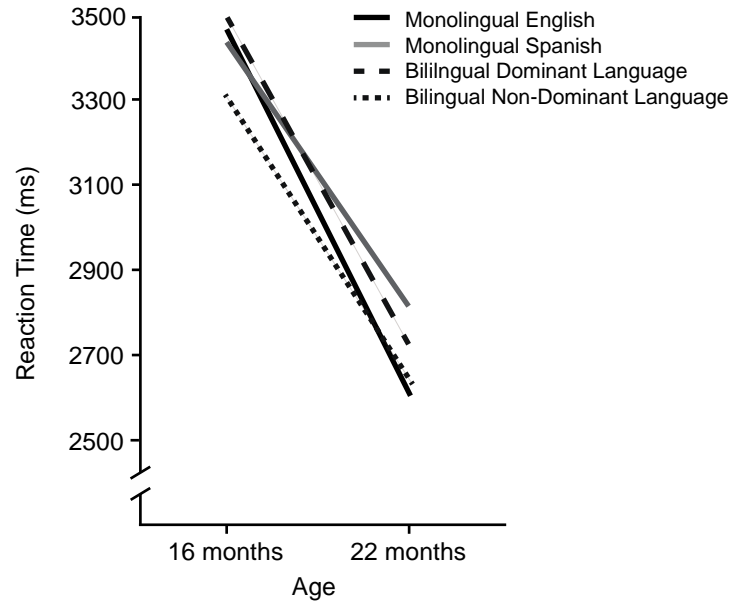
### 3.2 Relation between speed of word processing and vocabulary

#### 3.2.1 Monolinguals
We next examined the relation between speed of word processing and vocabulary within monolinguals and bilinguals, and whether this changed across 16 and 22 months of age. To replicate previous research, we first examined haptic RT and vocabulary size within monolinguals. A 2 X 2 hierarchical linear regression was run with haptic RT as the dependent variable and Age (16 or 22 months), Language (English or Spanish), and CCT Vocabulary score within monolinguals. There was a significant main effect of Age ($F(1, 243) = 56.64$, $p < .01$) indicating that haptic RT's decrease between 16- and 22-months within the monolingual groups.

In addition, there was a significant main effect of CCT Vocabulary score ($F(1, 243) = 21.68$, $p < .001$) on haptic RT (see Figure 2). Finally, there was no main effect of Language, nor significant interactions between Age, Language, and Vocabulary (all n.s. $p > .25$).

**Figure 1.** Changes in Haptic RT across all groups.



### 3.2.1    *Bilinguals*

Lastly, we tested whether the relation between word processing and vocabulary size extended to bilinguals at both 16 and 22 months of age. To examine patterns of language dominance, we assessed the relation between vocabulary and haptic RT within and across the dominant and non-dominant languages separately. We began by examining haptic RT in the *dominant language*. A hierarchical linear regression with haptic RT in the dominant language was conducted with Age (16 or 22 months) on the first step, Dominant Language Vocabulary on the second step, and Non-Dominant Language Vocabulary on the third step. Results revealed a significant main effect of Age ($F(1, 51) = 7.63$, $p = .008$), and a significant main effect of Dominant Language Vocabulary after controlling for Age ($F(1, 51) = 6.98$, $p = .01$), indicating a significant relation between vocabulary and speed of processing within the dominant language across 16 and 22 months of age. However, there was no significant effect of Non-Dominant Language Vocabulary after controlling for Dominant Language Vocabulary and Age. Further, no significant interactions were observed (all n.s. $p > .3$, see Figures 2 and 3).

Following analyses in the dominant language we examined within and cross-language associations between haptic RT and vocabulary size in the *non-dominant* language. A hierarchical linear regression with haptic RT in the non-dominant language was evaluated with Age (16 or 22 months) on the first step, Non-Dominant Language Vocabulary size on the second step, and Dominant Language Vocabulary size on the third step. Age was a significant predictor of haptic RT in the non-dominant language ($F(1, 52) = 9.64$, $p = .004$). However, Non-Dominant Language Vocabulary did not predict within-language haptic RT after controlling for Age. Nevertheless, cross-language Dominant Language Vocabulary was a significant predictor ($F(1, 52) = 5.7$, $p = $

.02, see Figures 2 and 3). No interaction terms were significant (all n.s. $p > .3$). Results for vocabulary size and haptic RT across the dominant and non-dominant language are summarized in Figure 3.

**Figure 2**. Relation between vocabulary size (CCT) and haptic RT (latency) across groups.

**A. Monolingual English and Spanish**

**B. Bilingual Dominant Language**

**C. Bilingual Non-Dominant Language**
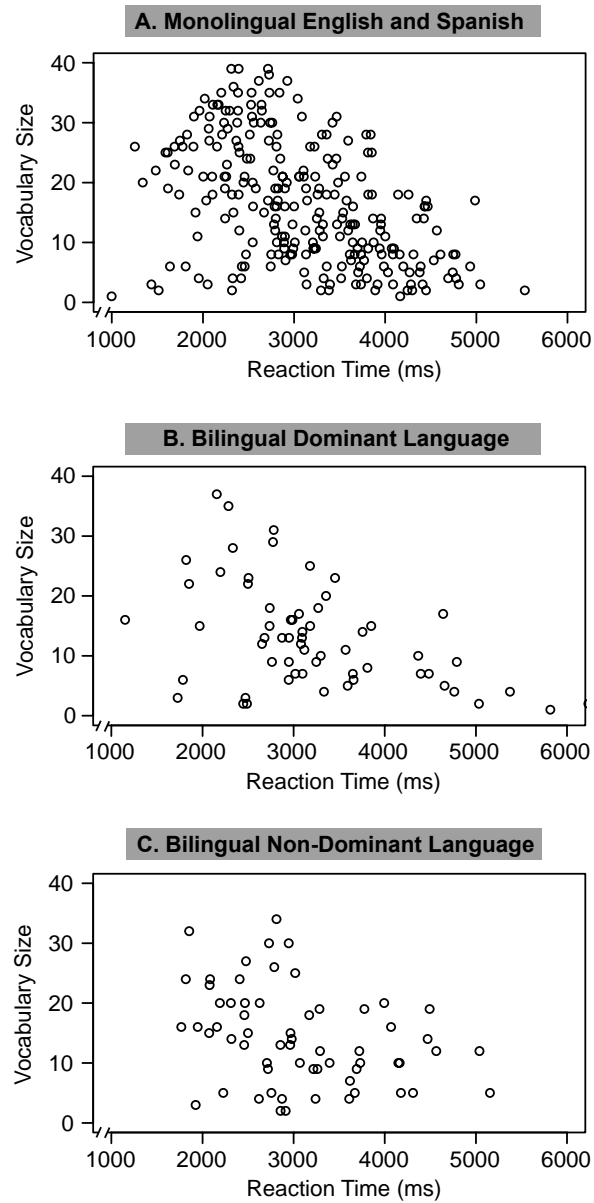
## 4    Discussion

In this study we examined speed of word processing and vocabulary within bilinguals and monolinguals longitudinally throughout the 2nd year of life. The first aim of the present study was

to evaluate changes in speed of word processing from 16 to 22 months within the dominant and non-dominant languages in Spanish-English bilinguals, and compare this to Spanish and English monolinguals over the same period. Our results revealed that speed of word processing increases at a similar rate in bilinguals (in both the dominant and non-dominant language) and monolinguals from 16 to 22 months of age.

**Figure 3**. Within and cross-language relations between speed of processing and vocabulary size within bilinguals.
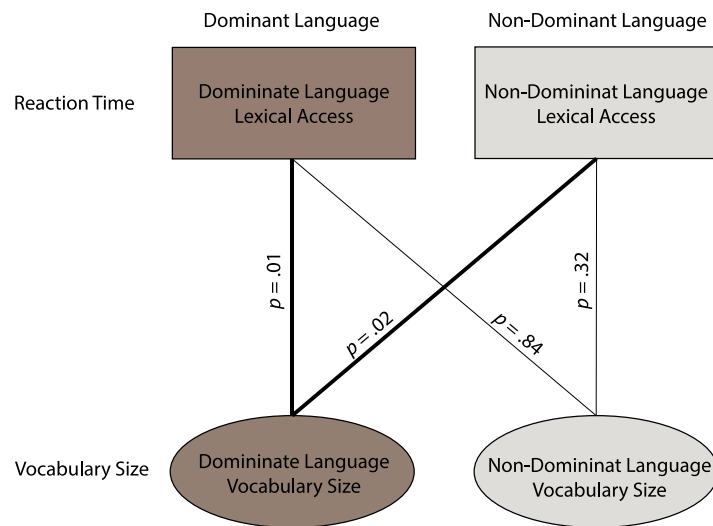


These results extend previous findings that show similar speed of word processing in bilingual English-French, monolingual French, and monolingual English speaking toddlers (Legacy et al., 2015, Legacy et al., in review). Thus, speed of word processing appears similar across language groups (Bilingual, Monolingual) and across languages (dominant and non-dominant) within diverse populations of bilinguals (Canadian English/French and Southern Californian English/Spanish). These differences in *speed of word processing* are in contrast to a large number of studies examining *vocabulary size* which demonstrating smaller vocabularies in bilinguals versus monolinguals when comparing a single language (Fenson, et al., 1994; Friend & Keplinger, 2008; Pearson et al., 1993; Hart & Risley, 1995; Hoff, 2003; Hoff & Tian, 2005; DeAnda et al., 2016). What could explain these significant differences between monolingual and bilingual children in vocabulary but not in speed of word processing? One explanation is that speed of word processing may be less influenced by language exposure than is vocabulary size. Specifically, measures of vocabulary size are highly dependent on children's exposure to the items tested (Campbell, Dollaghan, Needleman, & Janosky, 1997; Kohnert, Windsor, & Yim, 2006). Performance on such experience-dependent tasks may well represent a child's word knowledge if they have sufficient experience, but may underrepresent word knowledge for children whose cultural or linguistic backgrounds provide greater variation in exposure to the tested words (Kohnert et al., 2006; Silliman, Wilkinson, & Brea-Spahn, 2004). Measures of vocabulary size assess the number of words children understand in a static all-or-none fashion

whereas RT evaluates how long it takes the child to process the word *given that it is known*. These well-documented differences in experience versus process-dependent measures may explain why monolingual versus bilingual exposure does not seem to influence speed of spoken word processing in the second year of life, despite modulating vocabulary size. Indeed, the robustness of processing-based measures across levels of language exposure have made them effective in diagnosing language impairments within monolingual and bilingual children (Buac, Gross, & Kaushanskaya, 2016; Kohnert et al., 2006).

The second aim of the present study was to examine the relation between speed of word processing and vocabulary development within and across languages in bilinguals, and compare this to monolinguals. Within monolinguals, vocabulary size was related to speed of word processing, consistent with previous research (Hurtado, Marchman, & Fernald, 2007; Fernald, Perfors, & Marchman, 2006; Legacy et al., 2015; Legacy et al., in review). This relation held within bilinguals but was modulated by language dominance. Specifically, a significant within-language relation was evinced only within the dominant language, such that vocabulary size was significantly related to speed of word processing within the dominant language. Conversely, vocabulary size and speed of word processing were not related in the non-dominant language. Further, cross-language associations were also observed, but these were unidirectional: vocabulary size in the dominant language explained significant variance in speed of processing in the non-dominant language after controlling for age and within-language non-dominant vocabulary. However, non-dominant vocabulary did not significantly predict speed of processing in the dominant language (see Figure 3).

The results of the present study have implications for existing models of bilingual language processing. Our results showed that only vocabulary size in children's *dominant* language explained significant variance in speed of word processing in both the dominant and non-dominant language. This result is consistent with some previous findings. Within Mandarin-English bilingual toddlers, lexico-semantic priming effects were observed only when the prime word was in the L1 (Singh, 2014). That is, L1 words primed semantically related words in the L1 and in the L2, but L2 words did not prime L1 targets. This dissociation between languages as a function of dominance was also shown by Legacy et al., (2015; in review), although they found a significant within-language correlation between vocabulary size and speed of processing in the non-dominant language that was not observed in the present study. One possible explanation for these disparate findings is the analytic approach. In the present paper, we evaluated the relation between RT and vocabulary after controlling for age in a regression analysis. To test this explanation, we calculated a first-order correlation in the same manner as Legacy et al. and were able to replicate their finding ($r(60) = -.34$, $p = .008$). The present cross-linguistic findings support the conclusions from Marchman et al. (2011) suggesting that children's spoken word comprehension is associated with general language ability. The present study extends this finding by demonstrating independent but interrelated linguistic systems in early simultaneous bilinguals that are influenced by language dominance.

Importantly, however, although language dominance modulated the relation between word knowledge and processing, there was no significant difference in speed of word processing between the dominant and non-dominant language, consistent with prior findings (Marchman et al., 2011; Legacy et al., 2015; Legacy et al., in review). Given that weaker word knowledge is related to slower processing (e.g. Hurtado, Marchman, & Fernald, 2007; Fernald, Perfors, & Marchman, 2006), one might expect the non-dominant language to show slower speed of word processing than the dominant language where vocabulary proficiency is higher. However, the present study suggests that the dominant language may support processing in the non-dominant language as well, as there was a significant cross-linguistic relation between languages, but only

from the dominant language to the non-dominant language. That is, despite the weak association between processing and word knowledge in the non-dominant language, the cross-language effects suggest that word knowledge in the dominant language may support processing in the less-proficient language. Indeed, findings within young sequential bilinguals show that L1 knowledge supports the weaker L2 (Uccelli & Paez, 2007). These findings contrast with Marchman et al. (2011) who found no significant cross-linguistic correlations in young Spanish-English bilingual children at 30 months. However it is important to note that Marchman et al. did not assess the influence of language dominance on cross-language associations, which may account for this difference in findings. Importantly, our interpretation is consistent with that of Marchman et al. suggesting that general language knowledge supports speed of processing across languages.

The conclusion that languages within bilinguals are independent and interrelated, and that language dominance influences processing is consistent with a recently proposed model of bilingual language representation: processing rich information from multidimensional interactive representations (PRIMIR; Curtin, Byers-Heinlein, & Werker, 2011). Within this model of language acquisition and organization, bilingual children form language-specific representations that cluster together within languages, but representations also cluster based on shared semantics across both languages. That is, both languages are separable but also interconnected. Further, PRIMIR posits that relations within and between languages are influenced by task demands. In the present study, task demands in the form of processing in the dominant versus the non-dominant language influenced the links between word knowledge and speed of processing consistent with PRIMIR. This conclusion is also consistent with adult models of language representation, namely the Revised Hierarchal Model (RHM; Kroll & Stewart, 1994). Although a model of adult language processing during second language acquisition, the model extends to the present study in that it suggests that language proficiency modulates cross-language links between the dominant and non-dominant language. Indeed, in the present study cross-langauge associations between the dominant and non-dominant language differed as function of language proficiency.

In addition to theoretical applications, the present findings inform clinical practices. The finding that the dominant language supports the non-dominant language is consistent with findings in school-age children showing that prior L1 knowledge predicts later L2 attainment (Lewis, Sandilos, Hammer, Sawyer, & Méndez, 2015). From a clinical perspective, this supports the idea that bilingual children with language delays and impairments should receive treatment in both languages (e.g., Restrepo & Kruth, 2000). Indeed, a theoretical model that supports links within languages is in line with empirical findings demonstrating the effectiveness of dual language intervention in bilingual populations (Ebert, Kohnert, Pham, Disher, & Payesteh, 2014).

## 5      Conclusion

What do these results reveal about the nature and specificity of the relation between speed of word processing and vocabulary size in young children more generally? The present study evaluated the changes in speed of processing in monolinguals and bilinguals across two critical time points within the second year of life. Speed of spoken word processing in young bilinguals was similar to their monolingual peers, suggesting that exposure to one or two languages does not influence the rate of word recognition. Indeed, despite learning two separate languages, young bilinguals demonstrate cross-linguistic associations such that the dominant language may support processing in the non-dominant language. This supports the idea that language processing in each language is independent but interrelated within bilinguals, and that these processes are influenced

by language dominance. We find these cross-language relations between word processing and vocabulary size inconsistent with a strictly within-language account that suggests speed of word processing and vocabulary knowledge are dissociable across languages. Instead we find these results more in line with an account in which the relation between word processing and word knowledge does not rely solely on experience within a language, but also on general language experience.

## References

American Speech-Language-Hearing Association. (2007). *Scope of practice in speech-language pathology* [Scope of practice]. Available from www.asha.org/policy.http://www.asha.org/Practice/ethics/Cultural-and-Linguistic-Competence/

Arias-Trejo, N., & Plunkett, K. (2009). Lexical–semantic priming effects during infancy. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*, 3633-3647.

Arias-Trejo, N., & Plunkett, K. (2013). What's in a link: Associative and taxonomic priming effects in the infant lexicon. *Cognition*, *128*(2), 214-227.

Bailey, T.M., & Plunkett, K. (2002). Phonological specificity in early words. *Cognitive Development*, 17, 1265–1282.

Ballem, K.D., & Plunkett, K. (2005). Phonological specificity in children at 1; 2. *Journal of Child Language*, 32, 159–173.

Buac, M., Gross, M., & Kaushanskaya, M. (2016). Predictors of processing-based task performance in bilingual and monolingual children. *Journal of Communication Disorders*, *62*, 12-29.

Byers-Heinlein, K. (2015). Methods for studying infant bilingualism. In J.W. Schwieter (Ed.), *The Cambridge Handbook of Bilingual Processing*. Cambridge: UK: Cambridge University Press.

Campbell, T., Dollaghan, C., Needleman, H., & Janosky, J. (1997). Reducing Bias in Language Assessment Processing-Dependent Measures. *Journal of Speech, Language, and Hearing Research*, *40*, 519-525.

Curtin, S., Byers-Heinlein, K., & Werker, J. F. (2011). Bilingual beginnings as a lens for theory development: PRIMIR in focus. *Journal of Phonetics*, *39*, 492-504.

Dale, P. S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers, 28,* 125–127.

DeAnda, S., Arias-Trejo, N., Poulin-Dubois, D., Zesiger, P., & Friend, M. (2016). SES, Minimal L2 Exposure, and Early Word Comprehension: New Evidence from a Direct Assessment. *Bilingualism Language and Cognition,* 19, 162-180.

DeAnda, S., Bosch, L., Poulin-Dubois, D., Zesiger, P., & Friend, M. (in press). The Language Exposure Assessment Tool: Quantifying exposure for bilingual research in young infants and children. *Journal of Speech Language and Hearing Research.*

Ebert, K. D., Kohnert, K., Pham, G., Disher, J. R., & Payesteh, B. (2014). Three treatments for bilingual children with primary language impairment: Examining cross-linguistic and cross-domain effects. *Journal of Speech, Language, and Hearing Research*, *57*, 172-186.

Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science*, *16*, 234-248.

Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental Psychology*, *42*, 98.

Fernald, A., Swingley, D., & Pinto, J. P. (2001). When half a word is enough: Infants can recognize spoken words using partial phonetic information. *Child Development*, *72*, 1003-1015.

Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language. In I.A. Sekerina, E.M. Fernandez & H. Clahsen (Eds.), *Developmental psycholinguistics: On-line methods in children's language processing* (pp. 97– 135). Amsterdam: John Benjamins.

Fenson, L., Dale, P.S., Reznick, J.S., Bates, E., Thal, D.J., Pethick, S.J., Tomasello, M., Mervis, C.B., & Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, 59 (5, Serial No. 242).

Friend, M., & Keplinger, M. (2003). An infant-based assessment of early lexicon acquisition. *Behavior Research Methods, Instruments, & Computers*, *35*, 302-309.

Friend, M., & Keplinger, M. (2008). Reliability and validity of the Computerized Comprehension Task (CCT): data from American English and Mexican Spanish infants. *Journal of Child Language, 35,* 77-98. doi: 10.1017/S0305000907008264

Friend, M., Schmitt, S.A., & Simpson, A.M. (2012). Evaluating the predictive validity of the Computerized Comprehension Task: Comprehension predicts production. *Developmental Psychology*, *48*, 136.

Friend, M. & Zesiger, P. (2011). A systematic replication of the psychometric properties of the CCT in three languages: English, Spanish, and French. *Enfance, 3,* 329-344. doi: 10.4074/S0013754511003041

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., & Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory & Cognition*, *33*, 1220-1234.

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Paul H. Brookes Publishing.

Hendrickson, K., Mitsven, S., Poulin-Dubois, D., Zesiger, P., & Friend, M. (2015). Looking and touching: What extant approaches reveal about the structure of early word knowledge. *Developmental Science*, *18*, 723-735.

Hendrickson, K., & Friend, M. (2013). Quantifying the Relationship Between Infants' Haptic and Visual Response to Word-Object Pairings. *Proceedings of the Annual Boston University Conference on Language Development. (Conference Proceeding)*

Hirsh-Pasek, K., & Golinkoff, R. M. (1996). The intermodal preferential looking paradigm: A Window onto emerging language comprehension. In D. McDaniel, & C. McKee (Eds.), *Methods for assessing children's syntax. Language, speech, and communication* (pp. 105–124).

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development, 74,* 1368–1378. doi: 10.1111/1467-8624.00612

Hoff, E., & Tian, C. (2005). Socioeconomic status and cultural influences on language. *Journal of Communication Disorders, 38,* 271–278.

Hurtado, N., Marchman, V. A., & Fernald, A. (2007). Spoken word recognition by Latino children learning Spanish as their first language. *Journal of Child Language*, *34*, 227-249.

Ivanova, I., & Costa, A. (2008). Does bilingualism hamper lexical access in speech production? *Acta Psychologica*, *127*, 277-288.

Kohnert, K., Windsor, J., & Yim, D. (2006). Do language-based processing tasks separate children with language impairment from typical bilinguals? *Learning Disabilities Research & Practice*, *21*, 19-29.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*, 149-174.

Kroll, J. F., Van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The Revised Hierarchical Model: A critical review and assessment. *Bilingualism: Language and Cognition*, *13*, 373-381.

Lausberg, H., & Sloetjes, H. (2009). Coding gestural behavior with the NEUROGES-ELAN system. *Behavior Research Methods*, 41, 841–849.

Legacy, J., Zesiger, P., Friend, M, & Poulin-Dubois, D. (2015). Vocabulary size, translation equivalents, and efficiency in word recognition in very young bilinguals. *Journal of Child Language*, 1-24.

Legacy, J., Zesiger, P., Friend, M, & Poulin-Dubois, D. (in review). Vocabulary size, and speed of word recognition in very young French-English bilinguals: a longitudinal study. *Bilingualism, Language, & Cognition.*

Lewis, K., Sandilos, L. E., Hammer, C. S., Sawyer, B. E., & Méndez, L. I. (2015). Relations Among the Home Language and Literacy Environment and Children's Language Abilities: A Study of Head Start Dual Language Learners and Their Mothers. *Early Education and Development*, 1-17.

Marchman, V. A., & Fernald, A. (2008). Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental Science*, *11*, F9-F16.

Marchman, V. A., Fernald, A., & Hurtado, N. (2010). How vocabulary size in two languages relates to efficiency in spoken word recognition by young Spanish–English bilinguals. *Journal of Child Language*, *37*, 817.

Pearson, B. Z., Fernandez, S. C., & Oller, D. K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning*, *43*, 93-120.

Pearson, B. Z., Fernandez, S. C., Lewedeg, V., & Oller, D. K. (1997). The relation of input factors to lexical learning by bilingual infants. *Applied Psycholinguistics*, *18*, 41-58.

Poulin-Dubois, D., Blaye, A., Coutya, J., & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology*, *108*, 567-579.

Ransdell, S. E., & Fischler, I. (1987). Memory in a monolingual mode: When are bilinguals at a disadvantage? *Journal of Memory and Language*, *26*, 392-405.

Restrepo, M. A., & Kruth, K. (2000). Grammatical characteristics of a Spanish-English bilingual child with specific language impairment. *Communication Disorders Quarterly*, *21*, 66-76.

Silliman, E. R., Wilkinson, L. C., & Brea-Spahn, M. R. (2004). Policy and practice imperatives for language and literacy learning: Who will be left behind. *Handbook of language and literacy: Development and disorders*, 97-129.

Singh, L. (2014). One World, Two Languages: Cross-Language Semantic Priming in Bilingual Toddlers. *Child Development*, *85*, 755-766.

Styles, S. J., & Plunkett, K. (2009). How do infants build a semantic system? *Language and Cognition*, *1*, 1-24.

Uccelli, P., & Páez, M. M. (2007). Narrative and vocabulary development of bilingual children from kindergarten to first grade: Developmental changes and associations among English and Spanish skills. *Language, Speech, and*

*Hearing Services in Schools*, *38*, 225-236.

U.S. Census Bureau. (2011). Language spoken at home, 2011 American Community Survey 1-year estimates. Retrieved from: http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_11_1YR_S1601&prodType=table.

von Koss Torkildsen, J., Sannerud, T., Syversen, G., Thormodsen, R., Simonsen, H. G., Moen, I., Smith, L., & Lindgren, M. (2006). Semantic organization of basic-level words in 20-month-olds: An ERP study. *Journal of Neurolinguistics*, *19*, 431-454.

Willits, J. A., Wojcik, E. H., Seidenberg, M. S., & Saffran, J. R. (2013). Toddlers activate lexical semantic knowledge in the absence of visual referents: evidence from auditory priming. *Infancy*, *18*, 1053-1075.

Zangl, R., Klarman, L., Thal, D., Fernald, A., & Bates, E. (2005). Dynamics of word comprehension in infancy: Developments in timing, accuracy, and resistance to acoustic degradation. *Journal of Cognition and Development*, *6*, 179-208.

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