1. Introduction

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. 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.

1.1. Study aims

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. 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. 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.

2. Method

2.1. Participants

The participants 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). Bilinguals were those with $\leq 80\%$ to the dominant language (English or Spanish) and at least 20% exposure to their non-dominant language (English or Spanish).

2.2. Procedure and measures

Vocabulary size and speed of word recognition were assessed using the Spanish and English adaptations of the Computerized Comprehension Task (CCT; Friend & Keplinger, 2003; 2008; Hendrickson & Friend, 2013; Hendrickson, Mitsven, Poulin-Dubois, Zesiger, & Friend, 2015; DeAnda, Arias-Trejo, Poulin-Dubois, Zesiger, & Friend, 2015). The CCT is a behavioral measure that captures children’ haptic response to assess early decontextualized receptive vocabulary. 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). For each trial, two images (a target and distractor image) appeared simultaneously on the right and left side of the touch monitor. 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).
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.

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, 2016). Table 1 provides descriptive statistics across these two measures for all three groups of participants.

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

<table>
<thead>
<tr>
<th></th>
<th>Vocabulary Size</th>
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<th>Reaction Time (ms)</th>
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<tbody>
<tr>
<td></td>
<td>16 months</td>
<td>22 months</td>
<td>16 months</td>
<td>22 months</td>
</tr>
<tr>
<td>Bilingual Dominant</td>
<td>9.35 (5.82)</td>
<td>18.42 (10.98)</td>
<td>3479.34 (914.79)</td>
<td>2736.27 (989.49)</td>
</tr>
<tr>
<td>Bilingual Non-dominant</td>
<td>10.05 (5.67)</td>
<td>20.07 (8.52)</td>
<td>3318.01 (812.09)</td>
<td>2631.95 (664.77)</td>
</tr>
<tr>
<td>English Monolingual</td>
<td>11.9 (7.36)</td>
<td>26.82 (7.81)</td>
<td>3450.29 (905.70)</td>
<td>2605.44 (603.60)</td>
</tr>
<tr>
<td>Spanish Monolingual</td>
<td>9.19 (5.02)</td>
<td>17.54 (8.41)</td>
<td>3413.55 (737.89)</td>
<td>2853.37 (852.11)</td>
</tr>
</tbody>
</table>

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.](image-url)
Figure 2. Relation between vocabulary size (CCT) and haptic RT (latency) across groups.
3.2.2. 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.

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.
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 across 16 and 22 months of age. 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). 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 within- and cross-language findings from the present study support the conclusions of Marchman et al. (2011) suggesting that children’s speed of spoken word comprehension is associated with general language ability. That is, general language skills (e.g., auditory, phonological, lexical, semantic, and syntactic processes) subserve lexical knowledge across languages. The present study extends this finding by demonstrating independent yet interrelated linguistic systems in early simultaneous bilinguals that are influenced by language dominance. Specifically, the existence of cross-language relations between word processing and vocabulary size are inconsistent with a strictly
within-language account that suggests that speed of word processing and vocabulary knowledge are entirely dissociable across languages. Instead we find these results more in line with an account in which the relation between word processing and vocabulary does not rely solely on experience within a single language, but also on general language experience. That is, language experience in the dominant language predicts additional variance in speed of processing in the non-dominant language, providing evidence against a strictly within-language account. Despite eliminating a language-specific account, this leaves open the possibility that the relation between speed of processing and vocabulary are explained by either general language experience or cognitive efficiency.

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? 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-language associations such that the dominant language may support processing in the non-dominant language. We find these cross-language relations between word processing and vocabulary size inconsistent with a strictly within-language account that suggests that 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 vocabulary does not rely solely on experience within a language, but also on general language experience.

References


On-line methods in children’s language processing (pp. 97–135). Amsterdam: John Benjamins.


