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THE ROLE OF INDIVIDUAL DIFFERENCES

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by

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ABSTRACT

Bilingualism continues to grow among the world's population. Nevertheless, most research studies on language processing have focused on monolingual individuals, leaving questions about how language processing unfolds in bilingual individuals. Here, we investigated how individual differences in bilingual experience, indexed by current L2 exposure, impact eye movement measures of reading fluency, indexed by word frequency effects, in an understudied population: bilingual children. Prior eye movement research involving bilingual younger adults (aged 18 to 30) has reported a trade-off in L1 and L2 word frequency effects with greater levels of current L2 exposure (Whitford & Titone, 2012, 2017). We wanted to examine whether this trade-off also extends to bilingual children. Using linear mixed-effects models, we re-analyzed Whitford and Joanisse's (2018) data involving English-French bilingual children (aged 7 to 12). We had three main findings. First, we found that word frequency effects were larger in the L2 than in the L1 across both early and late stages of reading (gaze duration, total reading time). Second, we found that greater levels of current L2 exposure facilitated L2 reading performance, but hindered L1 reading performance (irrespective of word frequency) across both reading stages (gaze duration, total reading time). Third, we found that for late-stage reading only (total reading time), greater levels of current L2 exposure resulted in smaller L2 word frequency effects, but had no significant impact on L1 word frequency effects. This finding suggests that bilingual children may be temporarily immune to the trade-off of L1/L2 word frequency effects previously observed among bilingual younger adults, as individual differences in current L2 exposure influenced L2 word frequency effects only. This study has implications for models of bilingual word processing, including BIA+ (Dijkstra & Van Heuven, 2002) and the weaker links hypothesis (Gollan, Montoya, Cera & Sandoval, 2008; Gollan et al., 2011).

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CHAPTER 1: INTRODUCTION

Bilingualism is a growing global phenomenon. According to recent estimates, more than half of the world's population actively uses two or more languages (Bialystok, Craik, & Luk, 2012). In other words, most people worldwide are bilingual. Surprisingly, however, most research examining language processing has focused on monolingual populations, leaving questions about how language processing unfolds in bilingual populations. It is important to study language processing in bilingual populations specifically, as their language experiences differ from those of monolinguals in several ways. One area of language processing that has been relatively under-examined in bilinguals is reading. Reading is considered a strong predictor of individual differences in academic, economic, and occupational outcomes (Paro & Pianta, 2000). Meta-analyses studying the assessment of academic and cognitive development to predict school readiness in kindergarten-age children have found that reading development is important for increasing conceptual ability and later mastery of more complex reading tasks, such as understanding scientific articles and other college-level texts (Duncan et al., 2007).

One way of examining ease of reading in a language is by focusing on the word frequency effect. This is the finding that high frequency (HF) words (e.g., cat, dog, house) are recognized faster and more accurately than low frequency (LF) words (e.g., synecdoche, pseudonym, consciousness) (Rayner & Duffy, 1986). As an individual's exposure to LF words increases over time, recognition times for those words decrease until they reach a limit where exposure no longer impacts recognition time, as with HF words. Conversely, if exposure to HF words decreases over an extended period of time, recognition times increase.

While knowing more than one language is associated with a number of advantages (e.g., communicative, occupational, social), it is also associated with a number of consequences, especially for how lexical representations are accessed during online processing. One important consequence is that bilinguals experience reduced ease of word processing compared to bilinguals (which, again, can be captured by word frequency effects), due to their reduced total language exposure in each language. Gollan et al. (2008) explain the word frequency effect as an index of learning, where repeated exposure to items increases lexical accessibility until items reach a plateau. Since HF words are already near or at their plateaus, increased exposure no longer benefits those items. Accordingly, the magnitude of word frequency effects (or the processing difference between LF and HF words) decreases with repetition. Because bilinguals have reduced total language experience relative to their monolingual peers (because they divide their time between two languages), the magnitude of word frequency effects should be larger in bilinguals than in monolinguals. Moreover, because bilinguals generally have less second-language (L2) than first-language (L1) experience, the magnitude of word frequency effects should be larger in their L2 than in their L1.

Building on Gollan et al.'s (2008) seminal work, Diependaele, Lemhöfer, and Brybaert (2013) presented two different explanations for how word frequency effects unfold in bilinguals. The first explanation is rooted in language competition, and proposes that word frequency effects are an index of how many languages (cross-language competitors) an individual knows. For example, word frequency effects will decrease if words in the two languages resemble one another phonologically or orthographically (i.e., when there are many cross-language neighbors). The second explanation is that, in general, bilinguals have less proficiency in their L2 than in their L1, and thus exhibit larger L2 than L1 word frequency effects, consistent with what has been proposed by Gollan et al. (2008).

Although Gollan et al.'s (2008) and Diependaele et al.'s (2013) work has made important theoretical contributions to the field, it is important to highlight the limitations on the generalizability of their findings, which has almost exclusively focused on single word processing. Tasks that involve single word processing often lack ecological validity and cannot capture the cognitive processes involved in natural reading (discussed in Whitford, Pivneva, & Titone, 2016). As such, lexical processing is likely better captured by adopting contextualized reading approaches. Moreover, language practitioners have argued against the use of single word assessments, such as the Test of English as Foreign Language (TOEFL). They maintain that word-level items that are contextualized or integrated in full passages provide a more useful and reliable measure of word recognition and processing during reading (Qian, 2008).

Researchers have employed a variety of methods to capture word frequency effects. One of these methods is the eye-tracking reading task, which monitors eye movements (i.e., saccades) and points of gaze (i.e., fixations). Our eyes move from one location to the next to process visual information while reading; these saccades, which are separated by fixations, can be forward-going or backward-going—called regressions (reviewed in Rayner, 1998, 2009; Rayner, Pollatsek, Ashby, & Clifton, 2012; Whitford et al., 2016). There are many measures that can be extracted from the eye movement record. Depending on their timing, they can reflect early stages of reading (e.g., lexical access) or later stages of reading (e.g., semantic integration). These measures are influenced by word-level properties, including word frequency. HF words are usually fixated less often (i.e., skipped more) and for less time (i.e., shorter fixation durations) than LF words because they are encountered more often, and thus, are more readily accessible from the mental lexicon.

Whitford and Titone's (2012) study was one of the first eye-tracking studies to report on word frequency effects during reading in bilinguals. More specifically, it examined whether individual differences in current L2 experience modulate L1 and L2 word frequency effects among bilingual young adults. A sample of 117 English-French bilinguals (73 with English as their first language; 44 with French as their first language) read two paragraphs/stories, one in English and one in French, while their eye movements were recorded with an eye-tracker. The authors found that regardless of current L2 exposure levels, word frequency effects were larger during L2 reading than during L1 reading overall. They also found that higher levels of L2 exposure resulted in smaller L2 word frequency effects, and, more interestingly, larger L1 word frequency effects during both early and late stages of reading (described subsequently). These findings, which are consistent with leading models of bilingual word processing (also described subsequently), demonstrate that graded differences in current L2 usage influence how both L1 and L2 words are represented and accessed during online processing.

Another eye-tracking study that examined word frequency effects during reading in bilinguals was by Cop et al. (2015). In this study, the researchers were especially interested in analyzing how L1 proficiency (indexed by a vocabulary task) modulates L2 word frequency effects. The authors did not expect that higher levels of L2 exposure result in lower levels of L1 exposure, and therefore, expected to see a positive correlation between L1 and L2 proficiency. Nineteen Dutch (first language) – English (second language) bilingual and 14 English monolingual young adults read an entire novel in four sessions while their eye movements were recorded with an eye-tracker. Bilingual participants read half of the novel in Dutch and the other half in English. The authors had three main findings. First, L1 word frequency effects were similarly sized for bilinguals and monolinguals (see also Gollan et al., 2011, for similar findings during sentence reading). Second, bilingual word frequency effects were larger in the L2 than in the L1 (as in Whitford and Titone's 2012 study). Third, L1 proficiency reduced word frequency effects in both languages. It is important to highlight that Cop et al. (2015) found no differences in word frequency effects across the language groups because they were matched on L1 vocabulary—which rarely occurs outside experimental contexts. Indeed, it is well-established that bilinguals generally have smaller vocabularies in each language than monolinguals (Gollan et al., 2008). Thus, their findings may lack generalizability and should be interpreted with caution.

Although most eye-tracking research on bilingual word frequency effects has focused on younger adult populations, Whitford and Titone (2017) recently extended their 2012 findings by examining how individual differences in current L2 exposure modulate L1 and L2 word frequency effects in both bilingual younger and older adults. The authors recruited 62 English-French bilingual older adults (43 with French as their first language; 19 with English as their first language) aged 61 to 87, and 62 matched French-English bilingual young adults aged 19 to 30 for their study. Participants read four paragraphs, translated into English and French. The authors replicated their previous finding of larger L2 versus L1 word frequency effects, which were modulated by individual differences in current L2 exposure (albeit among younger adults only). This suggests that older adults' L1 and L2 lexical representations were insensitive to graded differences in current L2 experience—a finding that may be driven by greater levels of lexical entrenchment or age-related changes to the brain.

As mentioned above, most eye-tracking research on bilingual word frequency effects has focused on younger adult populations. To date, only one study has examined these effects in bilingual children. Whitford and Joanisse (2018) also employed eye movement recordings to examine monolingual versus bilingual word frequency effects, as well as L1 versus L2 word frequency effects among bilingual children. Thirty-three bilingual children (with English as their first language and French as their second language) and 34 English monolingual children were recruited. Thirty matched English-French bilinguals and 30 English monolingual young adults were also recruited to examine the developmental trajectory of such effects. Participants read four stories: bilingual children read two stories in their L1 (English) and two in their L2 (French), whereas English monolingual children read all four stories in English. There were three predictions: (1) Bilingual children should exhibit reduced L1 reading performance, including a larger L1 word frequency effects compared to their monolingual peers; (2) Bilingual children should show reduced L2 versus L1 reading performance, including larger L2 word frequency effects; (3) Both bilingual and monolingual children should show reduced reading performance relative to adults. All three predictions were confirmed: bilingual children had larger L1 word frequency effects than monolingual children; bilingual children had larger L2 versus L1 word frequency effects; and both groups of children had larger word frequency effects (across the L1 and L2) than their respective adult comparison groups. Importantly, these findings suggest that since bilinguals divide their time between languages throughout the day, their L1 lexical representations are farther from their plateaus than those of their monolingual peers, resulting in reduced lexical accessibility.

The key findings from studies using eye movement recordings (e.g., paragraph and novel reading) highlight a number of key findings. First, word frequency effects are comparable in monolingual and bilingual younger adults during L1 (or dominant-language) reading (Cop et al., 2015; Gollan et al., 2011), but not comparable between monolingual and bilingual children during L1 reading (Whitford & Joanisse, 2018). Second, word frequency effects are larger during

L2 versus L1 reading among bilingual younger (Cop et al., 2015; Whitford et al., 2016; Whitford & Titone, 2012, 2017) and older (Whitford & Titone, 2017) adults, as well as among bilingual children (Whitford & Joanisse, 2018). Third, greater levels of current L2 experience decrease L2 word frequency effects, but increase L1 word frequency effects among younger adults only (Whitford & Titone, 2012, 2017; cf. Cop et al., 2015).

1.1 Theoretical Framework

The theoretical framework for the above-reviewed work comes from two language models: The Bilingual Interactive Activation Plus (BIA+) model (Dijkstra & Van Heuven, 2002) and weaker links hypothesis (Gollan et al., 2008, 2011). The BIA+ model proposes that because bilinguals have reduced language exposure compared to their monolingual peers, their words have lower baseline activation levels, resulting in reduced lexical accessibility (especially for LF words) and larger word frequency effects overall. Moreover, because bilinguals generally have reduced L2 versus L1 language exposure, their L2 words have lower baseline activation levels (especially LF L2 words), resulting in reduced lexical accessibility and larger L2 word frequency effects.

In their paper evaluating the Bilingual Interactive Activation (BIA) model (i.e., BIA+'s predecessor), Dijkstra and Van Heuven (2002) also discuss some aspects of language that are not present in monolingualism. More specifically, they maintain that bilinguals' two language systems are stored together, within an integrated lexicon. When reading, bilinguals cannot completely shut down the non-target language. This causes slower word recognition, which may lead to slower processing overall and, consequently, longer reading times. This may be due to an inhibition effect that occurs in bilingual individuals as a consequence of knowing the meaning of a target word in both languages.

Similarly, the weaker links hypothesis proposes that because bilinguals have reduced language exposure compared to their monolingual peers, they experience weaker links between different types of word-related information (orthography, phonology, semantics), resulting in reduced ease of word processing (especially for LF words) and larger word frequency effects overall. Moreover, because bilinguals generally have reduced L2 versus L1 experience, they experience weaker L2 links (especially for LF L2 words) and larger L2 word frequency effects (Gollan et al., 2008, 2011).

Thus, according to these models, both LF and L2 words, which are encountered less often than HF and L1 words, have lower baseline activation levels and/or weaker links, leading to reduced lexical quality and accessibility, which are reflected in larger word frequency effects (see also Andrews & Hersch, 2010; Kuperman & Van Dyke, 2013; McClelland & Rumelhart, 1981; Monsell, 1991; Perfetti, 1992; Perfetti & Hart, 2002; Seidenberg & McClelland, 1990, for similar accounts from the monolingual word recognition literature). As mentioned earlier, work by Gollan et al. (2008), Whitford and Titone (2012, 2017), Cop et al. (2015), and Whitford and Joanisse (2018) is largely consistent with these models.

Additionally, these models would predict that individual differences in language exposure/proficiency modulate L1 and L2 word frequency effects, with greater L2 exposure/proficiency decreasing L2 word frequency effects, but increasing L1 word frequency effects. As reviewed earlier, Whitford and Titone (2012, 2017) examined this prediction in both bilingual younger and older adults, and found that only bilingual younger adults exhibit a trade-off in L1 and L2 word frequency effects with greater levels of current L2 exposure. Given that this trade-off has only been investigated among adult populations, an open question is whether it also extends to child populations. It is important to address this question in children, as their lexical representations have not benefited from an extensive amount of language exposure (potentially resulting in reduced lexical entrenchment), and thus, may be particularly sensitive to graded differences in language use.

CHAPTER 2: CURRENT STUDY

In Whitford and Joanisse's (2018) original study, they found larger L2 versus L1 word frequency effects among bilingual children overall. This is because L2 words have lower baseline activation levels than L1 words (according to BIA+) and/or weaker links between orthography, phonology, and semantics (according to the weaker links hypothesis). Building on this work, the current study focused on how individual differences in current (i.e., "in the moment") L2 experience modulates bilingual children's L1 and L2 word frequency effects. In line with BIA+ and the weaker links hypothesis, we predicted that bilingual children with relatively higher levels of current L2 exposure should show smaller L2 word frequency effects, but larger L1 word frequency effects than bilingual children with relatively lower levels of current L2 exposure. This is because greater levels of L2 exposure raise the baseline activation levels of L2 words (according to BIA+) and/or strengthen their orthographic, phonological, and semantic links (according to the weaker links hypothesis). Conversely, the opposite occurs for L1 words.

CHAPTER 3: METHODS

3.1 Participants

For the current study, 33 English-French bilingual children (with English as their L1 and French as their L2), aged seven to 12, were recruited from elementary schools from the London area of Ontario, Canada. The study was approved by University of Western Ontario's nonmedical research ethics board. Bilingual children were attending either a French or French immersion school, and therefore, had high levels of proficiency in both languages. Subjects were rewarded with movie gift cards for participating in the study.

Table 1 presents the children's background characteristics, including age, education, sex, parental socioeconomic status (SES) based on the Hollingshead Occupation Scale (Hollingshead, 1975). It also presents their language background and proficiency using a parental adaptation of the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007) This measure allowed us to estimate the percent of time that children are exposed to each language. Word-level reading skills were assessed with the Word Reading and Pseudoword Decoding subtests of the Canadian and French adaptations of the Wechsler Individual Achievement Test-Second Edition (WIAT-II; Wechsler, 2005). The Test of Nonverbal Intelligence-Third Edition (TONI; Brown, Sherbenou & Johnsen, 1997) was used to assess their nonverbal IQ.

Table 1. Participant Characteristics

	Bilingual Children (*n* = 33) [Mean (SD)]
Sex (Male, Female)	13:20
Age (Years)	10.02 (1.32)
Education (Years)	4.21 (1.39)
Parental SES	2.88 (1.36)
LEAP-Q Age of Acquisition (AoA) (Years)	
L1	Birth (-)
L2	3.82 (1.66)
LEAP-Q Reading AoA	
L1	4.48 (1.14)
L2	5.47 (1.05)
LEAP-Q L1 Proficiency Measure (scale = 1 to 7)	
Reading Ability	6.06 (1.41)
Overall Competence	6.15 (1.31)
LEAP-Q L2 Proficiency Measures (scale = 1 to 7)	
Reading Ability	4.58 (1.28)
Overall Competence	4.67 (1.31)
LEAP-Q Current Language Exposure (% time)	
L1	58.03 (12.93)
L2	39.70 (13.11)
LEAP-Q Current Reading Exposure (% time)	
L1	65.30 (25.98)
L2	33.58 (25.35)
L1 WIAT-II (Standard Scores)	
Word Reading	99.15 (17.38)
Pseudoword Decoding	103.12 (17.22)
L2 WIAT-II (Standard Scores)	
Word Reading	88.55 (23.77)
Pseudoword Decoding	95.70 (20.73)
TONI-III (Standard Scores)	117.18 (18.04)

3.2 Materials

Participants were presented with four paragraphs: English and French versions of fiction and nonfiction articles from the Reading Comprehension subtest of the WIAT-II (Wechsler, 2005). These were reflective of the type of reading conducted in general education classes across Canada. The four English paragraphs were composed of 105, 87, 103 and 195 words. The four paragraphs in French were composed of 118, 95, 109, 200 words. The fiction articles talked about a character who loved to clean her town, and another character who raised money for hospitalized children, while the nonfiction articles were about crickets and baobab trees.

Words of each paragraph were coded for length, frequency and predictability. English word frequencies were obtained from the Brysbaert and New (2009), corpus within the English Lexicon Project (Balota et al., 2007). French word frequencies were obtained from the Lexique database (New, Pallier, Ferrand, & Matos, 2001). Subtitle word frequency norms were obtained by summing the number of word appearances in subtitles of films and television series (Dimitropoulou, Duñabeitia, Avilés, Corral, & Carreiras, 2010), and are representative of everyday language exposure to these words within a country. Thus, log subtitle word frequency is a valid and reliable estimate of a word's occurrence in a language. Computerized tasks were used to obtain English and French word predictabilities, in which L1 English (n = 30) and L1 French (n = 30) speakers guessed words of each paragraphs in a sequential manner and one word at a time until each paragraph was presented in its entirely on the screen (Miellet, Sparrow, & Sereno, 2007; Whitford & Titone, 2012, 2014, 2017). Correct guesses were coded as 1, while incorrect guesses were coded as 0. Average close values were then computed for each word.

Two hundred and ten target words were selected from the paragraphs, which consisted of language-specific content words. Line-initial and line-final words; function, punctuated, and repeated words; proper nouns; and words with cross-language orthographic overlap (e.g. cognates, interlingual homographs) were excluded (Miellet et al., 2007; Pollatsek et al., 2006; Whitford & Titone, 2012, 2017).

3.3 Apparatus

Eye movements were recorded at a 1-kHz sampling rate using an EyeLink 1000 desktop-mounted eye-tracker (SR Research, Ottawa, Ontario, Canada). Padded headrests minimized head movements during reading. The four double spaced paragraphs were displayed on a 21-inch ViewSonic CRT monitor, with a 1024 x 768-pixel screen resolution, placed 60 centimeters in front of the participants on either one or two display screens in yellow 14-point Courier New font against a black background. Display screens contained a maximum of 10 lines of text, 70 characters per line, and 2 characters per 1 of visual angle. Viewing was binocular, but eye tracking was right-eye monocular. Calibration was performed with a 9-point grid, and the average fixation error was <0.5 of visual angle.

3.4 Procedure

The eye-tracking reading task consisted of having the children read the four paragraphs silently and naturally for comprehension. They read two paragraph versions in English (L1) and the other two in French (L2). After each paragraph, they answered opened-ended questions orally (4 questions per paragraph that were designed by the researchers) to assess their comprehension. Correct answers were coded as 1, partially correct answers were coded as 0.5, and incorrect answers were coded as 0 (Radach, Huestegge & Reilly, 2008; Whitford & Titone, 2012, 2014, 2017). Paragraph language (L1 and L2) was counterbalanced across the bilingual children. Paragraph version (1, 2, 3, and 4) was also counterbalanced across all participants using a Latin square design. Participants then completed the LEAP-Q, followed by the WIAT-II Word Reading and Pseudoword Decoding subtests. The TONI-III was administered at the end.

3.5 Design and Statistical Analyses

The present study was a within-subjects design. We analyzed two dependent variables (gaze duration and total reading time) using linear mixed-effects models to examine the relationship between subjects' word frequency (continuous; log-transformed to normalize its distribution), L1 and L2 paragraph language (categorical variable), percent of current L2 exposure (continuous variable), and their interaction. Current L2 exposure was based on parental self-report using the LEAP-Q. Parents were presented with the following question, "On average, how often is your child exposed to each of their languages (percentages must add up to 100%)".

We included a number of covariates (control predictors) in our models. First, to account for the gap between children ages 7 to 12 years, we controlled for age. Secondly, we controlled for word predictability since it can increase variability in reading times. Lastly, WIAT L1 and L2 Word Reading scores were included to control for variability in objective reading proficiency among the sample of bilingual children. Thus, our covariates were age, word predictability, and WIAT L1 and L2 standard scores. Our random effects were random intercepts for subjects and items (following Whitford & Titone, 2012, 2017; Whitford & Joanisse, 2018).

CHAPTER 4: RESULTS

We ran two linear mixed-effects models in R (Version 3.4.1) (Baayen, 2008; Bayyen, Davidson, & Bates, 2008; R Development Core Team, 2017) using the LME4 package (Bates, Mächler, Bolker, & Walker, 2014): one for gaze duration and one for the total reading time. The two continuous variables were scaled to reduce collinearity; the categorical variable was deviation coded (-0.5, 0.5). Any *t*-values greater than 1.96 with $\alpha = .05$ were considered significant effects. All fixed effects, covariates, and random effects are reported in each analysis.

We examined both early- and late-stage eye movement measures: gaze duration and total reading time. Early-stage measures reflect lexical access (i.e., initial word activation/retrieval from the mental lexicon), including all fixations and re-fixations made on a word during the first pass, while late-stage measures reflect post-lexical integration (i.e., semantic integration), including all fixations and regressions made on a word overall (Rayner, 1998). *Gaze duration* (i.e., sum of all fixations made on a word prior to a saccade to a subsequent word) is considered an early-stage measure, while *total reading time* (i.e., sum of all fixation and re-fixations on a word overall) is considered a late-stage measure. As explained earlier, eye movement measures reflect the cognitive processes involved in reading (Rayner, 1998). LF and L2 words, which are encountered less often, are more difficult to process because they have lower baseline activation levels and/or weaker links (Dijkstra & Van Heuven, 2002; Gollan et al., 2008, 2011). Thus, such words should receive longer fixation durations, ultimately resulting in larger word frequency effects.

Table 2 presents the results for *gaze duration*, and Table 3 presents the results for *total reading time*. As can be seen, we found a significant main effect of word frequency for both eye movement measures (gaze duration: $\beta = -78.36$, $SE = 5.59$, $t = -13.99$, $p < .001$; total reading time: $\beta = -124.66$, $SE = 7.85$, $t = -15.87$, $p < .001$); processing times were longer for lower-frequency than for higher-frequency words. We also found a significant two-way interaction between word frequency and paragraph language for both eye movement measures (gaze duration: $\beta = -25.49$, $SE = 11.01$, $t = -2.31$, $p = .020$; total reading time: $\beta = -30.79$, $SE = 15.46$, $t = -1.99$, $p = .046$); word frequency effects were larger in the L2 than in the L1 (as can be seen in Figure 1). Thus, L2 reading is more effortful than L1 reading performance across both reading stages.

Moreover, we found a significant two-way interaction between paragraph language and current L2 exposure for both eye movement measures (gaze duration: $\beta = -43.49$, $SE = 14.36$, $t = -3.03$, $p = .003$; total reading time: $\beta = -73.80$, $SE = 27.83$, $t = -2.65$, $p = .012$); L2 processing times decrease with greater levels of current L2 exposure, whereas L1 processing times increase with greater levels of current L2 exposure (as can be seen in Figure 2). Thus, there is a trade-off in L1 and L2 reading performance across both reading stages with greater levels of current L2 exposure (regardless of word frequency).

Table 2. Model 1: Linear Mixed-Effect Model for Gaze Duration

Variables	*β*	*SE*	*t*	*p*
Fixed Effects				
Intercept	400.19	20.98	19.07	<.001*
Paragraph Language (L1, L2)	-6.35	22.18	-0.28	.774
Word Frequency	-78.36	5.59	13.99	<.001*
Current L2 Exposure (% time)	-26.57	17.91	-1.48	.148
Paragraph Language * Frequency	-25.49	11.01	-2.31	.020 *
Paragraph Language * L2 % Exposure	-43.57	14.36	-3.03	.003*
Frequency * L2 % Exposure	-1.47	5.41	-0.27	.785
Paragraph Language * Frequency * L2 % Exposure	8.61	10.87	0.79	.428
Control Predictors				
Age	-48.50	16.34	-2.97	.005*
Word Predictability	-13.62	5.62	-2.42	.015*
WIAT L1 Standard Scores	-81.04	20.13	-4.03	.000*
WIAT L2 Standard Scores	29.82	20.25	1.47	.151
Random Effects	**Variance**			
Subjects	2152.65			
Items	30.07			
Residual	94815.31			

Note: $p < .05$

Table 3. Model 2: Linear Mixed-Effect Model for Total Reading Time

Variables	*β*	*SE*	*t*	*p*
Fixed Effects				
Intercept	591.65	34.35	17.27	<.001*
Paragraph Language (L1, L2)	31.06	43.48	0.71	.480
Word Frequency	-124.66	7.85	-15.87	<.001*
Current L2 % Exposure (% time)	-46.47	32.77	-2.99	.166
Paragraph Language * Frequency	-30.79	15.46	-1.99	.046*
Paragraph Language * L2 % Exposure	-73.80	27.83	-2.65	.012*
Frequency * L2 % Exposure	4.97	7.62	0.65	.513
Paragraph Language * Frequency * L2 % Exposure	31.99	15.27	2.09	.036*
Control Predictors				
Age	-88.39	29.50	-2.99	.005*
Word Predictability	-20.42	7.87	-2.59	.009*
WIAT L1 Standard Scores	-142.41	36.83	-3.87	.000*
WIAT L2 Standard Scores	36.89	37.46	0.98	.333
Random Effects	**Variance**			
Subjects	15629.1			
Items	233.3			
Residual	186416.6			

Note: $p < .05$

To allow for comparison with more traditional analyses of variance (ANOVAs), we dichotomized our two continuous fixed variables (word frequency and current L2 exposure) using a median split. Word frequency was divided into HF words (log subtitle word frequency > 1.64, *n* = 105 words) and LF words (log subtitle words frequency < 1.64, *n* = 105 words). Similarly, current percent L2 exposure was divided into high exposure (L2 percent exposure >

40%, *n* = 11 participants) and low exposure (L2 percent exposure < 40%, *n* = 22 participants). Table 4 presents the means and standard deviations for both eye movement measures.

Table 4. Descriptive Statistics for Gaze Duration and Total Reading Time

Eye Movement Measure	L1				L2			
	High L2 Exposure		Low L2 Exposure		High L2 Exposure		Low L2 Exposure	
	HF Words	LF Words	HF Words	LF Words	HF Words	LF Words	HF Words	LF Words
Gaze Duration (ms)	329 (185)	432 (337)	337 (235)	421 (302)	337 (314)	502 (494)	356 (247)	573 (595)
Total Reading Time (ms)	469 (341)	636 (546)	451 (315)	608 (451)	506 (411)	774 (737)	568 (503)	882 (885)

Figure 1. The effect of word frequency on bilingual children's gaze durations during L1 and L2 reading. Similar patterns were found for L1 and L2 total reading times.

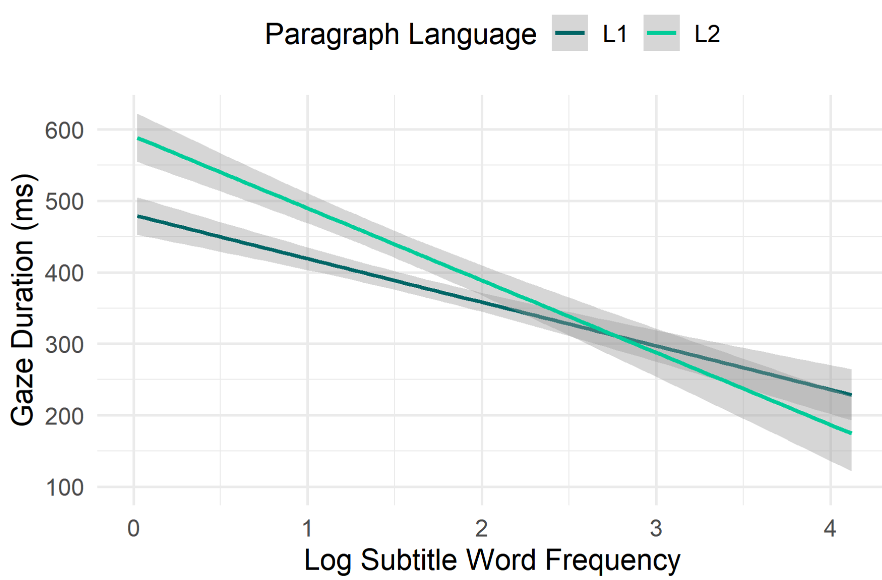
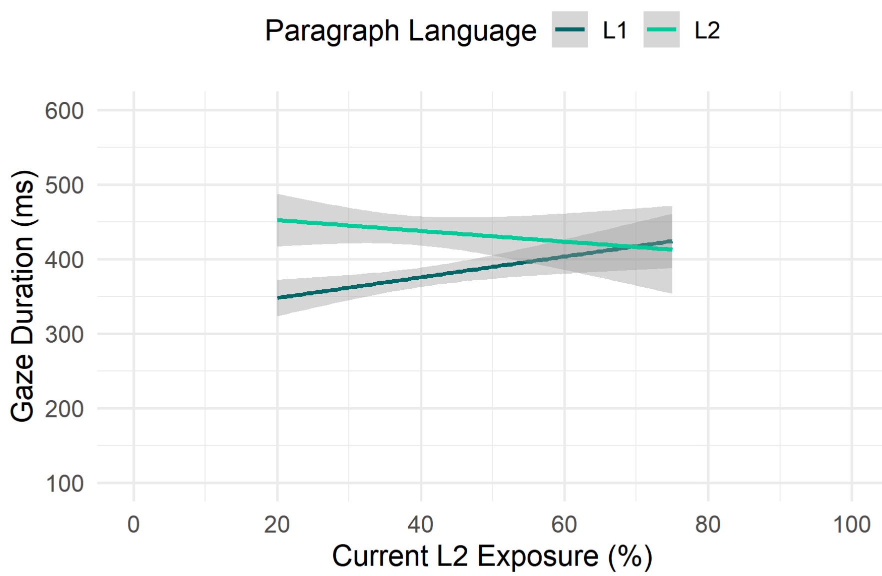


Figure 2. The effect of current L2 exposure on bilingual children's gaze durations during L1 and L2 reading. Similar patterns were found for L1 and L2 total reading times.



Lastly, we found a significant three-way interaction between word frequency, paragraph language, and current L2 exposure for total reading time only ($\beta = 31.99$, $SE = 15.27$, $t = 2.09$, $p = 0.03$). To break up the three-way interaction, we ran two sub-models that examined L1 and L2 reading separately.

4.1 Sub-Model Analyses

First, we examined the two-way interaction between word frequency and current L2 exposure (both continuous) during L1 reading. All other factors (covariates, fixed effects) were the same as in the models above. We found no significant interaction between word frequency and current L2 exposure ($\beta = -10.16$, $SE = 9.15$, $t = -1.11$, $p = .267$). Thus, word frequency effects were not significantly affected by current L2 exposure during L1 reading (see Table 5).

Second, we examined the two-way interaction between word frequency and current L2 exposure (both continuous) during L2 reading. All other factors (covariates, fixed effects) were the same as in the models above. We found a near-significant interaction between word frequency and current L2 exposure (β = 22.27, *SE* = 12.22, *t* = 1.82, *p* = 0.06). Thus, word frequency effects decrease with greater levels of current L2 exposure during L2 reading (see Table 6).

Table 5. Sub-model 1: Linear Mixed-Effect Model for Total Reading Time in L1

Variables	***β***	***SE***	***t***	***p***
Fixed Effects				
Intercept	572.30	52.60	10.88	<.001*
Word Frequency	-106.14	9.29	-11.41	<.001*
Current L2 Exposure (% time)	-7.63	29.76	26.93	.005*
Frequency * L2 % Exposure	-10.16	9.15	-1.11	.267
Control Predictors				
Age	-86.59	28.93	-2.99	.005*
Word Predictability	-12.02	9.39	-1.280	.200
WIAT L1 Standard Scores	-138.79	40.73	-3.41	.299
WIAT L2 Standard Scores	34.11	40.59	0.84	.408
Random Effects	**Variance**			
Subjects	19708.2			
Residual	140177.3			

Note: p < .05

Table 6. Sub-model 2: Linear Mixed-Effect Model for Total Reading Time in L2

Variables	*β*	*SE*	*t*	*p*
Fixed Effects				
Intercept	612.61	80.86	7.13	<.001*
Word Frequency	-143.36	12.87	-11.80	<.001*
Current L2 % Exposure	-81.45	45.13	-1.64	.082
Frequency * L2 % Exposure	22.27	12.22	1.82	.068
Control Predictors				
Age	130.81	49.43	-2.65	.014*
Word Predictability	-29.79	12.85	-2.32	.021*
WIAT L1 Standard Scores	-104.62	63.73	-1.64	.112
WIAT L2 Standard Scores	12.23	60.79	.20	.842
Random Effects	**Variance**			
Subjects	50646			
Residual	2234556			

Note: $p < .05$

CHAPTER 5: DISCUSSION

This study aimed to discover how language experience shapes both L1 and L2 word reading among children who are being exposed to an L2 at school from an early age. We presented our subjects with four paragraphs translated into English and French and recorded their eye movements. As opposed to other behavioral tasks (e.g., lexical decision), this more naturalistic approach allowed us to examine the cognitive processes involved in bilingual children's reading across their known languages in a temporally sensitive manner. Based on two leading language models, BIA+ (Dijkstra & Van Heuven, 2002) and the weaker links hypothesis (Gollan et al., 2008, 2011), we predicted that bilingual children with greater levels of current L2 exposure would have smaller L2 word frequency effects, but larger L1 word frequency effects. In other words, greater levels of current L2 proficiency should modulate both L1 and L2 word frequency effects, resulting in a trade-off. We had three main findings (discussed subsequently).

Our first main finding was that word frequency effects were larger in the L2 than in the L1 (indexed by a significant two-way interaction between word frequency and paragraph language), which was driven by slower processing of L2 LF words. This finding was found for both early-stage (gaze duration) and late-stage (total reading time) measures of reading, suggesting that word frequency impacts both lexical access and post-lexical integration. This finding is consistent with BIA+, which proposes that low-frequency words (especially those in the L2), have lower baseline activation levels, resulting in larger word frequency effects (especially in the L2). This finding is also consistent with the weaker links hypothesis, which proposes that the links between different types of word-related information (e.g., orthography, phonology, semantics) are weaker for low-frequency words (especially in the L2), resulting in larger word frequency effects (especially in the L2) (Gollan et al., 2008, 2011). Finally, this finding is consistent with a relatively small, but growing body of eye movement literature. As stated earlier, key findings from studies using eye movement recordings highlight that word frequency effects are larger during L2 versus L1 reading among younger adults (Cop et al., 2015; Whitford & Titone, 2012, 2016 2017), older adults (Whitford & Titone, 2017), and most recently, bilingual children (Whitford & Joanisse, 2018).

Our second main finding was that greater levels of current L2 exposure facilitated L2 reading behavior, but hindered L1 reading behavior (indexed by a significant two-way interaction between paragraph language and current L2 exposure). This finding was found for both early-stage (gaze duration) and late-stage (total reading time) measures of reading, suggesting that both reading stages are sensitive to graded differences in current L2 experience (regardless of word frequency). This finding is also consistent with BIA+ and the weaker links hypothesis (Dijkstra & Van Heuven, 2002; Gollan et al., 2008, 2011). Both language models predict that individual differences in language proficiency/exposure modulate L1 and L2 word processing, ultimately resulting in a trade-off with higher levels of current L2 exposure/proficiency (or lower levels of current L1 exposure/proficiency). Accordingly, we found that higher levels of current L2 exposure raised the baseline activation levels of L2 words and strengthened their word-related links. Conversely, we found that higher levels of current L2 exposure lowered the baseline activation levels of L1 words and weakened their word-related links. In other words, we observed the expected trade-off in L1 and L2 word processing.

Our third main finding was that greater levels of current L2 exposure resulted in smaller L2 word frequency effects, but had no significant impact on L1 word frequency effects (indexed by a significant three-way interaction between word frequency, paragraph language, and current L2 exposure). This finding was found for late-stage reading only (total reading time), suggesting that word frequency and graded differences in current L2 exposure jointly impact post-lexical integration during L2 reading. Thus, our hypothesis was only partially confirmed.

This finding only partially supports BIA+, weaker links hypothesis, and the prior literature (Whitford & Titone, 2012, 2017), as individual differences in current L2 experience modulated L2 word frequency effects only. It is likely that this finding is driven by differences in lexical entrenchment across the L1 and L2. Given that bilingual children are young and have less total life-long language experience, one possibility is that their lexical representations have not accrued enough overall exposure to be as sensitive to graded differences in current L2 exposure as younger adults. Despite acquiring an L2 from an early age, bilingual children's L2 lexical representations were not as well established (i.e., entrenched) as those in their L1, as they have benefitted from less absolute language experience. Thus, lexical representations in the weaker language (i.e., L2) may be the only ones susceptible to graded differences in current L2 experience at an early age. As children accrue more language experience over time, their L1 lexical representations may become more sensitive to ongoing L2 influences (like what has been found for younger adults in Whitford and Titone's studies). As they reach the tail end of the lifespan, their L1 and L2 lexical representations may reach a functional ceiling, rendering them insensitive to ongoing L2 influences (like what has been found for older adults in Whitford and Titone's study). Thus, both the early and late stages of the lifespan may be associated with reduced L2 influences on L1 lexical processing during naturalistic reading.

Another possibility is that these between-study differences are driven by qualitatively different language experiences, including differences in learning contexts (home vs. school), linguistic environments (bilingual vs. monolingual areas), and types of bilingualism (simultaneous vs. sequential). For instance, the younger adults included in Whitford and Titone's

(2012, 2017) studies were a mix of simultaneous and sequential bilinguals from Montreal, Canada – a highly multilingual environment. Moreover, their current L2 exposure levels (which were measured in the same manner) ranged from 0 to 50%. In contrast, our bilingual children were mostly sequential bilinguals who acquired their L2 in schools in London, Canada – a predominately English monolingual environment. Moreover, their current L2 exposure levels ranged from 20 to 75%.

Furthermore, the younger adults included in Whitford and Titone's (2012, 2017) studies may also use their languages in a different manner than our sample of bilingual children. Given the highly multilingual nature of Montreal, Canada, it is possible that those younger adults mix their languages more frequently (e.g., code-switch) in their day-to-day lives, whereas our sample of bilingual children use each language in different contexts (i.e., French in school vs. English home). In other words, the behavioral ecology might differ across these groups of bilinguals, which 'mixers' being included in the Whitford and Titone (2012, 2017) studies and 'compartmentalizers' being included in our current study.

5.1 Conclusion

Taken together, the findings of this study indicate that bilingual children may be temporarily immune to the L1/L2 trade-off in lexical accessibility (assessed by word frequency effects) with greater levels of current L2 exposure. This may be driven by qualitatively different language experiences or the fact that their L2 lexical representations have not accrued as much experience as those of younger adults. Although this trade-off may emerge in their teenage or young adult years, it is important to emphasize that this is not a bilingual disadvantage, but rather, a consequence of having two language systems in the brain.

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APPENDIX A

Hollingshead Socio-Economic Status Questionnaire

Father:

1) What is your father's highest level of education?
   Answer:

2) What is your father's occupation?
   Answer:

Mother:

1) What is your mother's highest level of education?
   Answer:

2) What is your mother's occupation?
   Answer:

Participant:

1) What is your highest level of education?
   Answer:

2) What is your occupation?
   Answer:

Scoring

Type:

1) Higher executives, major professionals
2) Proprietors of medium-sized businesses and lesser professionals
3) Administrative personnel, owners of small businesses, minor professionals
4) Clerical and sales workers, technicians, owners of little businesses
5) Skilled, manual employees
6) Machine operators, semi-skilled employees
7) Unskilled employees
8) Student
9) Unemployed

Salary:

1) <9,999
2) 10,000-19,999
3) 20,000-29,999
4) 30,000-39,000
5) 40,000-49,999
6) 50,000-59,999
7) 60,000-69,999
8) 70,000-79,999
9) 80,000-89,999
10) 90,000-99,999
11) >100,000

APPENDIX B

Language_Background_Questionnaire_(LEAP-Q)

1. Personal Information

1. Please enter your...

Child's Participant Number

2. Child's Gender:

- [ ] Male
- [ ] Female

3. Child's Age (in years, months)

4. Your Child's Place of Birth (city, country):

5. Your Child's Current Education Grade

- [ ] Grade 1
- [ ] Grade 2
- [ ] Grade 3
- [ ] Grade 4
- [ ] Grade 5
- [ ] Grade 6
- [ ] Grade 7

Other (please specify)

6. Education Level Of Your Child's Mother

- [ ] Elementary School
- [ ] High School
- [ ] CEGEP
- [ ] University
- [ ] Post-graduate studies

Other (please specify)

Language_Background_Questionnaire_(LEAP-Q)

7. Education Level Of Your Child's Father

- ☐ Elementary School
- ☐ High School
- ☐ CEGEP
- ☐ University
- ☐ Post-graduate studies

Other (please specify)

____

8. Occupation Of Your Child's Mother

____

9. Occupation Of Your Child's Father

____

10. If Your Child Was Not Born In Canada, At What Age Did They Move Here?

____

Language_Background_Questionnaire_(LEAP-Q)

2. General Language Questions

11. Please specify the known languages of:

	English Monolingual	French Monolingual	English-French Bilingual with English Dominance	French-English Bilingual with French Dominance
Your Child's Mother	○	○	○	○
Your Child's Father	○	○	○	○

If "other", please specify

12. Which is your child's main language of instruction?

	English Only	French Only	English School with French Immersion	French School with English Immersion	Officially Bilingual
Primary/Elementary School	○	○	○	○	○
High School	○	○	○	○	○

Other (please specify)

13. Which is your child's second language of instruction?

- ○ French
- ○ English

Other (please specify)

14. Please list all the languages your child knows IN ORDER OF DOMINANCE:

15. Please list all the languages your child knows IN ORDER OF ACQUISITION:

16. Please specify the age when your child...

Began acquiring English

Became fluent in English

Began reading in English

Became fluent in reading English

Language_Background_Questionnaire_(LEAP-Q)

17. Please specify the age when your child...

Began acquiring French

Became fluent in French

Began reading in French

Became fluent in reading French

18. Please list what percentage of time your child is CURRENTLY and ON AVERAGE exposed to each language (Percentages should add up to 100).

English

French

Other

19. When choosing to read a text available in all your child's languages languages, in what percentage of cases would they choose to read it in each of their languages? (Percentages should add up to 100).

English

French

Other

20. When choosing a language to speak with a person who is equally fluent in all your child's languages, what percentage of time would they choose to speak each language? (Percentages should add up to 100)

English

French

Other

21. Please rate the amount of each language that your child uses at HOME:

	1 None at all	2	3	4	5	6	7 A significant amount
English	○	○	○	○	○	○	○
French	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

Other (please specify)

Language_Background_Questionnaire_(LEAP-Q)

22. Please rate the amount of each language that your child uses in SOCIAL SITUATIONS:

	1 None at all	2	3	4	5	6	7 A significant amount
English	◯	◯	◯	◯	◯	◯	◯
French	◯	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯	◯

Other (please specify)

Language_Background_Questionnaire_(LEAP-Q)

3. All questions below refer to your child's knowledge of English and French

23. Please rate your child's linguistic ability in ENGLISH according to the following scale:

	1 Beginner	2	3 Intermediate	4	5 Advanced	6	7 Near-native
Speaking Ability	○	○	○	○	○	○	○
Reading Ability	○	○	○	○	○	○	○
Writing Ability	○	○	○	○	○	○	○
Translating Ability	○	○	○	○	○	○	○
Listening Comprehension	○	○	○	○	○	○	○
Pronunciation	○	○	○	○	○	○	○
Fluency	○	○	○	○	○	○	○
Vocabulary	○	○	○	○	○	○	○
Gramatical Ability	○	○	○	○	○	○	○
Overall Competence	○	○	○	○	○	○	○

24. Please rate your child's linguistic ability in FRENCH according to the following scale:

	1 Beginner	2	3 Intermediate	4	5 Advanced	6	7 Near-native
Speaking Ability	○	○	○	○	○	○	○
Reading Ability	○	○	○	○	○	○	○
Writing Ability	○	○	○	○	○	○	○
Translating Ability	○	○	○	○	○	○	○
Listening Comprehension	○	○	○	○	○	○	○
Pronunciation	○	○	○	○	○	○	○
Fluency	○	○	○	○	○	○	○
Vocabulary	○	○	○	○	○	○	○
Gramatical Ability	○	○	○	○	○	○	○
Overall Competence	○	○	○	○	○	○	○

Language_Background_Questionnaire_(LEAP-Q)

4. Health-Related Questions

25. Does your child have...

	Yes	No
A vision problem?	◯	◯
A hearing impairment?	◯	◯
A language disability?	◯	◯
A learning disability?	◯	◯

If you responded yes to any of the above questions, please specify.

26. Does your child have...

	Yes	No
A neurological disorder (e.g., epilepsy)?	◯	◯
A psychiatric disorder (e.g., ADHD, depression)?	◯	◯

If you responded yes to any of the preceding questions, please specify.

27. Does your child suffer from...

	Yes	No
Attention problems?	◯	◯
Sleeping problems?	◯	◯

If you responded yes to any of the preceding questions, please specify.

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VITA

Astrid Michelle Portillo was born in El Paso, Texas. She received her Bachelor of Arts in Psychology with a minor in Criminal Justice from the University of Texas at El Paso in May 2016. She joined the Clinical Psychology Program at the University of Texas at El Paso to earn her Master's degree. During that time, she was accepted to diversity programs in Minneapolis, Minnesota and in Austin, Texas, where she presented one of her projects about religious over-claiming and aggression. She also worked as a psychometrist at the Adult and Adolescent Counseling Center where she gained experience in administering and scoring psychological assessments.