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Age of Bilingual Exposure Is Related to the Contribution of Phonological and Semantic Knowledge to Successful Reading Development

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Bilingual children's reading as a function of age of first bilingual language exposure (AoE) was examined. Bilingual (varied AoE) and monolingual children (N = 421) were compared in their English language and reading abilities (6–10 years) using phonological awareness, semantic knowledge, and reading tasks. Structural equation modeling was applied to determine how bilingual AoE predicts reading outcomes. Early exposed bilinguals outperformed monolinguals on phonological awareness and word reading. Phonology and semantic (vocabulary) knowledge differentially predicted reading depending on the bilingual experience and AoE. Understanding how bilingual experiences impact phonological awareness and semantic knowledge, and in turn, impact reading outcomes is relevant for our understanding of what language and reading skills are best to focus on, and when, to promote optimal reading success.

Reading is a highly complex process involving all aspects of language, including phonology, morphology, syntax, and semantics. Early development in these aspects of language is linked to reading mastery. For example, phonological awareness and vocabulary knowledge are highly predictive of children's reading outcomes. There is a considerable body of research on monolingual children's phonological awareness and vocabulary knowledge, and the relation with subsequent reading mastery (Hulme et al., 2002; Nation & Snowling, 2004; Pugh et al., 2013; Wagner & Torgesen, 1987). However, comparatively less is known about the relation between phonological awareness and vocabulary knowledge with reading in the healthy, typically developing bilingual child (e.g., Jasińska & Petitto, 2013, 2014; Kovelman, Baker, & Petitto, 2008).

Does bilingual versus monolingual language exposure differentially impact knowledge of specific parts of language (phonology, semantics) that are important predictors for reading success? Specifically, is the predictive relation of phonology and semantics with reading mastery similar or different across monolingual and bilingual children, and bilingual children with different ages of first bilingual exposure? Answering these research questions can inform our understanding of how early-life language experience (monolingual vs. bilingual) impacts language development and subsequent reading outcomes. Nearly 25% of children growing up in the United States are raised in bilingual homes (Mather, 2009); in Canada, 17.5% of the population reports being bilingual (Statistics Canada, 2012), with 29% of youth report being conversationally bilingual in the two official languages, English and French (Statistics Canada, 2013). Understanding how literacy is acquired in this increasing segment of our population is critical to understanding how best to support successful reading outcomes.

Phonology and Reading

Reading involves multiple levels of language organization, with one level receiving much attention because of its importance in the very early years of life, phonology. Children's awareness of and ability to manipulate the sound units in their

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native language, termed *phonological awareness*, is a strong predictor of later reading development (Hulme et al., 2002; Nation & Snowling, 2004; Pugh et al., 2013; Wagner & Torgesen, 1987). A child's phonological awareness skills prior to or at the onset of reading instruction are correlated with later literacy skills (Badian, 2001). Furthermore, there is a reciprocal process between phonological awareness and reading, such that reading acquisition improves phonological awareness (Stanovich, 1986). Children who perform well on tasks such as indicating how many syllables or phonemes are in a word; naming a word that differs from other words in onset; rime or vowel such as "toy," "boy," "bay"; repeating a word while omitting a phoneme; or matching words that contain the same sound, tend to be better readers, and perform better on tasks measuring reading skill. Moreover, the ability to maintain phonological units in a phonological memory loop is also predictive of reading outcomes (Swanson & Jerman, 2007). Four-year-old children with poor phonological memory ability show poorer literacy skills at age 8 (Gathercole, Tiffany, Briscoe, & Thorn, 2005). Similarly, children with reading disabilities show poorer growth in working memory ability as compared with typical readers (Swanson & Jerman, 2007).

Phonology-based intervention has previously been shown to improve reading fluency (Shaywitz et al., 2004). Shaywitz et al. (2004) found that tutoring sessions focused on helping children understand how letters and combinations of letters map onto phonemes lead to positive gains in scores on the Gray Oral Reading Test (Wiederholt & Bryant, 2012). Furthermore, children receiving this phonology-based intervention showed greater activation in the brain's language and reading circuits during a reading task (Shaywitz et al., 2004).

Phonology is implicated in reading because understanding that phonemes can correspond to letters is a fundamental foundation for learning to read. This grapheme to phoneme correspondence allows the young reader to successfully decode an unfamiliar word by "sounding out" each letter (Share, 1995). When a child is faced with the task of recognizing a printed word, she can map phonological representation onto orthographic representations in order to access the word from the lexicon, deemed the *phonological route* (e.g., Frost, 1998). Indeed, there is evidence that all young readers access phonological representations in association with print for all languages (Goswami, 2008). The role of phonological awareness is comparatively transparent for reading in languages such as Spanish, Italian, and German as compared to, for example, English, as Spanish, Italian, and German show a higher degree of grapheme to phoneme correspondence, termed *shallow orthography*, whereupon each letter has a close one to one mapping to a phoneme (Katz & Frost, 1992). Many alphabetic languages have a shallow orthography, whereas English orthography is comparatively idiosyncratic. English has a complex and irregular grapheme to phoneme correspondence, termed *deep orthography*, with both regularly and irregularly spelled words. For example, the letter "c" can correspond to both the phoneme /s/ and /k/ as in "circus." Although a grapheme to phoneme reading strategy will produce the correct pronunciation of regular English words such as "dog," this reading strategy fails for irregular words such as "caught." French, in comparison to Spanish, has more irregular sound to letter print correspondence, and thus is not truly a shallow orthography but is not as irregular as English and therefore not as deep. Irrespective of such cross-linguistic orthographic variation, phonology is a key component of learning to read in both shallow and deep orthography languages (Katz & Frost, 1992). Moreover, this general principle holds true across different writing systems, for example, alphabetic languages where the orthography is associated with phonemes, such as English; syllabic languages where the orthography is associated with syllables, such as Japanese; and logographic languages where the orthography is associated with morphemes, such as Chinese (Wang, Yang, & Cheng, 2009). These orthographies involve an assembled phonology, whereby letters or graphemes are transformed to phonemes. Phonology is also a key part of reading in languages such as Hebrew or Arabic (Frost, 1995), which have both a transparent orthography (with diacritics providing vowel information) and an opaque orthography (without diacritics). The opaque orthography does not have a direct reliance on phonological information; yet, evidence from psycholinguistic studies and studies of reading disorders indicate that phonology is accessed when reading the opaque orthography (Frost, 1995). Visual sign language phonology is also a predictor of reading among deaf children. Deaf children are found to utilize visual signed phonology through fingerspelling (hand shapes corresponding to the alphabet) and sign-phonetic or syllabic units to support reading acquisition (Emmorey & Petrich, 2012; Holowka & Petitto, 2002; Petitto, Holowka, Sergio, & Ostry, 2001). Therefore, phonology is important for reading development across languages, including signed languages.

There is wide agreement that deficits in phonological awareness contribute to reading impairments (Wagner & Torgesen, 1987; Wolf & Bowers, 1999). However, there is also extensive evidence that children with reading impairments show deficits not limited to phonological awareness (Wolf & Bowers, 1999). Minimally, the processes contributing to successful reading include: (a) attention to visual letters and visual processes involved in feature detection and letter–pattern identification, (b) the integration of this visual information with orthographic representations, (c) integration of orthographic representations with phonological representations, and (d) activation of semantic and lexical information (Wolf & Bowers, 1999). Theoretically, and practically, any of these reading processes can serve as the basis for reading impairments. Difficulties at the single word level in assembling the phonological code, referred to as developmental dyslexia (Liberman, Shankweiler, & Liberman, 1989), as well as difficulties at both the word and text (i.e., comprehension) levels contribute to reading impairments.

Semantics and Reading

Although phonology has a crucial role in reading development, skilled reading is also predicted by other linguistic factors, such as vocabulary and semantic knowledge (Tannenbaum, Torgesen, & Wagner, 2006), syntactic knowledge (Cooper & Stewart, 1987), cognitive factors, such as phonological working memory (Alloway, Gathercole, Willis, & Adams, 2004), and social factors. Skilled readers must recognize words rapidly and accurately, thus skilled reading involves more than decoding based on grapheme to phoneme correspondence. Strong vocabulary knowledge is related to reading mastery (Anderson & Freebody, 1983; Berends & Reitsma, 2006). Familiarity with words may permit the child to bypass the phonological route while reading and accessing the lexical entry directly from print recognition. Thus, semantic knowledge is an important link between decoding a word and reading comprehension. For example, Berends and Reitsma (2006) observed that practice with printed words, with specific instructions focusing on the semantic characteristics of the word, promotes reading acquisition. Moreover, the size of a child's vocabulary is related to the ability to understand printed words (Proctor, August, Carlo, & Snow, 2006).

Maturational Indices of Phonology and Semantics in Reading

The relative importance of phonology and semantics for reading changes throughout development. Phonological awareness is predictive of reading ability in the beginning stages of reading (Badian, 2001). Beginning readers rely on a mapping between the sound and letter to successfully decode an unfamiliar word by "sounding it out." Thus, phonological awareness is an important *early* reading skill.

Studies indicate that phonological sensitivity is maturationally guided, exhibiting critical developmental changes during the 1st year of life. At birth, all infants possess the capacity to discriminate all the phonemes in all of the world's languages, termed *universal phonetic discrimination*. However, at around 6 months of age, this universal capacity diminishes, and instead, infants find most salient the phonetic contrasts of the language they are exposed to, their native language. By 12–14 months of age, the young infant no longer discriminates non-native phonetic contrasts (Kuhl, 2011; Petitto et al., 2012; Werker, 2012). Children's phonetic sensitivity continues to undergo developmental changes in the first 5 years of life (Coady & Aslin, 2004; Fox & Routh, 1975). Between 2.5 and 3.5 years of age, children show heightened phonological sensitivity (Coady & Aslin, 2004). At this age, children demonstrate higher accuracy in repeating pseudowords that contain higher probability phone transition (i.e., diphones) found in their language (Coady & Aslin, 2004). As children's vocabulary sizes increase over development, so does their phonological sensitivity. Children with higher expressive vocabulary scores perform better on tasks measuring sensitivity to part words (vowel–consonant clusters) as compared with children with comparably smaller vocabularies (Storkel & Hoover, 2010). Fox and Routh (1975) compared phonological awareness among 3- to 7-year-old children using a segmentation task where children were asked to segment syllables into phonemes. Although 3-year-old children were only able to segment about 25% of the syllables correctly, 6- and 7-year-old children showed markedly improved phonological awareness and achieved accuracy scores of 85% (Fox & Routh, 1975). Berninger, Abbott, Nagy, and Carlisle (2010) modeled growth curves in phonological awareness among 241 children between Grades 1 and 6 (corresponding to ages 6 and 12) and observed greatest gains in phonology between the first and third grades. Learning to read also improves phonological awareness (Stanovich, 1986). For example, illiterate adults demonstrate difficulty with initial phoneme deletion (Morais, Cary, Alegria, & Bertelson, 1979), and fourth-grade readers are better at phonemic segmentation of nonsense tasks after learning their orthographic forms (Ehri & Wilce, 1980). These findings indicate not only changes in phonological awareness over the child's development, both as a function of maturation, but also as a function of reading (Berninger et al., 2010; Fox & Routh, 1975; Liberman, Shankweiler, Fischer, & Carter, 1974).

As children become skilled readers, they shift from a greater reliance on phonological decoding to semantic knowledge, which is important for *later* reading skill (Berends & Reitsma, 2006). For example, training in semantics for reading is only beneficial at later stages of reading but not at early stages of reading (Berends & Reitsma, 2006). This tuning in from phonological to semantic processing over the course of reading development corresponds to a shift in the recruitment of brain regions classically associated with aspects of language function (Jasińska & Petitto, 2014; Turkeltaub, Gareau, Flowers, Zeffiro, & Eden, 2003). Younger readers show greater neural activation in brain regions involved in phonological processing at an age when children rely more heavily on phonology for reading and do not yet have refined mapping between phonology and orthography. However, older readers also show greater neural activation in brain regions classically associated with lexical access at an age when children begin to utilize larger grain sizes in processing words, including whole-word units (Jasińska & Petitto, 2014).

Contemporary computational models of reading, known collectively as "triangle models of reading," posit that reading primarily consists of processes distributed over three levels of linguistic representation: orthography, phonology, and semantics (Harm & Seidenberg, 2004). In order to decode a written word and access its corresponding meaning, orthographic networks activate corresponding phonologic and semantic networks. Skilled reading involves both the direct orthography–semantic connections and the orthography–phonology–semantics connections; and although the division of labor among these pathways changes over development, all connections remain crucial to skilled word identification (Harm & Seidenberg, 2004).

Decoding orthographic representations into phonemes (i.e., a phonological route) represents one means of accessing a word's meaning. Another possible route of lexical access would be to directly map orthographic representations onto meaning (i.e., direct route). The direct route of lexical access from print is expected to be faster, as phonological decoding can be bypassed when the orthographic representation directly activates lexical entries. However, phonological decoding is effective when the direct route fails to yield the correct reading of a word, as is the case with novel words for which orthographic representations do not automatically activate known, familiar words stored in the lexicon. Reading by associating the mapping between phonology and orthography or by associating whole words with orthography constitutes *a dual-access model* of reading (Coltheart, 2006).

The mutual roles of phonology and semantics in reading development are implicated in current approaches to children's learning to read and contribute to what has become known as the "great phonics versus whole-word debate" (Hempenstall, 1997). More recently, this debate has honed in on the distinction between decoding versus constructing meaning. Word recognition based on letter to sound decoding, as well as text comprehension are critically important components of skilled reading. Phonics-based approaches to reading programs focus on improving phonological awareness ability as a basis for improving print word recognition. Whole-word approaches focus instead on word-level processing and improvements in vocabulary and comprehension. Both approaches have their merits, controversy continues as to which strategy is optimal and at what times in development this is most true. Most of this debate has been limited to the monolingual child learning to read one language.

Bilingualism

Substantial research indicates bilinguals have a cognitive advantage relative to their monolingual peers, for example, in verbal and nonverbal reasoning (Ben-Zeev, 1977) and cognitive flexibility (Bialystok, 2001). But it is only recently that researchers have provided compelling evidence that there is also a language and reading advantage (Kovelman et al., 2008; Petitto & Holowka, 2002; Petitto et al., 2012; Sebastian-Galles, Albareda-Castellot, Weikum, & Werker, 2012). The advantage in metalinguistic awareness may arise from the young bilingual's early understanding of the arbitrary relation between real-world referents and their linguistic labels. A bilingual child will have two labels for the same object, for example "chat" in French and "cat" in English for the same cat. Exposure to two languages affords the bilingual access to two vocabularies, and overall vocabulary is equivalent or larger than that of a monolingual (Bialystok, 2001; Petitto & Holowka, 2002). Mancilla-Martinez and Vagh (2013) tracked vocabulary development in Spanish–English bilingual toddlers between the ages of 24 and 36 months and found that children's total conceptual vocabulary (in both languages) was a better indicator of vocabulary development over single language vocabulary in either Spanish or English. Moreover, the choice of whether a child's conceptual vocabulary is compared with norms for one language or the other affects how vocabulary differences are interpreted. Their finding supports existing literature on vocabulary development in bilingual children. Mancilla-Martinez and Vagh (2013) did observe vocabulary scores in bilingual children that were below monolingual norms; however, their sample consisted of entirely low-income families, and thus socioeconomic status (SES), rather than bilingualism, is the contributing factor to lower vocabulary scores in their sample. There are still some inconsistencies in the literature specifically concerning differences in vocabulary size. Differences emerge between monolinguals' vocabulary size when compared with bilinguals' vocabulary size in only *one* of their two languages, which can be misleadingly interpreted as a bilingual disadvantage. Yet, when monolinguals and bilinguals are matched for SES, similarities are found when monolinguals' vocabulary size is compared with bilinguals' vocabulary size in *both* of their two languages (Petitto & Holowka, 2002; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013).

Bilingual children show a phonological advantage, which has strong theoretical implications given the pivotal role of phonology in emergent reading. Bilingual school-aged children outperform their monolingual peers on measures of phonological awareness (Eviatar & Ibrahim, 2000; Kovelman et al., 2008). Children educated in bilingual English–Spanish schools from monolingual English-speaking homes outperform children educated in monolingual English schools on a complex phonological awareness task requiring children to break apart a word into individual phonemes (Kovelman et al., 2008). English-speaking children in French immersion language programs were also found to show advantages in linguistic awareness. Bilingual children who were learning French at school were better at phonological tasks as segmenting words into syllables and phonemes (Rubin & Turner, 1989).

This bilingual phonological advantage is apparent early in life (Petitto et al., 2012). Infants demonstrate greater and longer neural sensitivity to universal phonetic distinctions when monolingual infants can no longer make such discriminations. Remarkably, bilinguals' resilient neural sensitivity to universal phonetic distinctions is not at the expense of their sensitivity to phonetic contrasts in their native language (Petitto et al., 2012). Early bilingual exposure may provide a linguistic "perceptual wedge" that extends infants' sensitivity to universal phonetic contrast and may later aid language and reading development in childhood (Petitto et al., 2012).

Early bilingual exposure also has important implications for ultimate dual-language proficiency and competency. Early, simultaneous exposure to two languages from birth results in greater language proficiency (Jasińska & Petitto, 2013; Johnson & Newport, 1989; Kovelman et al., 2008). Behavioral research shows that language attainment levels can be lower with first bilingual AoE as early as the age of 3 as compared to birth (Guion, 2005). Bilinguals who begin learning their new language in adulthood often fail to achieve native-like proficiency levels in aspects of language such as phonology and syntax. Crucially, these specific parts of language knowledge required exposure early in development in order to achieve mastery (Lenneberg, 1967; Petitto, 1997). In contrast, aspects of language such as semantics remain "open for life," with bilinguals and monolingual alike being able to add new vocabulary and semantic knowledge throughout the life span (Johnson & Newport, 1989; Petitto, 1997). This distinction in the acquisition of phonology and semantics, with early exposure being most critical for phonology but less for semantics, may have vital implications for bilingual language acquisition and, in turn, reading. The central question of this study is whether the age of first bilingual exposure yields different and specific predictions for the acquisition of specific parts of language, such as phonological and semantic knowledge.

We tested the hypothesis that bilingual exposure can impact phonological awareness and semantic knowledge, and change how these aspects of language contribute to reading development. Building on existing evidence indicating phonological processing is influenced (and indeed appears advantaged) by bilingual experience in early life, we predict phonology to have a more significant contribution over semantics to reading mastery for bilingual children as compared to their monolingual peers. This prediction should only hold true for the early exposed bilingual but not for the later exposed bilingual. That is, phonological awareness skills are predicted to have the strongest contribution to reading for early exposed bilinguals given the pivotal role of early language exposure for phonological development. Should early exposed bilinguals, later exposed bilinguals, and monolinguals differentially rely on phonology and semantics for reading, this would provide new evidence of how optimal learning contexts may be established based on the child's language background.

Method

Participants

Four hundred and twenty-one children in Grades 1–4 took part in the study between 2009 and 2011 (Grade 1: ages 6–7, Grade 2: ages 7–8, Grade 3: ages 8–9, Grade 4: ages 9–10). Four groups of participants were formed based on their language exposure at home and at school (see Table 1).

Group I: *English monolinguals*. English is the only language used at home and the primary language of school instruction.

Group II: *Early bilinguals*. II-a English and French used in the home before age 3; French is the primary language of school instruction. II-b English and another language are used in the home before age 3; English is the primary language of school instruction.

Group III: *Late French bilinguals*. English is the only language used at home. French exposure is in school between ages 4 and 6. French is the primary language of school instruction.

Group IV: *Late English bilinguals*. Other non-English language used at home before age 3. English exposure in school between ages 4 and 6. English is the primary language of school instruction. As a specific design feature of this study, other languages included Spanish, Tamil, Arabic, Hungarian, Urdu, and Chinese, and reflect the diverse immigrant population of Toronto, Canada. In including this diverse sample, we could compare monolinguals with bilinguals across different languages beyond one language pairing.

Fourteen schools in the Greater Toronto Area took part in the study. Three schools provided a 50/50 English–French program and the remaining 11 schools provided a monolingual English program (see Table 2). However, students in English monolingual schools had some exposure to French. All Ontario elementary schools have some level of mandatory French instruction. Three programs varying in the amount of French instruction are offered: (a) French as a second language, *Core French* program, where students accumulate a minimum of 600 hr of French language instruction during Grades 4–8, and English is the language of instruction for all other subjects; (b) *Extended French* program where French must be the language of instruction for a minimum of 25% of the total instruction time during Grades 4–8; and (c) *French Immersion* program where French must be the language of instruction for a minimum of 50% of the total instruction time during Grades 1–8 (Ontario Ministry of Education, 2013). It is important to note that although we have a group of monolingual children in this study, they may have had some minimal exposure to French through the "Core French" program in Ontario. However, the "Core French" program does not begin until the fourth grade, thus only our fourth-grade monolingual participants would have had exposure to French as a second language.

Table 1
Participant Demographics

Group	Language at home	School	Age of English exposure	Age of French exposure	Age of other language exposure	*N*	Grade 1	2	3	4	Age (*M*)
Monolinguals	English	Monolingual	Birth	NA	NA	196	17	87	74	18	8;0
Early bilingual–French	English and French	Bilingual	Birth	Birth	NA	33	1	7	15	10	8;8
Early bilingual–other	English and other	Monolingual	Birth	NA	Birth	106	17	36	35	18	8;1
Late French bilingual	English	Bilingual	Birth	4–6	NA	77	1	42	25	9	7;7
Late English bilingual	Other	Monolingual	4–6	NA	Birth	31	4	8	10	9	8;4

Note NA refers to not applicable values.

Table 2
School Demographics

Elementary school	Income score	Education score	Unemployment score	EQAO reading	EQAO writing	Fraser Institute score	% of ESL students	Average SES score
1	1	2.5	2	N/A	N/A	N/A	N/A	1.8
2	2	2.4	3	2.4	2.7	6.3	14.30	2.5
3	2	2.6	3	2.9	3.2	6.6	4.10	2.5
4	2	3.0	3	2.9	3	7.1	12.50	2.7
5	3	2.7	4	2.8	2.9	8.1	0	3.2
6	2	2.6	1	2.4	2.8	6.5	1.60	1.9
7	2	2.8	4	2.9	2.9	7.6	3.30	2.9
8	4	2.4	4	2.6	2.8	6.1	2.30	3.5
9	3	2.4	4	2.7	2.9	6.3	0	3.1
10	2	2.4	4	2.7	3.1	7.7	0	2.8
11	2	2.5	3	N/A	N/A	N/A	N/A	2.5
12	2	2.9	4	2.8	2.9	7.6	3.10	3.0
13	2	2.9	4	2.9	2.9	6.6	21.20	3.0
14	2	2.5	3	N/A	N/A	N/A	N/A	2.5

Note. Community-level indicators of socioeconomic status (SES) are provided as income, education, and unemployment scores, and averaged to a composite SES score. Education Quality and Accountability Office (EQAO) test scores and Fraser Institute scores (Canada) are provided as school quality metrics. ESL: English as a second language.

In order to equate all participants along socioeconomic and academic differences between schools, we collected measures of SES and school performance for each school and controlled for these variables in our analysis (see Analysis below). Each school's academic ranking, the Fraser Institute's School Report Card, as well as each school's average performance on Ontario standardized Grade 3 reading and writing tests were included in our analysis. SES was calculated for each elementary school that participated in the study. Multiple community-level factors were incorporated into a composite SES score (Bornstein & Bradley, 2003), whereby several factors pertinent to their participant base were collected and weighed. Area-based measures of SES have been used when individual SES measures (family income, education, etc.) are not readily available or consistently reported. Variability in individual-level SES measures within area is the chief limitation of a community-based metric. However, community-based metrics reflect living circumstances that are not captured by individual-level data. Many of the families participating in the present study did not supply income and education information (through take-home questionnaires), therefore, in lieu of this information, we used a community-based SES score.

Each individual school's SES score ranged on a scale from 1 through 4 and was comprised of three widely used variables in the calculations of SES: average family income, unemployment rate, and educational attainment of each school's community (Statistics Canada, 2006a, 2006b, 2006c). Schools received a family income score of 1 through 4 if average family income was under $30,000, between $30,000 and $70,000, between $70,000 and $110,000, or above $110,000, respectively. Schools received an unemployment score of 1 through 4 if unemployment rates were 9% and above, between 8% and 9%, between 7% and 8%, and between 6% and 7%, respectively. Schools also received an education attainment score. Educational attainment was divided into five categories: a score of 1 was given to those who had no high school certificates, 2 for high school certificates, 2½ for apprenticeships, 3 for college diplomas, and 4 for university degrees. Scores were multiplied by the respective percentage of the community population at each education level to attain a final value. Each school's final SES score was calculated as an average of their family income, unemployment, and educational attainment scores (see Table 2).

Schools were located in diverse multicultural communities of Toronto and surrounding suburbs (Town of Markham and Peel Region, Greater Toronto Area), which is a characteristic of the City of Toronto—140 languages are spoken in the city, over 200 distinct ethnic groups, half of the city's population of 2.79 million residents (5.5 million residents in the Greater Toronto Area) was born outside of Canada, and 47% of residents report themselves as part of a visible minority (City of Toronto, 2016).

Language Background Screening

Parents filled in a version of the standardized, published, and previously validated Bilingual Language Background and Use Questionnaire (see Jasińska & Petitto, 2013, 2014; Kovelman et al., 2008 for more details on this extensive bilingual language questionnaire). Participants were as follows: Group I, monolinguals; Group II-a, early exposed English–French bilinguals; Group II-b, early exposed English–Other language bilinguals; Group III, later exposed French bilinguals; and Group IV, later exposed English bilinguals, based on the languages used in the home and at school, and the age of first exposure to each of their two languages.

Tasks

All participants completed three phonological awareness tasks (initial and final phoneme deletion and phoneme segmentation), three semantic tasks (passage comprehension, synonym and antonym generation), three reading tasks (regular, irregular, and pseudoword), and one language competence and expressive proficiency task (LCEP). English–French bilingual participants also completed the French language version of the same tasks.

Phonological Awareness Tasks

The initial and final phoneme deletion tasks consist of 10 items each where participants are asked to say the word that remains after the initial or final phoneme has been removed (e.g., "cat" without the /k/ = "at," or "seat" without /t/ = "sea"). The phoneme segmentation task consisted of 22 standardized Yopp–Singer items and matched standardized French items (Yopp, 1995). Participants are asked to articulate each phoneme in a word (e.g., "dog" = /d/ /o/ /g/). Both tasks reliably measure children's phonological awareness and are strong predictors of reading skill (Holowka, Brosseau-Lapré, & Petitto, 2002; Ziegler & Goswami, 2005).

Semantic Knowledge Tasks

Semantic knowledge tasks were chosen from the standardized Woodcock Language Proficiency Battery–Revised (Woodcock, McGrew, & Mather, 2001) and have been previously used to measure language and reading development in bilingual populations (Kovelman et al., 2008). The passage comprehension task measures children's ability to understand text by supplying a missing word in a sentence. The synonym and antonym generation task measures children's reading vocabulary by supplying a synonym or antonym to a printed word (e.g., small–tiny, right–wrong).

Reading Tasks

Reading tasks were also chosen from the standardized Woodcock Language Proficiency Battery–Revised (Woodcock et al., 2001). There were three reading tasks involving regular, irregular, and pseudowords. The regular and irregular reading tasks consisted of 10 items each, which measure children's ability to read words with shallow orthography, that is, one to one grapheme to phoneme correspondence (e.g., "stop"), and deep orthography, or not a one to one grapheme to phoneme correspondence (e.g., "jewel"). The pseudoword reading task consisted of 30 items that measured children's ability to apply grapheme to phoneme correspondence rules to unfamiliar and nonexistent words. The three word types differentially engage letter to sound decoding processes and the accessing of semantic content, and thus provide a measure of children's phonological abilities.

Language Task

Children's language proficiency was assessed using a standardized LCEP (Senghas & Kegl, 1994). A subset of children completed this language task (n = 58). The task assesses language competence, language expression (production and performance), and proficiency using a fun 90-s cartoon depicting a series of events that the participant is instructed to watch and then describe to the experimenter (see Figure 1). This task has been successfully used to assess language proficiency in six different languages: English, French, Spanish, American Sign Language, Langue des Signes Quebecoise, and Nicaraguan Sign Language (Petitto & Kovelman, 2003).

Procedure

English–French bilingual participants completed two 30-min testing sessions (in English, and in French). Monolingual participants and bilingual participants who did not speak French completed one testing session. Taken together, each testing session consisted of (a) initial phoneme deletion, (b) final phoneme deletion, (c) phoneme segmentation, (d) regular word reading, (e) irregular word

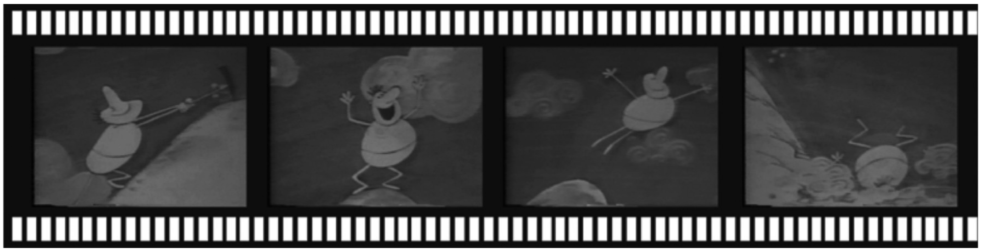

Figure 1. Expressive language task. Screen shots from a 90-s cartoon viewed by all participants.

reading, (f) pseudoword word reading, (g) passage comprehension, (h) synonym generation, (i) antonym generation tasks, which were presented in the same order for each participant, and (j) the LCEP was completed by a subset of the participants in English only. Native English speakers administered English sessions and native French speakers administered French sessions. All sessions were videotaped for data transcription and/or coding, analysis, and reliability checks.

Data Transcription, Coding, and Analyses

Phonological Awareness and Reading Tasks

The testing experimenters coded the children's responses for phonological awareness tasks and reading tasks during the testing session. Twenty percent of the sessions were also verified posttesting from the video recording by a coder other than the one who conducted the session with the child. The coder was a native speaker of the language of the session.

Language Competence and Expressive Proficiency Task

Children's videotaped narratives, describing the events of a 90-s cartoon, were transcribed by a native English speaker using the Codes for the Human Analysis of Transcripts format. The narrative transcripts were analyzed using computerized language analysis program (MacWhinney, 2000). For each narrative, the number of linguistic utterances produced by the child (phrases, clauses, or sentences) and their grammaticality (correct/incorrect phonological, semantic, and morphosyntactic) were coded (see Kovelman et al., 2008 for a detailed discussion of this task). To assess intercoder reliability for the children's narrative portion of this study, three trained coders transcribed and coded 30% of the videotaped interactions between participants and experimenters in English. The videotapes of the children's narratives were transcribed and coded independently of each coder. Cronbach's coefficient alpha (Cronbach, 1951) was used to measure the internal consistency across the coders' transcriptions and codes. Cronbach's alpha was calculated for the total number of words and number of different words for each transcription of the narratives produced by children as part of the LCEP task, as well as the total number of correct and erroneous utterances in the transcript. The Cronbach's alpha for the total number of words, the number of different words, and the total number of correct and erroneous utterances was .98, indicating high agreement among all coders and transcription reliability.

Results

English Tasks

We began by asking whether bilingual exposure and the age of first bilingual exposure can impact children's phonological awareness, semantic knowledge, reading and language performance in English. To answer this question, we compared the task performance of Groups I–IV. We performed a 4 (Groups I–IV, between-subject factor) × 4 (Grades 1–4, between-subject factor) × 9 (3 phonological awareness, 3 semantic knowledge, 3 reading tasks; multivariate dependent variables) multivariate analysis of covariance (MANCOVA) while covarying out the effects of SES, Wilk's lambda $F(9, 436) = .980$, $p > .05$, and school quality score, Wilk's lambda $F(9, 436) = .836$, $p < .01$. Group, Wilk's lambda $F(27, 436) = .836$, $p < .001$ (see Table 3 for participants' scores), and grade, Wilk's lambda $F(27, 436) = .643$, $p < .001$, were significant predictors of task performance (see Figure 2). We observed a significant interaction between group and grade, Wilk's lambda $F(72, 436) = .733$, $p < .001$. Significant MANCOVA results are followed by univariate analyses of variance (ANOVAs) for effects of group and grade for each dependent variable, with pairwise comparisons between all levels of grade and group with Bonferroni correction for multiple comparisons.

Table 3
Participant Mean Scores and Standard Deviations on English and French Language and Reading Tasks

Language	Group	Grade	Initial phoneme deletion	Final phoneme deletion	Phoneme segmentation	Pseudoword reading	Regular word reading	Irregular word reading	Passage comprehension	Synonym generation	Antonym generation	Incorrect: Correct events ratio	Language # events
English	Monolinguals	1	8.4 (0.3)	7.1 (0.5)	17.3 (1.1)	14.4 (1.6)	7.6 (0.4)	4.1 (0.6)	10 (0.8)	4.1 (0.6)	8.9 (0.7)	0.4:1 (0.4)	4.7 (6.7)
		2	9.5 (0.1)	8.6 (0.2)	16.1 (0.5)	17 (0.7)	8.8 (0.2)	5.5 (0.3)	11.5 (0.4)	4.9 (0.3)	9.9 (0.3)	0.2:1 (0.1)	13.7 (2.4)
		3	9.6 (0.2)	9 (0.3)	15.4 (0.5)	19.3 (0.8)	9.2 (0.2)	7.3 (0.3)	13.8 (0.4)	6.5 (0.3)	11.4 (0.3)	0.1:1 (0.1)	13.3 (2)
		4	9.2 (0.3)	7.8 (0.5)	15.1 (1)	20.2 (1.6)	9.4 (0.4)	8 (0.6)	14.7 (0.8)	7.8 (0.6)	11.9 (0.7)	0.2:1 (0.2)	17.8 (3.2)
	Early	2	9.5 (0.2)	9 (0.3)	16.1 (0.7)	16.1 (1.1)	8.8 (0.3)	5 (0.4)	13 (0.6)	5.9 (0.4)	10.3 (0.5)	0:1 (0.2)	17.9 (3.7)
	bilinguals	3	10 (0.3)	9.7 (0.4)	16.9 (0.9)	22 (1.3)	9.6 (0.3)	7 (0.5)	15.1 (0.7)	6.2 (0.5)	11.8 (0.6)	0.3:1 (0.2)	7.9 (3.7)
		4	9.7 (0.7)	9.4 (1.1)	18.4 (2.2)	29 (3.3)	7.9 (0.8)	8.3 (1.3)	17.1 (1.7)	10 (1.2)	13.4 (1.5)	0:1 (0)	0 (0)
	Late French	1	9.3 (0.3)	9.1 (0.5)	19.7 (1.1)	16.6 (1.6)	8.6 (0.4)	4.2 (0.6)	10.3 (0.8)	3.7 (0.6)	8.4 (0.7)	0.5:1 (0.2)	11.2 (2.8)
	bilinguals	2	9.6 (0.2)	9.1 (0.3)	16.6 (0.7)	18.1 (1)	9.1 (0.3)	6.3 (0.4)	13.1 (0.5)	5.1 (0.4)	10.9 (0.5)	0.6:1 (0.2)	13.5 (2.9)
		3	9.7 (0.2)	8.8 (0.3)	17.1 (0.6)	19.7 (0.9)	9.1 (0.2)	6.7 (0.4)	14 (0.5)	7 (0.3)	12.1 (0.4)	0.1:1 (0.2)	21.6 (4.1)
		4	9.9 (0.3)	9.6 (0.4)	17.8 (0.8)	26.1 (1.2)	9.9 (0.3)	8.7 (0.5)	16.3 (0.7)	10 (0.5)	14.4 (0.6)	0.2:1 (0.2)	23 (3.3)
	Late English	1	8.8 (0.7)	3.6 (1.1)	17.7 (2.2)	10.9 (3.3)	8.3 (0.8)	3.7 (1.3)	6.7 (1.7)	2.4 (1.2)	6.7 (1.5)	2.8:1 (0.3)	16.2 (4.9)
	bilinguals	2	7.3 (0.5)	5.9 (0.8)	12 (1.6)	13.6 (2.3)	8.8 (0.6)	4.9 (0.9)	10 (1.2)	3.4 (0.9)	7.7 (1)	0.8:1 (0.3)	10.4 (4.6)
		3	9.6 (0.4)	8.6 (0.7)	14.1 (1.4)	16.7 (2.1)	8.5 (0.5)	6.3 (0.8)	12 (1.1)	4.8 (0.8)	9.5 (0.9)	1:1 (0.2)	21.7 (3.9)
		4	9.9 (0.5)	9.2 (0.7)	16.7 (1.5)	22.2 (2.2)	9.8 (0.6)	7.8 (0.9)	14.7 (1.2)	8.4 (0.8)	13.9 (1)	5.3:1 (0.4)	25.7 (6.7)
French	Early French	2	9.4 (0.5)	8.7 (0.7)	17.9 (15)	14.9 (2.1)	7.4 (0.8)	2.2 (0.9)	8.1 (1.6)	3.2 (1.4)	2.7 (1.4)	N/A	N/A
	bilinguals	3	9.2 (0.4)	9.2 (0.5)	15 (1.5)	15.7 (1.5)	7.4 (0.6)	4.1 (0.6)	10.1 (1.2)	4.4 (1)	6 (1.1)	N/A	N/A
	Late French	2	8.8 (0.2)	8.4 (0.3)	16.3 (0.8)	12.9 (0.9)	7.3 (0.3)	2.7 (0.4)	7.7 (0.7)	1.7 (0.6)	2.2 (0.6)	N/A	N/A
	bilinguals	3	9.4 (0.3)	9.3 (0.4)	14.3 (1.2)	17.6 (1.2)	9 (0.5)	5.1 (0.5)	10.6 (0.9)	2.2 (0.8)	4.8 (0.8)	N/A	N/A

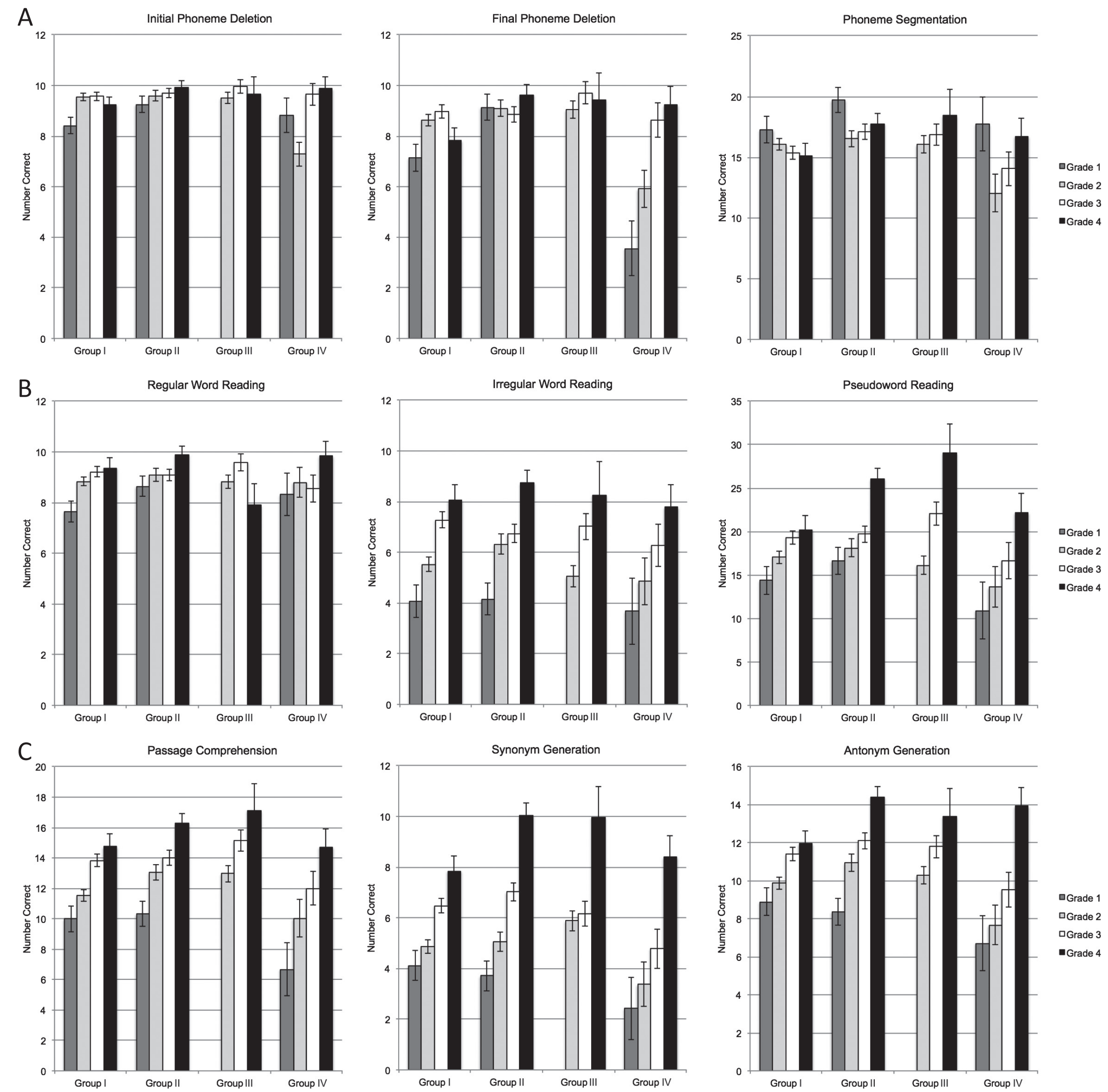

Figure 2. Participants' scores on (A) phonological awareness, (B) semantic, and (C) reading tasks by group and grade.

For the subset of participants who also completed the expressive language task, we performed a 4 (Groups I–IV, between-subject factor) × 4 (Grades 1–4, between-subject factor) × 2 (incorrect:-correct event ratio, number of total events, multivariate dependent variables) MANCOVA with covariates as SES, Wilk's lambda $F(2, 41) = .946$, $p > .05$, and school quality score, Wilk's lambda $F(2, 41) = .925$, $p > .05$. Group, Wilk's lambda $F(6, 82) = .170$, $p < .001$ (see Table 3 for participants' scores), and grade, Wilk's lambda $F(6, 82) = .299$, $p < .001$, were significant predictors of task performance. We observed a significant interaction between group and grade, Wilk's lambda $F(14, 82) = .205$, $p < .001$. Significant MANCOVA results are followed by univariate ANOVAs for effects of group and grade for each dependent variable, with pairwise comparisons between all levels of grade and group with Bonferroni correction for multiple comparisons.

To note in our analyses, we combined early exposed French–English children and early exposed

Table 4
Main Effects of Grade, Group, and Grade × Group Interaction on English Tasks

English tasks		Grade			Group			Grade × Group		
		F	p	Effect size	F	p	Effect size	F	p	Effect size
Phonology	Initial phoneme deletion	$F(3, 420) = 6.42$	$< .001$	.044	$F(3, 420) = 3.722$	.012	.026	$F(8, 420) = 2.715$	.006	.049
	Final phoneme deletion	$F(3, 420) = 9.714$	$< .001$	.065	$F(3, 420) = 12.202$	$< .001$	.08	$F(8, 420) = 3.764$	$< .001$	.067
	Phoneme segmentation	$F(3, 420) = 3.812$	.01	.065	$F(3, 420) = 4.712$	.003	.08	$F(8, 420) = 1.013$	.426	.019
Semantics	Passage comprehension	$F(3, 420) = 22.484$	$< .001$	.11	$F(3, 420) = 8.255$	$< .001$	.049	$F(8, 420) = 0.558$	.812	.011
	Synonym generation	$F(3, 420) = 33.866$	$< .001$	.017	$F(3, 420) = 6.499$	$< .001$	.009	$F(8, 420) = 1.529$	.145	.028
	Antonym generation	$F(3, 420) = 21.571$	$< .001$	.017	$F(3, 420) = 5.182$	.002	.009	$F(8, 420) = 1.399$	.195	.026
Reading	Pseudoword reading	$F(3, 420) = 17.366$	$< .001$	.027	$F(3, 420) = 7.185$	$< .001$	.033	$F(8, 420) = 1.605$	.121	.03
	Regular word reading	$F(3, 420) = 2.38$	.069	.027	$F(3, 420) = 1.331$	.264	.033	$F(8, 420) = 1.328$	.228	.025
	Irregular word reading	$F(3, 420) = 17.359$	$< .001$	.11	$F(3, 420) = 1.127$	.338	.049	$F(8, 420) = 0.669$	.719	.013
Expressive language	Incorrect:Correct event ratio	$F(3, 42) = 29.171$	$< .001$	.676	$F(3, 42) = 61.703$	$< .001$	.815	$F(7, 42) = 17.161$	$< .001$	.741
	Number of events	$F(3, 42) = 3.459$	.025	.198	$F(3, 42) = 2.02$	.126	.126	$F(7, 42) = 1.508$	.191	.201

Note. Effects sizes are reported as partial η^2.

other language–English bilingual children into one group of early exposed bilingual children as there were no significant group differences in language and reading measures (MANCOVA with covariates as SES and school quality score), Wilk's lambda $F(9, 134) = .878$, $p > .05$. Furthermore, one participant who was a first-grade late French bilingual was grouped with second-grade late French bilinguals, and four participants who were first-grade late English bilinguals were grouped with second-grade late English bilinguals (Table 4).

Phonological Awareness

Early bilinguals outperformed monolinguals and late English bilinguals in final phoneme deletion (see Table 5), suggesting a role for the age of first bilingual language exposure (AoE) as a predictor of language mastery and corroborating earlier results suggesting that bilingual children are generally language advantaged as compared with monolingual peers (Kovelman et al., 2008). Late French bilinguals outperformed late English bilinguals in final phoneme deletion (see Table 5). Interactions between group and grade revealed first-grade early bilinguals outperform late English bilinguals in final phoneme deletion (see Table 5 and Figure 2). Second-grade early bilinguals, late French bilinguals, and monolinguals outperformed late English bilinguals in the initial and final phoneme deletion (see Table 5 for all pairwise comparisons, and Figure 2). However, there were no significant group differences among third- and fourth-grade children (see Figure 2).

Semantic Knowledge

Early bilinguals outperformed late English bilinguals in passage comprehension, synonym generation, and antonym generation (see Table 5). Late French bilinguals outperformed monolinguals in passage comprehension and outperformed late English bilinguals in passage comprehension and synonym generation (see Table 5). There were no significant group differences among first-, third-, and fourth-grade children. Interactions between group and grade revealed second-grade early bilinguals outperformed late English bilinguals in antonym generation (see Table 5 and Figure 2).

Reading

Early bilinguals and late French bilinguals outperformed monolinguals and late English bilinguals in pseudoword reading (see Table 5). Interactions

Table 5

Main Effect of Group at Each Grade (and Collapsed Across Grades)

	Test	F	p	Effect size	Monolingual versus later exposed French bilingual	Monolingual versus early exposed bilingual	Monolingual versus later exposed English bilingual	Early exposed bilingual versus later exposed French bilingual	Later exposed French bilingual versus later exposed English bilingual	Early exposed bilingual versus later exposed English bilingual
Grade 1	Final phoneme deletion	$F(2, 34) = 6.728$	.003	.049	N/A	$t(33) = -2.21$, $p > .05$	$t(19) = 1.909$, $p > .05$	N/A	N/A	**$t(20) = 3.46$, $p = .004$**
	Initial phoneme deletion	$F(3, 174) = 6.143$	.001	.096	$t(127) = 0.074$, $p > .05$	$t(130) = -0.076$, $p > .05$	**$t(93) = 4.138$, $p < .001$**	$t(83) = -0.131$, $p > .05$	**$t(48) = 3.991$, $p < .001$**	**$t(49) = 4.055$, $p < .001$**
	Final phoneme deletion	$F(3, 174) = 5.739$	.001	.09	$t(127) = -0.757$, $p > .05$	$t(130) = -1.101$, $p > .05$	**$t(93) = 3.551$, $p = .003$**	$t(83) = -0.203$, $p > .05$	**$t(48) = 3.883$, $p < .001$**	**$t(49) = 3.984$, $p < .001$**
Grade 2	Phoneme segmentation	$F(3, 174) = 2.309$	.078	.09	$t(127) = -0.122$, $p > .05$	$1(130) = -0.76$, $p > .05$	$t(93) = 2.305$, $p > .05$	$t(83) = -0.509$, $p > .05$	$t(48) = 2.315$, $p > .05$	$t(49) = 2.611$, $p > .05$
	Passage comprehension	$F(3, 174) = 3.856$	.011	.016	$t(127) = -2.167$, $p > .05$	$t(130) = -2.387$, $p > .05$	$t(93) = 1.167$, $p > .05$	$t(83) = 0.052$, $p > .05$	$t(48) = 2.353$, $p > .05$	$t(49) = 2.31$, $p > .05$
	Synonym generation	$F(3, 174) = 3.344$	.021	.004	$t(127) = -1.845$, $p > .05$	$t(130) = -0.4$, $p > .05$	$t(93) = 2.052$, $p > .05$	$t(83) = 1.383$, $p > .05$	**$t(48) = 3.032$, $p = .017$**	$t(49) = 2.186$, $p > .05$
	Antonym generation	$F(3, 174) = 5.145$	.002	.004	$t(127) = -0.703$, $p > .05$	$1(130) = -2.23$, $p > .05$	**$t(93) = 2.699$, $p = .046$**	$t(83) = -1.18$, $p > .05$	**$t(48) = 3.024$, $p = .017$**	**$t(49) = 3.72$, $p = .002$**
Grade 3	Phoneme segmentation	$F(3, 153) = 2.51$	.061	.021	$t(97) = -1.39$, $p > .05$	$t(122) = -2.126$, $p > .05$	$t(82) = 0.888$, $p > .05$	$t(73) = -0.207$, $p > .05$	$t(33) = 1.744$, $p > .05$	$t(58) = 2.019$, $p > .05$
	Synonym generation	$F(3, 153) = 2.219$	.088	.019	$t(97) = 0.378$, $p > .05$	$t(122) = -1.185$, $p > .05$	$t(82) = 1.861$, $p > .05$	$t(73) = -1.257$, $p > .05$	$t(33) = 1.471$, $p > .05$	$t(58) = 2.478$, $p > .05$
	Final phoneme deletion	$F(3, 53) = 2.214$	.097	.111	$t(20) = -1.3$, $p > .05$	$t(44) = -2.522$, $p > .05$	$t(25) = -1.105$, $p > .05$	$t(30) = -0.092$, $p > .05$	$t(11) = 0.397$, $p > .05$	$t(35) = 0.775$, $p > .05$
Grade 4	Pseudoword reading	$F(3, 53) = 5.729$	.002	.055	**$t(20) = -2.865$, $p = .036$**	**$t(44) = -3.224$, $p = 0.013$**	$t(25) = -0.303$, $p > .05$	$t(30) = 1.152$, $p > .05$	$t(11) = 2.405$, $p > .05$	$t(35) = 2.285$, $p > .05$
	Regular word reading	$F(3, 53) = 2.266$	.091	.055	$t(20) = 2.162$, $p > .05$	$t(44) = -0.553$, $p > .05$	$t(25) = 0.019$, $p > .05$	$t(30) = -2.601$, $p > .05$	$t(11) = -1.967$, $p > .05$	$t(35) = 0.475$, $p > .05$
	Initial phoneme deletion	$F(3, 420) = 3.722$	.012	.026	$t(265) = -1.854$, $p > .05$	$t(333) = -2.381$, $p > .05$	$t(225) = 0.963$, $p > .05$	$t(208) = 0.325$, $p > .05$	$t(100) = 2.233$, $p > .05$	$t(168) = 2.493$, $p > .05$
	Final phoneme deletion	$F(3, 420) = 12.202$	$< .001$	.08	**$t(265) = -2.783$, $p = .034$**	**$t(333) = -3.599$, $p = .002$**	**$t(225) = 2.797$, $p = .032$**	$t(208) = 0.465$, $p > .05$	**$t(100) = 4.453$, $p < .001$**	**$t(168) = 5.163$, $p < .001$**
	Phoneme segmentation	$F(3, 420) = 4.712$	.003	.08	$t(265) = -1.282$, $p > .05$	**$t(333) = -3.103$, $p = .012$**	$t(225) = 0.835$, $p > .05$	$t(208) = -0.723$, $p > .05$	$t(100) = 1.681$, $p > .05$	**$t(168) = 2.83$, $p = .029$**
	Pseudoword reading	$F(3, 420) = 7.185$	$< .001$	.033	**$t(265) = -3.367$, $p = .005$**	**$t(333) = -2.672$, $p = .047$**	$t(225) = 1.333$, $p > .05$	$t(208) = 1.657$, $p > .05$	**$t(100) = 3.716$, $p < .001$**	**$t(168) = 3.065$, $p = .014$**

Table 5
Continued

	Test	F	p	Effect size	Monolingual versus later exposed French bilingual	Monolingual versus early exposed bilingual	Monolingual versus later exposed English bilingual	Early exposed bilingual versus later exposed French bilingual	Later exposed French bilingual versus later exposed English bilingual	Early exposed bilingual versus later exposed English bilingual
All grades	Regular word reading	$F(3, 420) = 1.331$	.264	.033	$t(265) = -0.026$, $p > .05$	$t(333) = -1.875$, $p > .05$	$t(225) = -0.309$, $p > .05$	$t(208) = -1.188$, $p > .05$	$t(100) = -0.231$, $p > .05$	$t(168) = 0.87$, $p > .05$
	Irregular word reading	$F(3, 420) = 1.127$	.338	.049	$t(265) = -1.004$, $p > .05$	$t(333) = -0.738$, $p > .05$	$t(225) = 1.032$, $p > .05$	$t(208) = 0.532$, $p > .05$	$t(100) = 1.625$, $p > .05$	$t(168) = 1.53$, $p > .05$
	Passage comprehension	$F(3, 420) = 8.255$	< .001	.049	**$t(265) = -3.522$, $p = .003$**	$t(333) = -1.906$, $p > .05$	$t(225) = 2.198$, $p > .05$	$t(208) = 2.309$, $p > .05$	**$t(100) = 4.539$, $p < .001$**	**$t(168) = 3.468$, $p = .003$**
	Synonym generation	$F(3, 420) = 6.499$	< .001	.009	**$t(265) = -2.93$, $p = .021$**	$t(333) = -1.904$, $p > .05$	$t(225) = 2.006$, $p > .05$	$t(208) = 1.719$, $p > .05$	**$t(100) = 3.926$, $p < .001$**	**$t(168) = 3.273$, $p = .007$**
	Antonym generation	$F(3, 420) = 5.182$	.002	.009	$t(265) = -2.111$, $p > .05$	$t(333) = -2.338$, $p > .05$	$t(225) = 1.676$, $p > .05$	$t(208) = 0.608$, $p > .05$	**$t(100) = 3.014$, $p = .016$**	**$t(168) = 3.203$, $p = .009$**

Note. Significant results ($p < .05$) and trends ($p < .1$) are displayed for each grade in bolded font. Bonferroni corrections applied to all pairwise comparisons between each level of group. Effects sizes are reported as partial η^2.

between group and grade revealed fourth-grade late French bilinguals outperformed monolinguals and late English bilinguals in pseudoword reading (see Table 5 and Figure 2). For preliminary interpretation, we note that significant effects were only observed for pseudoword reading but not regular and irregular word reading. Overall performance on regular word reading task was 90% accuracy, suggesting ceiling effects. Irregular words and regularly spelled pseudowords differ in the transparency of mapping between phonology and orthography. Reading regularly spelled words may be more reliant on a predominantly phonological reading route, and bilinguals better performance on phonological awareness tasks may contribute to better pseudoword reading. Bilinguals also have greater experience with novel words (across two languages), which may facilitate reading of pseudowords.

Expressive Language

There was a significant main effect of group and grade (see Table 5). Pairwise comparisons show monolinguals, $t(30) = -12.054$, $p < .001$, early exposed bilinguals, $t(24) = -12.279$, $p < .001$, and later exposed French bilinguals, $t(12) = -10.953$, $p < .001$, outperformed later exposed English bilinguals. Later exposed English bilinguals had the poorest English expressive language scores. Older grades outperformed younger grades on incorrect to correct event ratio—1 vs. 2: $t(26) = 3.981$, $p = .002$; 1 vs. 3: $t(27) = 4.308$, $p < .001$; 1 vs. 4: $t(17) = -2.933$, $p = .032$; 2 vs. 4: $t(27) = -8.187$, $p < .001$; 3 vs. 4: $t(28) = -8.539$, $p < .001$—and on number of events—1 vs. 4: $t(17) = -2.89$, $p = .036$. Expressive language scores improve as children progress from the first to the fourth grade.

French Tasks

We then asked whether the age of first bilingual exposure could impact children's phonological awareness and reading performance in French. To answer this question, we compared task performance in early exposed French–English bilinguals and later exposed French–English bilinguals (Groups II–III). We performed a 2 (Groups II–III between-subject factor) × 2 (Grades 2–3, between-subject factor) × 9 (3 phonological awareness, 3 semantic knowledge, 3 reading tasks; multivariate dependent variables) MANCOVA with covariates as the effects of SES, Wilk's lambda $F(9, 62) = .815$, $p > .05$, and school quality score, Wilk's lambda $F(9, 62) = .850$, $p > .05$. Grade, Wilk's lambda $F(9, 62) = .699$, $p < .01$

(see Table 3 for participants' scores), was a significant predictor of task performance. Third-grade children outperformed second-grade children (irregular word reading; $F = 13.713$, $p < .001$). Group, Wilk's lambda $F(9, 62) = .876$, $p > .05$, was not a significant predictor of task performance. There was also no significant interaction for group and grade for task performance, Wilk's lambda $F(9, 62) = .957$, $p > .05$. Although we did not observe significant group differences in the MANCOVA analysis, we observed greater scores for early versus late French bilinguals for nonsense word reading (early $M = 16.5$, late $M = 15.7$), $F(1, 86) = 4.549$, $p < .05$, and synonym generation (early $M = 5.0$, late $M = 2.2$) $F(1, 86) = 4.881$, $p < .05$. Overall, the trend in the French language data shows better scores for early exposed French bilinguals as compared with later exposed French bilinguals.

Predictors of Reading Skill

Next, we asked whether any relations exist among specific English and French language and reading tasks. Specifically, what variables predict reading skill in English and in French? Before we could examine the predictive relations among these variables, we needed to know their factorial structure. We performed a factor analysis on English tasks and French tasks separately implementing maximum likelihood estimation and varimax rotation. For English tasks, three factors with eigenvalues above 0.9 accounted for 63.6% of the variance and provided a good fit to the data, $\chi^2(12, N = 442) = 28.245$, $p < .01$. The rotated factor loadings indicate regular, irregular, and pseudoword reading and passage comprehension tasks load onto the first factor; synonym and antonym generation and passage comprehension tasks, which indicate vocabulary and semantic knowledge, load onto the second factor; and initial and final phoneme deletion and phoneme segmentation tasks, which indicate phonological awareness, load onto the third factor. For French, three factors with eigenvalues above 1 accounted for 58.1% of variance but did not provide a good fit, $\chi^2(12, N = 97) = 13.933$, $p > .05$.

A hypothesized English-language reading model based on this analysis' resulting factor loadings is presented in Figure 3. Regular, irregular, and pseudoword reading and passage comprehension tasks serve as indicators of reading skill (first factor),

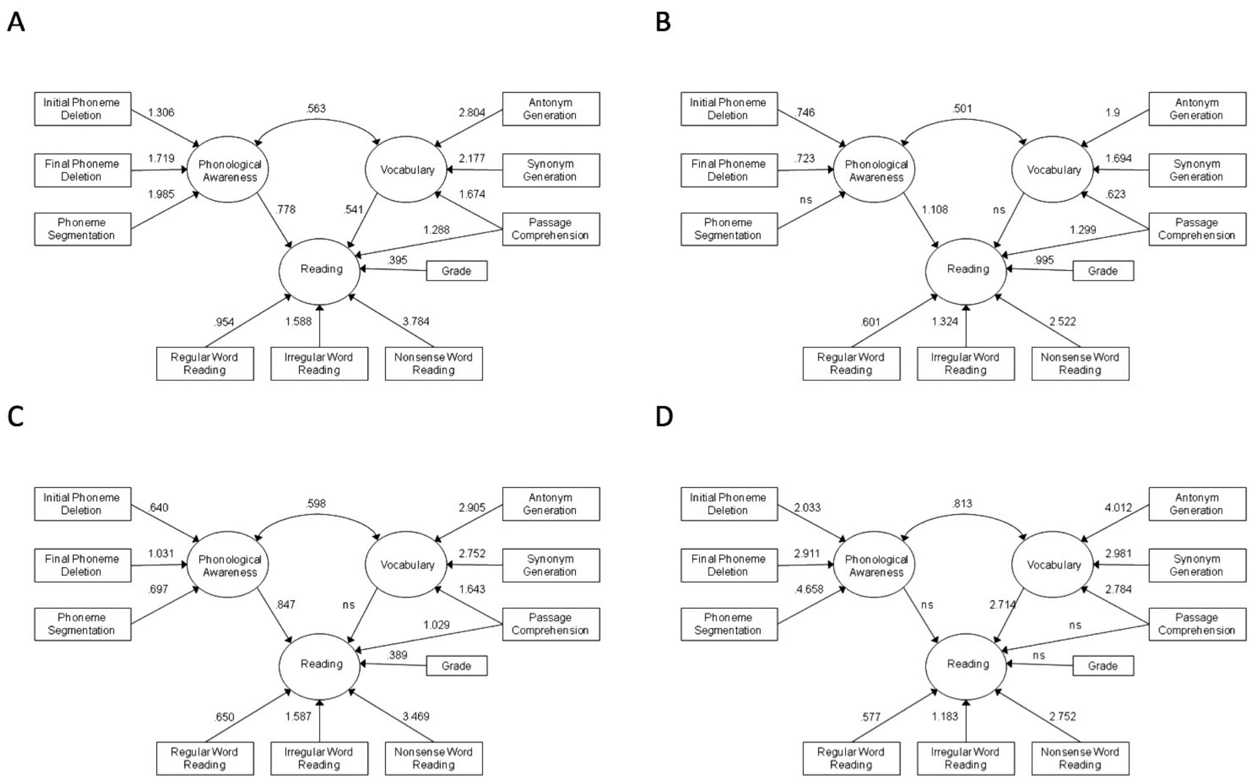

Figure 3. Model of phonological awareness, semantic knowledge, and reading for (A) monolingual participants (Group I), (B) early exposed bilingual participants (Group II), (C) later exposed French bilingual participants (Group III), (D) later exposed English bilingual participants (Group IV).

synonym and antonym generation and passage comprehension tasks serve as indicators of semantic knowledge (second factor), and initial and final phoneme deletion and phoneme segmentation tasks serve as indicators of phonological awareness (third factor), circles represent latent variables and rectangles represent measured variables. Multigroup structural equation modeling (SEM) analyses were performed on Groups I–IV. Maximum likelihood estimation was used to estimate all models. Support for the hypothesized model was found, $\chi^2(124, N = 443) = 398.364$, $p < .001$; comparative fit index = .88. Grade was a significant predictor of reading skill in all groups. Increased reading skill was predicted by greater phonological awareness and semantic knowledge; however, group differences were observed. Monolingual children's reading skill was predicted by phonological awareness (unstandardized coefficient = .778, $p < .001$) and semantic knowledge (unstandardized coefficient = .541, $p < .001$; see Figure 3A). Early exposed bilingual and later exposed French bilingual children's reading skills in English were more robustly predicted by phonological awareness than monolingual children (early exposed bilinguals, unstandardized coefficient = .847, $p < .01$; see Figure 3D; later exposed French bilinguals, unstandardized coefficient = 1.108, $p < .05$; see Figure 3C) but was not predicted by semantic knowledge. We observed a trend in which later exposed English bilingual children's reading skill in English was more robustly predicted by semantic knowledge with approaching significance (unstandardized coefficient = 2.714, $p = .057$; see Figure 3D) but was not predicted by phonological awareness.

Discussion

We asked whether bilingual exposure and the age of bilingual exposure differentially impact knowledge of specific parts of language that are important predictors of reading development. We examined the predictive relation of phonology and semantics with reading across monolingual, early exposed bilingual, later exposed French bilingual, and later exposed English bilingual children during critical ages in reading development.

Bilingualism and Phonology, Semantics, and Reading Development

We began by examining whether bilingual exposure and the age of first bilingual exposure impact children's phonological awareness, semantic knowledge, and reading. Consistent with previous findings indicating that children's later-learned language attainment levels can be lower with later AoE (i.e., age of first bilingual exposure; Johnson & Newport, 1989; Petitto, 1997), we observed lower performance on all English language (including expressive language) and reading measures among later exposed English bilinguals (exposed to another language from birth and English between the ages of 4 and 6) relative to children for whom English was the first language. Importantly, by the time later exposed English bilinguals were in the fourth grade, they demonstrated language and reading scores comparable to the other three groups (monolinguals, early exposed bilinguals and later exposed French bilinguals). The positive implication is that later exposure to a new language in childhood (here, ages 4–6) does not prohibit the child from "catching-up" and becoming a skilled reader in their new language. Moreover, we did observe a similar trend in our French language measures suggesting greater language and reading performance in early exposed French bilinguals as compared with later exposed French bilinguals (specifically nonsense word reading and synonym generation). However, there was no overall significant effect of early versus late French exposure as revealed by a MANCOVA analysis, and although interpretation must be cautionary, this trend corroborates a large body of research demonstrating poorer language performance with later age of exposure (Jasińska & Petitto, 2013; Johnson & Newport, 1989; Kovelman et al., 2008).

Our findings revealed a bilingual advantage in phonological awareness skills that was associated with early bilingual exposure, corroborating previous research (Kovelman et al., 2008). Early exposed bilinguals outperformed monolinguals on measures of phonological awareness. An advantage in phonological awareness may support better reading of words with regular letter to sound mapping, such as the regularly spelled pseudowords in our test battery.

Moreover, we also observed a bilingual advantage among later exposed French bilingual children. Although these children had been exposed to their new language for the first time when they entered a French language program in school, they showed higher performance on measures of semantic knowledge and pseudoword reading in English relative to their monolingual peers who were attending monolingual English schools. Bilingual exposure and the age of first bilingual exposure do indeed impact children's language and reading abilities. These results provide compelling evidence of a language and reading advantage for the bilingual child. Early bilingual exposure supports the best outcomes; these benefits were also available to a later exposed bilingual, in this case, a monolingual English child who begins learning French later in school. Here, the later exposed French bilingual group is still exposed to their new language (French) at a relatively early stage in life. Frequently, the term "later exposed" refers to a bilingual who has acquired their new language in adulthood. Here, we highlight a difference between bilinguals exposed to two languages from birth (early exposed bilinguals) and bilinguals exposed to two languages early in childhood (later exposed bilinguals). Importantly, we found no evidence of a bilingual delay or disadvantage. Bilinguals do not fall behind or even keep par with monolinguals, instead, our data overwhelmingly indicate that bilinguals outperform their monolingual peers.

Age and Phonology, Semantics, and Reading Development

We next examined how children's performance on measures of phonological awareness, semantic knowledge, and reading and expressive language in English changed over a critical developmental period for reading. Here, we compared children in Grades 1 through 4, or between the ages of 6 and 10. Older readers outperformed younger beginner readers on all tasks in English and on semantic and reading tasks in French. Moreover, language and reading scores among monolingual, early exposed bilinguals, later exposed French bilinguals, and later exposed English bilinguals differed between younger beginner readers and older readers in ways that carry significant theoretical implications. Group differences in phonological awareness were most robust among early first- and second-grade readers. Differences in semantic knowledge were most robust in second-grade readers. This observation follows from findings that show the relative importance of phonology and semantics for reading changes throughout development, with phonology being important early (Badian, 2001) and semantic processing important as the child progresses through Grades 2, 3, and beyond.

Contribution of Phonology and Semantics to Reading Development

Next, we asked whether phonology and semantics contribute to reading mastery similarly or differently among our groups. Phonological awareness and semantic knowledge are strong predictors of reading development for all children. Using SEM, we found differences in the relation between these aspects of linguistic knowledge and reading among our groups. Monolingual children's reading skills were predicted by both phonological awareness and semantic knowledge. However, a different pattern emerged for bilingual children. Early exposed bilinguals' and later exposed French bilinguals' reading skills were more robustly predicted by phonological awareness than monolingual children but were not significantly predicted by semantic knowledge. Why is phonology more strongly implicated in bilingual versus monolingual reading development? Early exposed bilingual children showed better performance on measures of phonological awareness relative to monolingual children, their increased phonological skills were the strongest predictor of reading skill, and they outperformed their monolingual peers on reading tasks. The bilingual child has exposure to phonological systems in two languages and must differentiate between those two languages from an early age. This dual-language experience may support the bilingual child's perceptual learning of phonological categories and ability to discriminate phonemes. Indeed, bilingual infants demonstrate greater sensitivity to universal phonetic distinctions when monolingual infants can no longer make such discriminations (Petitto et al., 2012; Werker, 2012).

The dual-language experience afforded to early exposed bilingual children influences reading in ways that are advantageous to the young bilingual child. Similarly, later exposed French bilingual children, who were exposed to English from birth and French between the ages of 4 and 6, demonstrated the same pattern. It is noteworthy that later exposed French bilingual children, who were English monolinguals until beginning a French language program at school, showed greater similarities with early exposed bilingual children instead of monolingual children. Thus, a monolingual English child who begins learning a new language at a later age in school (e.g., later exposed French bilingual) gains benefits in phonological awareness that positively impact reading acquisition in the *first language*. These findings suggest that bilingual exposure, and the age of bilingual exposure, can influence language and reading in *both* of a bilingual's two languages. Following from this, we predict that monolingual children (native speakers of a non-English language in our sample) who are first exposed to English in early childhood would also show reading advantages in their first-exposed language as a function of bilingual exposure.

Later exposed English bilingual children (exposed to another language from birth and English between the ages of 4 and 6) demonstrated a pattern opposite of early exposed bilinguals and later exposed French bilinguals. This group's phonological awareness skills in English were not a significant predictor of reading ability, however, their semantic knowledge in English did predict reading ability. This distinction between phonology and semantics is predicted from the age of language exposure. Early language exposure is more critical for the acquisition of phonology as compared with the acquisition of semantic knowledge or new vocabulary items. Peak proficiency in a language, particularly for phonology and grammatical structure, follows from early exposure in infancy or early childhood. Proficiency in phonological and grammatical structure of a language decline as the age of exposure to a language increases, including in degree of accent, ability to discriminate phonemes, and production and comprehension of morphology and syntax (Newport, 1990). However, the age of language exposure does not affect all aspects of language equally (Newport, 1990). Vocabulary learning and semantic processing continue normally in later exposed individuals. Research demonstrating sensitive periods for the acquisition of phonology and grammar but less so for vocabulary acquisition, indicates that early exposed and later exposed bilinguals differ in the proficiency of their phonological knowledge. This is a potential, but compelling, explanation for why we observed phonology to be a less robust predictor of reading as compared with vocabulary knowledge among later exposed bilingual children. Thus, bilingual children with later exposure to English may ostensibly learn to read by relying more heavily on their knowledge of English vocabulary, instead of phonology. Importantly, the later exposed English bilingual *does* learn to read in English, although the route by which the child will come to master literacy in a new language differs as a function of bilingual exposure and the age of bilingual exposure.

Limitations

Although we provided new information about bilingual children's reading development as a function of age of language exposure, this study is not without limitations. Given the very small francophone population in Toronto, Canada, we did not have access to French monolingual children, and the number of French bilingual children in our study was smaller than our other groups. We would predict that early exposed French bilingual children (exposed to French and another language from birth) would show the same phonological processing advantage in French relative to French monolinguals as we observed among early exposed English bilingual children relative to their monolingual peers in English. Moreover, this advantage should extend to French children who begin learning English in an English language school. We expect a similar pattern of reliance on phonological and semantic knowledge in reading development.

We compared phonological and semantic abilities relative to reading in four groups of children: English monolinguals, early exposed bilinguals (English and French, English and other from birth), later exposed French bilinguals (English from birth, French from ages 4 to 6), and later exposed English bilinguals (other language from birth, English from ages 4 to 6). A limitation of the present study is that these groups are not fully equated on method of classroom instruction. For example, children attending French language immersion schools (early exposed bilinguals) may be receiving language and reading instruction that more heavily favors phonology as compared to peers in largely monolingual English schools. Children who are learning English as second or other language (later exposed English bilinguals) may also be exposed to classroom instruction that more heavily favors vocabulary building. Additional research with carefully controlled classroom variables is therefore necessary in order to understand whether instructional differences exists between groups, and whether they have an effect on language and reading outcomes.

Conclusion

Language experience has important consequences for how a young child learns to read. Specific parts of language knowledge and their contribution to reading mastery are indeed changed as a result of language experience. Our comparison of phonological awareness and semantic knowledge, and their predictive relation with reading development in children varying in the age of bilingual experience, reveals new information about the optimal timing of bilingual exposure in development. Exposure to two languages provides children with specific language advantages that, in turn, provide a literacy advantage. It is important to note that bilingualism remains a complex and diverse phenomenon, as only a subset of all bilinguals have equal and perfect fluency in both of their two languages (see Grosjean, 2010 for discussion of diversity in bilingualism). Here, we observed a group difference between early exposed bilinguals and monolinguals in phonological awareness, as well as a group difference between later exposed French bilinguals and monolinguals in passage comprehension and pseudoword reading. Crucially, the language and literacy advantage afforded through bilingualism is available to children who receive bilingual exposure upon beginning formal schooling in their new language—a finding that has translational applications for education planning and policy. Even the later exposed bilingual child who only first received exposure to English between the ages of 4 and 6 demonstrated remarkable gains in language and literacy acquisition over Grades 1–4, matching the performance of their monolingual peers by the fourth grade.

Our findings also have potential applications for reading in children who may have reading difficulties. The type of reading instruction that is most optimal for a young child will depend on a number of factors such as the child's ability level and presence of any learning disabilities. We found that the age of that bilingual exposure is related to the relative weighting of phonology versus semantics as a predictor of reading. Phonology and semantics, along with other cognitive and linguistic abilities, are strong predictors of reading. Here, we observed that the predictive relation between phonology and reading was greater for an early exposed bilingual, whereas the predictive relation between semantics and reading was greater for a later exposed bilingual. Thus, future research is necessary to investigate whether a young bilingual child for whom English is the first language and the language in which they are learning to read may show more benefit from reading instruction that focuses on phonological awareness and whether, in comparison, a bilingual child learning to read in their later exposed language may gain more benefit from reading instruction that focuses on vocabulary knowledge.

Our findings are relevant for discussion regarding whether literacy instruction ought to be weighted more toward phonics-based approaches focused on improving phonological awareness ability as a basis for improving print word recognition, or weighted more toward whole-word approaches focused instead on word-level processing and improvements in vocabulary and comprehension. For example, our findings suggest that literacy instruction focused on phonological awareness may be more appropriate for early exposed bilingual, but literacy instruction focused on vocabulary building may be more appropriate for later exposed bilinguals. Such a hypothesis needs to be tested in future research. This future research would also address how differences in reading instruction (focused on phonological awareness vs. vocabulary knowledge) between predominantly monolingual or bilingual classrooms impact literacy outcomes. Here, we provide new information about bilingual children's reading development as a function of age of language exposure that has implications for the optimal learning of reading in children with diverse language backgrounds.

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