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Do eye movements reveal differences between monolingual and bilingual children's first-language and second-language reading? A focus on word frequency effects

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ABSTRACT

An extensive body of research has examined reading acquisition and performance in monolingual children. Surprisingly, however, much less is known about reading in bilingual children, who outnumber monolingual children globally. Here, we address this important imbalance in the literature by employing eye movement recordings to examine both global (i.e., text-level) and local (i.e., word-level) aspects of monolingual and bilingual children's reading performance across their first-language (L1) and second-language (L2). We also had a specific focus on lexical accessibility, indexed by word frequency effects. We had three main findings. First, bilingual children displayed reduced global and local L1 reading performance relative to monolingual children, including larger L1 word frequency effects. Second, bilingual children displayed reduced global and local L2 versus L1 reading performance, including larger L2 word frequency effects. Third, both groups of children displayed reduced global and local reading performance relative to adult comparison groups (across their known languages), including larger word frequency effects. Notably, our first finding was not captured by traditional offline measures of reading, such as standardized tests, suggesting that these measures may lack the sensitivity to detect such nuanced between-group differences in reading performance. Taken together, our findings demonstrate that bilingual children's simultaneous exposure to two reading systems

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leads to eye movement reading behavior that differs from that of monolingual children and has important consequences for how lexical information is accessed and integrated in both languages.

Introduction

Reading is arguably one of the most important neurocognitive skills that children learn. Indeed, it is strongly linked to their academic success (e.g., La Paro & Pianta, 2000) and, ultimately, to their economic, occupational, and social success in later years (e.g., Green & Riddell, 2007; Kirsch, Jungeblat, Jenkins, & Kolstad, 2002). Given its centrality to nearly all domains of modern life, it is no surprise that a rich body of literature has investigated the perceptual, oculomotor, cognitive, and linguistic processes implicated in reading through the use of online reading measures, most notably eye-tracking, which offers a direct, naturalistic, and temporally precise measure of these processes (reviewed in Rayner, 1998, 2009; Rayner, Pollatsek, Ashby, & Clifton, 2012; Whitford, Pivneva, & Titone, 2016). In turn, this literature has given rise to several well-formulated computational models that can account for these key reading processes, such as EZ Reader (e.g., Pollatsek, Reichle, & Rayner, 2006; Reichle, Pollatsek, Fisher, & Rayner, 1998) and SWIFT (e.g., Engbert, Nuthmann, Richter, & Kliegl, 2005). Although this work has proved crucial in advancing our knowledge and understanding of reading behavior, its primary focus has been on skilled reading in university-aged young adults. Thus, less is known about reading behavior in children for whom many of these key reading processes are still developing.

The relatively small but growing developmental eye movement reading literature has reported largely quantitative differences in the eye movement record of typically developing children versus young adults (reviewed in Blythe & Joseph, 2011; Frey, 2016; Rayner, 1998, 2009; Rayner et al., 2012; Reichle et al., 2013). These differences include more fixations, longer fixation durations, less skipping, more saccades (both progressive and regressive), and shorter saccade amplitudes in children that, collectively, culminate in slower overall reading rates. Children also show reduced parafoveal processing, including a smaller attentional or perceptual span, which reflects the amount of useful visual information obtained during fixation (e.g., Häikiö, Bertram, & Hyönä, 2010; Häikiö, Bertram, Hyönä, & Niemi, 2009; Rayner, 1986; Sperlich, Meixner, & Laubrock, 2016; Sperlich, Schad, & Laubrock, 2015; Tiffin-Richards & Schroeder, 2015). These differences, however, decrease as children's reading skills improve with age (e.g., Ducrot, Pynte, Ghio, & Lété, 2013; Huestegge, Radach, Corbic, & Huestegge, 2009; Leeuw, Segers, & Verhoeven, 2015; McConkie et al., 1991; Vorstius, Radach, & Lonigan, 2014), with some reports suggesting that their eye movements and perceptual span pattern with those of young adults at approximately 11 or 12 years old (e.g., Blythe & Joseph, 2011; Rayner, 1986; Reichle et al., 2013).

Age differences in the eye movement record likely reflect some combination of children's developing linguistic knowledge and more peripheral visual and oculomotor processes (e.g., Liang, Wang, Yang, & Bai, 2017; Luke, Henderson, & Ferreira, 2015; Mancheva et al., 2015; Reichle et al., 2013). As children's language proficiency (across sublexical, lexical, syntactic, and discourse levels) increases through continued exposure and/or as their oculomotor system further develops, their eye movements likely become more fine-tuned, resulting in adult-like reading behavior. Consistent with this conjecture, recent eye movement reading research has found that children differ from young adults in terms of pragmatic (Joseph et al., 2008) and syntactic (Joseph & Liversedge, 2013) processing, as well as in their sensitivity to key linguistic variables known to affect lexical processing, such as word length and word frequency (reviewed in Blythe & Joseph, 2011; Frey, 2016; Rayner, 1998, 2009; Rayner et al., 2012; Reichle et al., 2013).

With respect to word length, studies have found that both children and young adults fixate longer words more often and for more time than shorter words (e.g., *refrigerator* vs. *stove*). However, these