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The Development of Visual Word Recognition in German Bilinguals

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für Opa

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Summary

The present dissertation investigated the development of visual word recognition in bilingual children at the beginning of initial reading acquisition. The central aim was to contribute to the debate on differences in orthographic processing between bilinguals and monolinguals, expanding the body of existing research by knowledge on bilingual word recognition mechanisms in beginning readers of German. The two main goals were to (1) study differences in the developmental trajectories of reading between first (L1) and second (L2) language speakers, and (2) to investigate the development of orthographic processing mechanisms that are specific to the bilingual word recognition system.

To disentangle developmental effects between dominant and balanced bilinguals, four studies were conducted, of which two focused on children learning to read in German as their L2, and two examined German-English balanced bilinguals learning to read concurrently in both languages. Study 1 investigated performance differences between L1 and L2 speakers in different component processes of reading, while controlling for the impact of linguistic and executive functioning skills. Study 2 zoomed in on the mechanisms of lexical access and compared L1 and L2 speakers' lexical decision performance with regard to the impact of linguistic characteristics throughout elementary school. In study 3, the parallel activation of orthographic as well as semantic representations in both languages of balanced bilingual children was examined by studying the processing of cognates and false friends in German and English. Study 4 investigated the presence of an early language detection mechanism by exploring balanced bilingual children's sensitivity to language-specific nonwords.

With regard to the first goal, findings show that orthographic processing differences between beginning readers in L1 and L2 are surprisingly small. After decomposing the process of reading, results from study 1 revealed that groups only differ in their performance on the text level. This difference, however, was completely accounted for by participants' linguistic skills, which shows that the reading deficits often reported for L2 speakers can be fully explained by their smaller vocabulary size and lower listening comprehension skills. Confirming these results, reaction times and accuracy data from isolated word processing in study 2 suggested that throughout the course of reading development in elementary school there are no quantitative differences in word recognition between L1 and L2 speaking children. Yet, L2 speakers showed to be more sensitive to word length and frequency information than their monolingual peers, which indicates qualitative differences in the mechanisms of lexical access. The fact that these effects persisted after controlling for participants' vocabulary size and reading fluency implies that behavioral data in bilingual versus monolingual children cannot be merely interpreted in terms of variations in language exposure. Consequently, results point to the involvement of a factor unique to the development of lexical access in bilingual beginning readers that has yet to be identified.

Concerning the second goal, results demonstrate that bilingual children differ from bilingual adults in the architecture of their word recognition system. Findings from study 3 revealed a facilitation effect for cognates and a lack thereof for false friends. This demonstrates that in balanced bilingual children orthographic as well as semantic representations are activated in both languages and interact during word recognition already at the beginning of reading development. It further shows that cross-linguistic interference does not depend on the time of bilinguals' experience with print but occurs as a function of language proficiency. In contrast to findings in adults, data from nonword rejection in study 4 showed that bilingual children do not (yet) benefit from language-specific orthographic cues to speed up their recognition process. This points towards a lack of sensitivity to sub-lexical information at the beginning of reading development, suggesting that language detection in the early developmental stages of the bilingual lexicon seems to be completely based on lexical information. Taken together, these findings indicate that the word recognition system in bilingual children is exclusively language-nonselective in nature. This challenges the current view of language membership detection in bilinguals and calls for the need to incorporate a developmental perspective into existing models of bilingual word processing.

In sum, the research presented within this dissertation demonstrates that overall bilingualism neither fosters nor impedes the development of visual word recognition in German. Although there is evidence that monolingual and bilingual beginning readers differ in certain mechanisms of lexical access, they seem to acquire orthographic processing skills in largely the same way. In conclusion, the present findings emphasize that initial reading acquisition is crucial for the development of the word recognition system, regardless of individuals' proficiency in the respective language(s).

Zusammenfassung

Die vorliegende Dissertation untersuchte die Entwicklung visueller Worterkennungsprozesse bei bilingualen Kindern zu Beginn des Erstleseerwerbs. Vor dem Hintergrund des wissenschaftlichen Diskurses über Unterschiede in der orthographischen Verarbeitung zwischen mono- und bilingualen Lesern war es die zentrale Zielsetzung der Arbeit, bestehende Erkenntnisse mit Forschungsergebnissen zu Mechanismen der Worterkennung bei Leseanfängern im Deutschen zu erweitern. Die zwei primären Ziele bestanden darin, (1) Unterschiede in den Entwicklungsverläufen von Leseanfängern mit Deutsch als Erst- (L1) und Zweitsprache (L2) zu beschreiben, und (2) die Entwicklung orthographischer Verarbeitungsmechanismen zu untersuchen, die als spezifisch für das bilinguale Worterkennungssystem gelten.

Mit der Absicht, Entwicklungseffekte in dominant bilingualen und ausbalanciert bilingualen Kindern getrennt voneinander zu untersuchen, wurden insgesamt vier Studien durchgeführt, von denen sich zwei auf Leseanfänger mit Deutsch als L2 konzentrierten, und zwei auf Deutsch-Englisch ausbalanciert bilinguale Kinder, die in beiden Sprachen gleichzeitig lesen lernen. Studie 1 untersuchte Leistungsunterschiede zwischen Kindern mit Deutsch als L1 und L2 auf verschiedenen Prozessebenen des Lesens unter Berücksichtigung des Einflusses linguistischer Fähigkeiten und exekutiver Funktionen. Studie 2 fokussierte auf Mechanismen des lexikalischen Zugriffs und verglich über die gesamte Grundschulspanne hinweg Kinder mit Deutsch als L1 und L2 in ihrer Leistung bei einer lexikalischen Entscheidungsaufgabe im Hinblick auf den Effekt linguistischer Worteigenschaften. In Studie 3 wurde die Verarbeitung von Kognaten und Homographen in Deutsch und Englisch bei ausbalanciert bilingualen Kindern betrachtet, um die parallele Aktivierung von sowohl orthographischen als auch semantischen Repräsentationen in beiden Sprachen zu untersuchen. Studie 4 explorierte die Existenz eines Mechanismus zur frühzeitigen Spracherkennung, indem bilinguale Kinder auf Ihre Sensitivität gegenüber sprachspezifischen Nichtwörtern getestet wurden.

In Bezug auf das erste Ziel der Dissertation zeigen die Ergebnisse, dass Unterschiede in der orthographischen Verarbeitung zwischen Leseanfängern mit Deutsch als L1 und L2 überraschend gering ausfallen. Durch die Dekomposition des Leseprozesses in verschiedene Ebenen konnte in Studie 1 gezeigt werden, dass sich die Gruppen nur in ihrer Leistung auf der Textebene voneinander unterscheiden. Dieser Unterschied war jedoch vollständig auf

Differenzen in den linguistischen Fähigkeiten der Probanden zurückzuführen, was deutlich macht, dass die oft berichteten Defizite im Lesen für Kinder mit Deutsch als L2 durch deren kleineren Wortschatz und geringere Fähigkeiten im Hörverstehen erklärt werden können. Reaktionszeiten und Akkuratheitsdaten für isolierte Wörter aus Studie 2 bestätigten diesen Befund, indem sie zeigten, dass über die gesamte Spanne der Leseentwicklung über die Grundschule hinweg keine quantitativen Unterschiede in der Worterkennung zwischen Kindern mit Deutsch als L1 und L2 erkennbar sind. Bilinguale Kinder wiesen jedoch eine größere Sensitivität gegenüber Wortlängen- und Wortfrequenzinformationen auf, was darauf hindeutet, dass qualitative Unterschiede in Bezug auf lexikalische Zugriffsmechanismen zwischen den Gruppen bestehen. Die Tatsache, dass diese Effekte auch nach Kontrolle von Unterschieden in Wortschatzgröße und Leseflüssigkeit bestehen blieben, zeigt weiterhin, dass behaviorale Daten von bilingualen versus monolingualen Kindern nicht ausschließlich im Rahmen ihrer Differenzen hinsichtlich des kumulativen Gebrauchs der deutschen Sprache interpretiert werden können. Folglich lassen diese Ergebnisse vermuten, dass es einen noch unidentifizierten Faktor gibt, der die Entwicklung des lexikalischen Zugriffs bei bilingualen Leseanfängern messbar beeinflusst.

Bezüglich des zweiten Ziels demonstrieren die vorliegenden Befunde, dass sich bilinguale Kinder von bilingualen Erwachsenen in der Architektur ihres Worterkennungssystems deutlich unterscheiden. Ergebnisse aus Studie 3 zeigten einen Verarbeitungsvorteil für Kognate, der für Homographen jedoch ausblieb. Dies bedeutet, dass bei ausbalanciert bilingualen Kindern sowohl orthographische als auch semantische Repräsentationen in beiden Sprachen aktiviert sind und bereits zu Beginn der Leseentwicklung während des Worterkennungsprozesses interagieren. Die Ergebnisse zeigen weiterhin, dass das Vorkommen sprachübergreifender Interferenzen bei Bilingualen nicht von ihrer Leseerfahrung abhängig ist, sondern von ihren Fähigkeiten in der jeweiligen Sprache. Im Gegensatz zu den Befunden für Erwachsene demonstrieren die Daten zur Nichtworterkennung aus Studie 4, dass bilinguale Kinder (noch) nicht in der Lage sind, sprachspezifische orthographische Hinweise für den Erkennungsprozess effizient zu nutzen. Dies impliziert, dass zu Beginn der Leseentwicklung keine Sensitivität gegenüber sub-lexikalischen Informationen besteht, und dass die Spracherkennung in den frühen Entwicklungsstadien des bilingualen Lexikons ausschließlich auf lexikalischen Informationen basiert. Im Zusammenhang zeigen diese

Ergebnisse, dass das Worterkennungssystem in bilingualen Kindern zunächst unselektiv gegenüber Sprachen operiert. Diese Feststellung stellt die vorherrschende Ansicht zur Erkennung der Sprachzugehörigkeit bei Bilingualen in Frage und fordert die Einbeziehung einer Entwicklungsperspektive in bestehende Modelle zur bilingualen Wortverarbeitung.

Zusammengefasst zeigen die im Rahmen der vorliegenden Dissertation vorgestellten Forschungsergebnisse, dass Bilingualismus weder einen Vor- noch einen Nachteil für die Entwicklung visueller Worterkennungsprozesse im Deutschen darstellt. Obwohl Evidenz dafür vorliegt, dass sich mono- und bilinguale Leseanfänger in gewissen Mechanismen des lexikalischen Zugriffs voneinander unterscheiden, scheinen sie sich im Erwerb orthographischer Verarbeitungsfähigkeiten weitestgehend gleich zu entwickeln. Schlussfolgernd betonen die gewonnenen Erkenntnisse, dass der Prozess des Erstleseerwerbs entscheidend für die Ausbildung des Worterkennungssystems ist, unabhängig vom individuellen Gebrauch der jeweiligen Sprache(n).

Chapter 1

Introduction

1. The notion of bilingualism

Whereas people who are brought up in societies that promote monolingualism as the norm often think that only a few 'special' people are bilingual, in fact, multilingual speakers outnumber monolingual speakers in the world's population (Tucker, 1999). In times of globalization, one in three individuals routinely uses two or more languages every day, and even more people make regular use of a different language at school or at work (Wei, 2000). In a survey conducted by the European Commission in 2006, 56% of all Europeans reported being able to have a conversation in a language other than their mother tongue. According to the American Community Survey, endorsed by the U.S. Census Bureau, in 1980 11% of Americans spoke a language other than English at home, whereas in 2007 it was already 20% (Shin & Kominski, 2010). The increasing awareness of the role of bilingualism in today's society has resulted in a growing body of research, ranging from bilingual education and biculturalism to the specifics of bilingual cognition and neurophysiology. Naturally, the main interest of research on bilinguals is of psycholinguistic nature, concerning areas such as bilingual language acquisition, speech production and written language processing. The present dissertation is located within the research branch of bilingual word recognition, which investigates the ability of a bilingual reader to visually recognize written letter strings. The following chapters will describe research on aspects of reading development in bilingual children, focusing on orthographic processing mechanisms that are specific to the bilingual word recognition system.

When reviewing the literature, to begin with, there is a striking lack of consensus about what bilingualism actually means. For some researchers, an individual needs to have native-like proficiency in both languages to be truly bilingual. Others argue that any knowledge about a second language leads to a certain type of bilingualism. In 1983, Gass and Selinker differentiated between 37 types of bilinguals, which can be analyzed along the dimensions of age, manner of acquisition, proficiency level, domains of language use, self-identification, and attitude. Today, the most common distinctions are made between early and late bilingualism, referring to the age when the second language was acquired, and simultaneous versus sequential bilingualism, describing the manner of language acquisition.

Consensus is that bilingualism is not a one-dimensional variable and that the answer to the question of how to define a bilingual depends on the definition of language proficiency. But at what point of the scale concerning their second language skills do we define individuals as bilingual? As many answers as there are to this question, as many differences in methodology and outcomes can be found across the field of research on bilingualism.

The vast majority of studies on bilingual language processing is conducted with participants who are either fluent speakers of two languages or learners of a second language (L2) who initially developed some level of proficiency in their native tongue (L1). The first group includes individuals who have either learnt both of their languages simultaneously from birth or very early in life, and usually use them equally on a regular basis. As a consequence, they are highly proficient in both languages, and thus referred to as balanced bilinguals. The second group has learnt their L2 later in life and usually uses it (much) less often compared to their L1. Accordingly, individuals are much more proficient in their L1, which is why they are referred to as dominant bilinguals or, simply, L2 learners. The reason why researchers have started to focus on these two groups separately is that given their different characteristics groups differ in the effects ascribed to bilingualism. Given the wealth of studies, therefore, it is of crucial importance to distinguish between different forms of bilingualism when interpreting findings on the impact of speaking two languages. Yet, especially concerning cognitive advantages, findings tend to be generalized across all forms of bilingualism, which is vividly promoted by the mass media. In the following, therefore, effects of bilingualism will be disentangled with regard to the degree of bilingual language proficiency.

2. Advantages and disadvantages of being bilingual

Today's knowledge on the advantages and disadvantages of bilingualism largely aligns with the theories postulated by the Canadian linguist James Cummins in the 1970s. In his Threshold Theory, he claimed that bilinguals need to achieve high levels of proficiency in both languages before bilingualism can promote cognitive development. He postulated a model with two thresholds: in order to overcome the first, bilinguals have to achieve an age-appropriate level in one language, whereas they need to be proficient in both languages to also overcome the second. Cummins claimed that bilingualism on the bottom floor, i.e. in individuals with low levels of proficiency in both languages, is likely to cause negative consequences on cognitive processing. On the middle floor, the effect of bilingualism is neutral, since bilinguals only fluent in one language do not differ from their monolingual peers. It is only on the top floor, i.e. when age-appropriate proficiency in both languages is balanced, that individuals can experience the positive benefits of bilingualism (Cummins, 1976). Cummins also argued for a two-way transfer across languages in the brain, which led him to posit a model of Common Underlying Proficiency (Cummins, 1981). In contrast to the Separate Underlying Proficiency model of bilingualism, which assumes the two languages of a bilingual to operate independently, he postulated that they are not stored separately in the brain but rely on a common source. With his theories Cummins changed the perspective of research on the impact of bilingualism. The bilingual brain was no longer considered to be the sum of two monolingual language systems, but assumed to process information in ways that differ essentially from those of monolinguals. Decades of subsequent research have pointed to a vast spectrum of effects based on the bilingual experience, ranging from a greater level of creativity (Ricciardelli, 1992a) and better understanding of complex instructions (Dakowska, 1993) to a higher density of gray matter (Mechelli et al., 2004) and an enlarged hippocampus (Maguire et al., 2000). Yet, the most salient differences between monolingual and bilingual speakers are found in their cognitive and linguistic skills, which are elaborated in the following.

2.1 Cognitive skills

The probably most influential but at the same time most controversial debate within research on bilingualism concerns the bilingual benefit of enhanced cognitive functioning. Substantial evidence suggests that bilingualism impacts executive skills, which are broadly defined as a set of cognitive control mechanisms that regulate human thought and behavior (Miyake et al., 2000). Typically, studies compare monolinguals and bilinguals on tasks that are superficially simple but include a condition that additionally requires one aspect of executive control, containing the inhibition of prepotent responses (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004), shifting between mental task sets (e.g., Prior & MacWhinney, 2010), and updating of working memory contents (e.g., Bialystok, Craik, & Luk, 2008). The prevailing hypothesis to explain the superior performance of bilinguals over monolinguals at these tasks is that bilinguals have extensive practice in managing multiple language systems. After a vast body of research has demonstrated that the two languages of a bilingual are activated simultaneously (e.g., van Heuven, Dijkstra, & Grainger, 1998; van Hell & Dijkstra, 2002), the constant need for bilinguals to pay attention to the language in use while inhibiting the other is assumed to enhance the development of their cognitive control (Green, 1998). An alternative hypothesis postulates that because of their constant need to adapt to the language of the current interlocutor, bilinguals continuously need to monitor their environment for conflicting information (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). Further attempts to explain the differences in executive skills include a bilingual advantage in shifting between two tasks (Luk, Green, Abutalebi, & Grady, 2012) and an overall cognitive advantage of bilinguals over monolinguals, assuming that the bilingual experience is so profound that it enhances mental flexibility in general (Kroll & Bialystok, 2013).

Notwithstanding ambiguities on the specific locus of the bilingual advantage in executive functioning, the vast amount of evidence led to the view that overall bilingualism yields cognitive performance benefits. Vividly disseminated by the media, bilingualism was reported to cause positive effects throughout the lifespan (e.g., Bialystok et al., 2004), postponing the onset of age-related cognitive decline which even include symptoms of dementia (e.g., Bialystok, Craik, & Freedman, 2007). However, assuming a publication bias favoring the report of significant effects, recent studies have failed to replicate results on the bilingual cognitive advantage (e.g., Duñabeitia et al. 2014; Gathercole et al., 2014; Kirk, Fiala, Scott-Brown, & Kempe, 2014; Paap & Greenberg, 2013). Researchers reviewing the literature have suggested that beneficial results only occur under certain circumstances, i.e. when investigating small sample sizes, comparing extreme ends of the bilingual spectrum like monolinguals without any L2 exposure to highly balanced bilinguals, selecting participants with weaker cognitive powers such as children and elderly adults, not controlling for highly confounding factors like socio-economic status or cultural environment, or choosing tasks too specific to measure overall cognitive ability (Hilchey & Klein, 2011; Paap, Johnson, & Sawi, 2015; von Bastian, Souza, & Gade, 2016). Accordingly, they consider the bilingual advantage to be an artifact generated by task-specific effects that were prematurely interpreted as universal evidence. In conclusion, after decades of research there are two opposing views on whether or not bilingualism affects executive functioning, and while some researchers have turned their backs on the matter (Yong, 2016), others have started to set out a protocol for future investigations of the issue (Paap & Greenberg, 2013). One objective of the present dissertation was to contribute to this ongoing debate by seizing the question whether an effect of bilingualism on executive functioning can also be observed in dominant bilingual children.

2.2 Linguistic skills

With regard to the impact of bilingualism on linguistic skills, the situation is much more clear-cut. Studies of vocabulary knowledge have consistently reported lower scores for bilinguals in each language than for monolingual speakers of that language (e.g., Droop & Verhoeven, 2003; Perani et al., 2003; Portocarrero, Burright, & Donovick, 2007). Assumingly, lexicalized concepts are distributed across a bilingual's two languages, so that some words are known in one language, some in the other, and only some in both (Oller, 2005). This, however, depends on the context and frequency of L2 use, naturally resulting in a larger vocabulary for L1 in dominant bilinguals than in balanced bilinguals. Given that vocabulary size is a central measure of children's progress in both spoken and written forms of language development (Bialystok, 2009), it is not surprising that bilingual children often lag behind their monolingual peers on linguistic tasks. Findings from large-scale studies such as the Program for International Student Assessment (PISA) show that in most participating countries students who do not typically speak the test language at home reach lower scores on the reading literacy scale (Stanat & Christensen, 2006). Even after controlling for children's socio-economic status, which is often lower for individuals who speak a second language due to immigration, the gap in reading comprehension between monolingual and bilingual speakers remained (Baumert & Schümer, 2001). Similar results were found for oral text comprehension (Droop & Verhoeven, 2003), reading fluency (Duzy, Ehm, Souvignier, Schneider, & Gold, 2013), syntactic awareness, and verbal working memory (Lesaux, Lipka, & Siegel, 2006). Yet, it is not clear which factors exactly cause these inequalities between groups, which was one of the questions this dissertation set out to examine.

Bilinguals were also found to show a disadvantage in lexical access, demonstrated by slower reaction times (RTs) in lexical decision tasks (e.g., Ransdell & Fischler, 1987), slower RTs and lower accuracy scores on picture naming (e.g., Gollan, Montoya, Fennema-Notestine, &

Morris, 2005; Ivanova & Costa, 2008) and category fluency tasks (e.g., Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000), more tip of the tongue experiences (e.g., Gollan & Silverberg, 2001; Gollan & Acenas, 2004), and poorer word identification skills through noise (Rogers et al., 2006). Bilinguals' deficits in lexical access, which have been shown to persist with aging (Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007), are attributed to two potential causes. One is the parallel activation of both of their languages, leading to the necessity to inhibit competing non-target items during lexical access (Green, 1998). The other is the reduced frequency of use of each of their languages, creating weaker links among the connections between orthographic, phonological and semantic representations (Gollan, Montoya, Cera, & Sandoval, 2008). These, in turn, lead to greater processing costs especially for words in the lower frequency range, which are naturally encountered less often. Established evidence for this view is the stronger word frequency effect in L2 over L1 processing (e.g., Brysbaert, Lagrou, & Stevens, 2016; Cop, Keuleers, Drieghe, & Duyck, 2015; de Groot, Borgwaldt, & van den Eijnden, 2002; Lemhöfer, Dijkstra, Schriefer, Baayen, Grainger, & Zwitserlood, 2008), which has been interpreted in terms of the lexical entrenchment account. Accordingly, any processing differences between L1 and L2 can be explained by variations in exposure, which is most reliably measured by vocabulary knowledge (Diependaele, Lemhöfer, & Brysbaert, 2013; Kuperman & van Dyke, 2013). The question is, however, whether this view also holds true for children, who have naturally had less exposure in any of their languages relative to adults.

Yet, not all effects of bilingualism on linguistic skills are disadvantageous. A large body of evidence suggests that when being exposed to two languages at a very young age children may have an advantage in their general understanding of the symbolic function of words and of the way in which writing systems encode spoken language (Bialystok, 2001). Often referred to as metalinguistic awareness, the knowledge of linguistic structure and the ability to access it intentionally, in turn, are assumed to be crucial for the acquisition of literacy. A great number of studies have demonstrated that bilingual children outperform their monolingual peers on tasks separating the meaning of words from their form and making independent judgements about the semantic (Ben-Zeev, 1977), syntactic (Ricciardelli, 1992b), and even morphological (Barac & Bialystok, 2012) aspects of language. The metalinguistic concept most clearly promoting literacy acquisition is phonological awareness, which has been shown to differ between bilingual and monolingual children depending on the similarity of the bilingual's languages. Several studies have found that children who speak two languages with a similar writing system and phonological structure show improved phonological awareness abilities, such as syllable awareness or onset-rime segmentation (Bialystok & Barac, 2012; Bialystok, Luk, & Kwan, 2005; Bruck & Genesee, 1995). Based on the finding that phonological awareness transfers across languages (Durgunoğlu, Nagy, & Hancin-Bhatt, 1993), there is reason to believe that enhanced skills in one language foster reading acquisition in another. Summarizing her research on English reading acquisition in Spanish native speakers, Durgunoğlu (1998) reported a strong correlation between children's phonological awareness in Spanish and their English word recognition skills. In conclusion, bilingualism bears the chance to facilitate reading acquisition regardless of the language in which initial literacy instruction takes place. A further aim of the present dissertation was to test this assumption by investigating whether bilingual beginning readers would be able to compensate for potential disadvantages in lexical access and benefit from their improved metalinguistic awareness.

3. Models of bilingual word recognition

Amongst a variety of computational models to explain the process of reading, one of the first and still most influential one is the Interactive Activation (IA) model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Based on the idea of connectionism, which assumes models to be artificial neural networks, the IA model posits letter features, letters and words as nodes on three different levels, which are connected by excitatory and inhibitory links. Upon activation of the lowest level, information flows between adjacent levels in a bi-directional manner, exciting nodes with which they are consistent and inhibiting nodes with which they are inconsistent. Once a word node reaches a critical activation threshold, the word is selected by the recognition system (Rastle, 2007). Upon activation of a word's orthographic entry in the mental lexicon, associated phonological and semantic representations are activated, until the word is recognized. This whole process is typically referred to as lexical access.

Sharing the assumption of location-specific letter positioning, one of the most successful successors of the IA model is the Dual-Route Cascaded (DRC) model of visual word recognition (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Accordingly, there are two routes by which print can be converted into speech. First, similar to the postulation of the original IA model, words can be processed via a lexical route through activating compatible units while inhibiting incompatible ones. That is, all the letters of a word are processed in parallel, which is then retrieved as a whole from the orthographic lexicon and connected to the corresponding entry in the phonological lexicon. Given that behavioral data has been successfully simulated by the DRC without including semantic representations, the involvement of semantic activation within this process is still unclear (see part A in Figure 1). Second, words can be decoded letter by letter via a sub-lexical route through using grapheme-to-phoneme correspondence (GPC) rules that are applied serially from left to right (see part B in Figure 1). This route is of particular relevance for processing words that are not stored in the mental lexicon, i.e. new words or nonwords, and thus likely to be used by beginning readers. Evaluating the DRC for its ability to correctly read German words, researchers pointed out that especially in orthographically shallow languages, which are characterized by a consistent mapping of phonemes on graphemes, the sub-lexical route could be more reliable (Ziegler, Perry, & Coltheart, 2000). This, in turn, could make reading acquisition easier in German than in orthographically opaque languages like English, which require a large

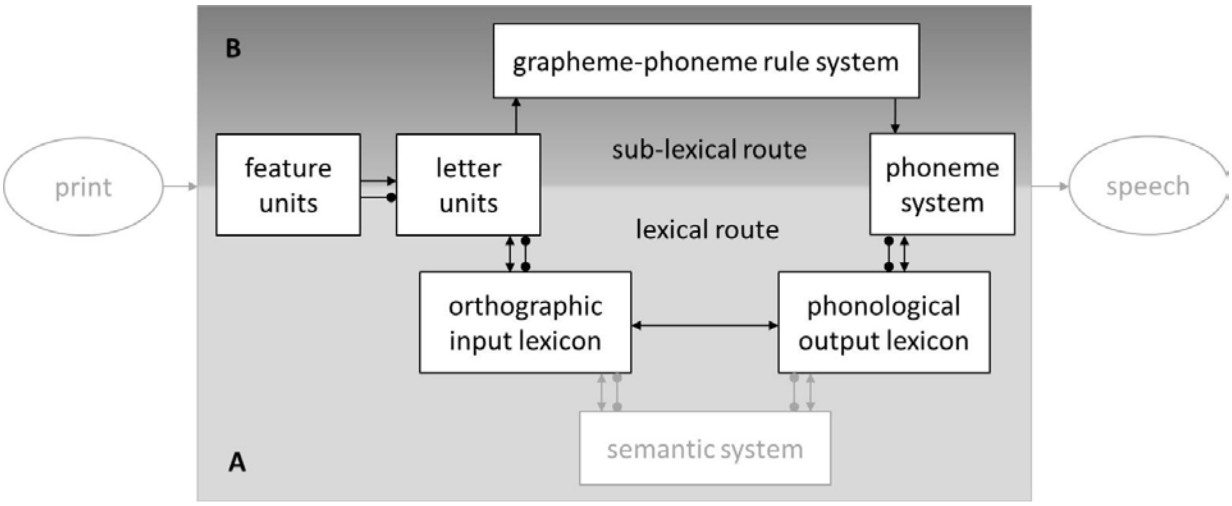


Figure 1. *The basic architecture of the DRC model (Coltheart et al., 2001) including the lexical (A) and sub-lexical route (B).*

number of irregularities to be mastered in order to successfully compute phonology. Providing evidence for this assumption, cross-linguistic studies comparing bilingual reading beginners' performance in a shallow versus opaque language have shown that they processed words and nonwords faster and less error-prone in the first compared to the latter (e.g., Geva & Siegel, 2000). One of the aims of this dissertation was to investigate whether the DRC would also explain behavioral data in children learning to read in German as their L1 as well as in their L2.

The most widely cited model of bilingual word recognition, the Bilingual Interactive Activation Plus (BIA+) model (Dijkstra & van Heuven, 2002), postulates that in balanced bilinguals lexical access is language-nonselective and based on an integrated lexicon. This view is based on a large body of research which has demonstrated that visually presented words are simultaneously accessed in both languages of a bilingual (e.g., Duyck, 2005; van Assche, Duyck, Hartsuiker, & Diependaele, 2009). The most established evidence for this cross-linguistic activation is the cognate facilitation effect, which refers to the processing advantage for words that are orthographically and semantically identical in both of a bilingual's languages. The effect is commonly attributed to the fact that cognates share their semantic representation in the mental lexicon and thus reach their activation threshold sooner than matched non-cognates (e.g., Lemhöfer & Dijkstra, 2004). In contrast, false friends, which share their form but not their meaning between languages, have been found to cause null or even inhibitory effects (e.g., Dijkstra, van Jaarsveld, & Ten Brinke, 1998; Dijkstra, Grainger, & van Heuven, 1999; Dijkstra, Timmermanns, & Schriefers, 2000). Assumingly, this is due to the competition of their different semantic representations, which annuls or even reverses the benefit in activation on the orthographic level (Jared, Cormier, Levy & Wade-Woolley, 2012). The mechanism of this semantic-to-orthographic feedback is illustrated in Figure 2. It is not clear, however, how this mechanism develops and whether it can be found already at the beginning of reading development. One of the objectives of the present dissertation was to explore this issue by investigating the processing of cognates and false friends in balanced bilingual children.

As posited by the BIA+ model, the processing costs caused by language interference are limited by top-down inhibitory control from language nodes, which account for the detection of language membership. After the language of a word is identified, language nodes feed information back to the lexical level, whereupon the word is recognized (see Figure 3 A).

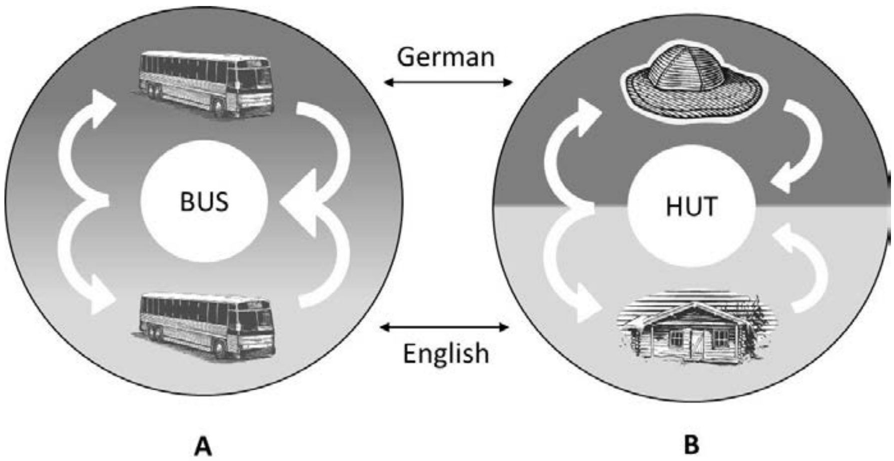


Figure 2. *The mechanism of semantic-to-orthographic feedback for a German-English example of a cognate (A) and a false friend (B).*

Latest findings on the mechanisms of language detection, however, suggest that balanced bilinguals are sensitive to the orthographic structure of their languages prior to word recognition. Recent studies have shown that if presented with language-specific cues – such as unique graphemes, more frequent bigrams, or larger orthographic neighborhood size – bilinguals show reduced parallel language activation (e.g., Casaponsa & Duñabeitia, 2015; Casaponsa, Carreiras, & Duñabeitia, 2014). In other words, lexical access seems to be language-nonselective only in the absence of language-specific cues, while in their presence language-selective access is enabled. Based on this conclusion, the BIA+ was extended by adding sub-lexical language nodes (van Kesteren, Dijkstra, & Smedt, 2012), which allow language detection to also happen prior to lexical access (see Figure 3 B). Yet, this theory is purely grounded on adult data, which calls for the need to test the applicability of the BIA+ extended model for bilingual children.

Studies on language co-activation in bilinguals have further shown that the magnitude of cross-linguistic interference effects varies as a function of language proficiency. Cognate facilitation, for instance, has been found to occur primarily in dominant bilinguals' L2, i.e. their less proficient language, and not in their L1 (e.g., Dijkstra et al., 1999). Based on the assumption that frequently used words have a high resting level of activation, and that words with a high resting level need less input to become activated, it is argued that a word in L1 is activated faster than in L2, and that thus L2 processing can be affected by L1 information but not vice versa (Dijkstra & Van Heuven, 2002). Likewise, studies on translation could show that

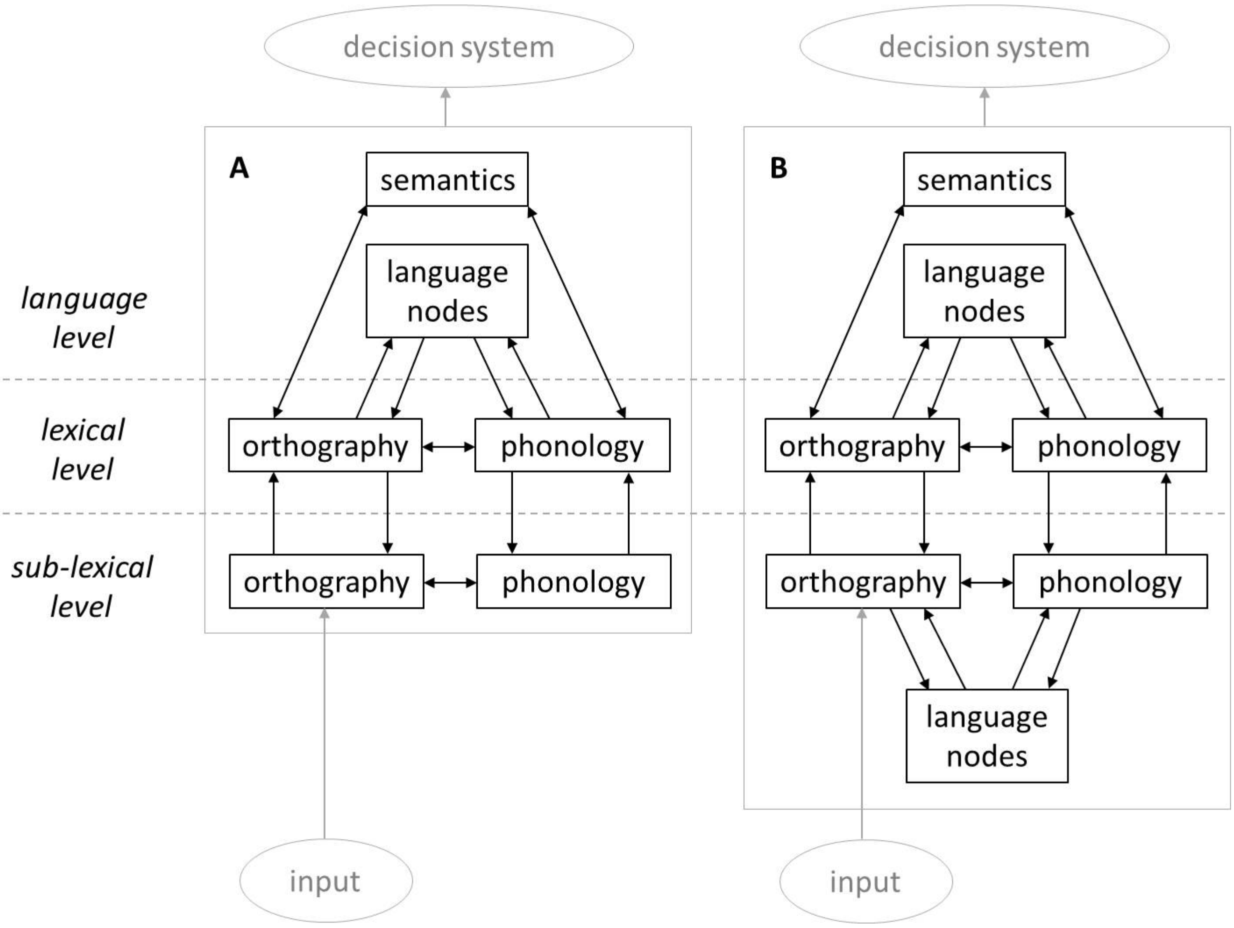


Figure 3. *A: The BIA+ model of bilingual word recognition (Dijkstra & van Heuven, 2002). B: A representation of the BIA+ extended model including sub-lexical language nodes as postulated by van Kesteren et al. (2012).*

L2 learners were faster at translating words from L2 to L1 than from L1 to L2, and that the degree of this asymmetry was larger for less proficient learners than for more proficient leaners or balanced bilinguals (Kroll, Michael, Tocowicz, & Dufour, 2002). Findings such as these are often interpreted in line with the Revised Hierarchical Model (RHM; Kroll & Stewart, 1994), which was primarily developed to explain conceptual access in adult L2 learners. Accordingly, bilingual memory organization consists of two independent lexicons (L1 and L2) and an integrated conceptual system (CS). Whereas L1 and L2 are lexically linked to each other, initially there is only a direct connection between CS and L1. As the link between CS and L2 will first develop during L2 acquisition, learners have to derive meaning in L2 via their L1. With growing proficiency in L2, this dependency will diminish, until eventually both links are equally strong. In an attempt to capture this transition, the Developmental Bilingual

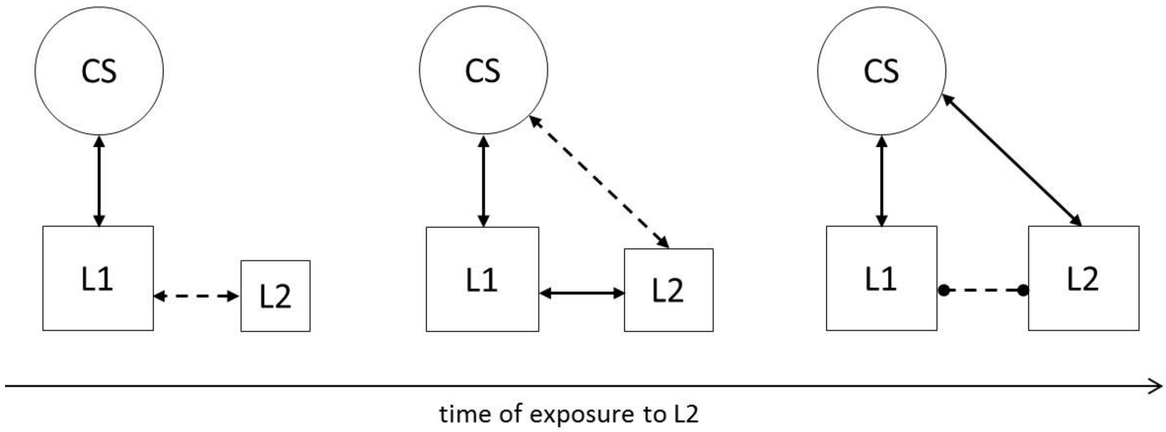


Figure 4. *The development of L1-L2 connectivity throughout L2 acquisition as proposed by Grainger et al. (2010). Arrows represent excitatory connections (with full lines representing stronger connections than dashed lines), while circles denote inhibitory connections*.

Interactive Activation (BIA-d) model was proposed (Grainger, Midgley, & Holcomb, 2010), which provides a framework for uniting the RHM and the basic BIA model initially described by Grainger and Dijkstra (1992). It states that in the course of L2 acquisition, L2 word form representations strengthen and become gradually integrated into a lexicon that is eventually shared between the languages. At the same time, excitatory connections between translation equivalents in L1 and L2 become inhibitory, which leads to an improved control over L2 activation (see Figure 4). The authors depict this point as the "magic moment in L2 acquisition when suddenly understanding and producing L2 becomes significantly less effortful" (p.276). Accordingly, even at the beginning of reading acquisition, balanced bilinguals should show interference effects in both of their languages, which was one of the assumptions the present dissertation set out to investigate.

4. Motivation for this dissertation

Concluding from the evidence provided above, findings on the effects of bilingualism depend largely on bilinguals' level of L2 proficiency and their age of L2 acquisition. Yet, the main body of current knowledge on bilingual word recognition originates from experiments with biliterate adults, who typically have been exposed to print in at least one of their languages for about two decades at the time of testing. So far, little is known about the role of bilingualism at the beginning of initial reading acquisition, when the word recognition system is yet to develop. The present dissertation set out to close this gap by studying orthographic processing in bilingual children, who move from not being able to read at all to adult-like reading proficiency in one or both of their languages in just a few years. Catering to the challenges of globalization posed to education in the twenty-first century, more and more schools teach reading in more than one language. Whereas some programs start reading instruction in L1 before they introduce children to print in L2, others teach reading concurrently in two languages from the very beginning of schooling. In contrast, especially given the recent developments in migration movements, a growing number of children has to start schooling in their L2 only, facing the difficult task to learn how to read in their weaker language. Notwithstanding the diversity of reading instruction programs, knowledge on the development of bilingual compared to monolingual beginning readers and their differences in word recognition is still scarce. Though there is an extensive body of literature on L2 speaking children, little research has been conducted on the effects of bilingualism with regard to the development of the exact mechanisms underlying the visual word recognition system. Based on the fact that the degree of bilingual language proficiency has been demonstrated to make a difference in experiments on cognitive processing, for this undertaking, however, it is of crucial importance to differentiate between dominant and balanced bilinguals. The central aim of this dissertation was thus to contribute to the debate on orthographic processing in bilinguals by investigating the impact of bilingualism on reading development in dominant as well as in balanced bilingual children.

More specifically, the present research pursued two goals. The first was to compare monolingual and bilingual children on their reading performance, and to investigate discrepancies with regard to underlying cognitive processes. In contrast to describing differences merely on an output-based level of reading, which is how most of the studies on reading in bilingual versus monolingual children are designed, the objective was to identify differences in their trajectories by examining the development of orthographic processing right from the start of reading acquisition. Apart from investigating dissimilarities in component processes of reading, this objective included analyzing the effects of linguistic characteristics as well as the impact of reading-relevant factors known to differ between groups, such as language-specific vocabulary size, reading fluency, or executive functioning skills. The second goal was to zoom in on the bilingual mental lexicon and to investigate the development of mechanisms that have been demonstrated to differ in bilingual adults compared to their monolingual peers. Naturally, these mechanisms are connected to the acquisition, storage and usage of two language systems, such as bilingual lexical access and the detection of language membership. Both goals taken together, the intention was to provide a better understanding of the impact of bilingualism by depicting the source as well as the manifestation of differences between monolingual and bilingual beginning readers.

In light of these two goals, i.e. (1) to study developmental trajectories of reading in L1 and L2 speakers and (2) to investigate the development of orthographic processing mechanisms specific to the bilingual lexicon, four studies were conducted. To disentangle developmental effects between L2 speakers and balanced bilinguals, studies 1 and 2 focused on children who were learning to read in their L2, while studies 3 and 4 were based on a sample of students who were learning to read concurrently in both of their languages. Given that most studies on visual word recognition in bilinguals used English as the target language and other languages are still underrepresented in this area of research, we chose German as the language of investigation. Based on a very consistent grapheme-phoneme correspondence, German provides a degree of orthographic transparency that enables beginning readers to master decoding fairly quickly. In English, on the other hand, which is characterized by an opaque transparency, more time is necessary to memorize the amount of irregular mappings between letters and sounds. Thus, it is likely to expect that German speaking bilingual children show a different developmental trajectory of reading acquisition than their English speaking peers. The motivation to select German as the target language for the present research was therefore not only driven by the lack of data in languages other than English, but also by the need to investigate whether the impact of bilingualism generalizes across languages with different orthographic depths. All L2 speakers participating in studies 1 and 2 were native speakers of a language other than German, who spoke this language at home, but who had started schooling in a German speaking environment. Balanced bilingual children participating in studies 3 and 4 were fluent speakers of German and English, who had learnt both languages very early in life and used them at home as well as in school equally on a daily basis. The combination of German and English was selected because of two reasons.

First, this way it was possible to study effects of orthographic depth using a within-subject design. Second, results could be linked to previous research conducted in English.

5. Aims of the studies

All fours studies conducted within this dissertation examined German speaking children between the ages of 6 and 12 years. The purpose of Study 1 was to provide an overview on the differences in reading between monolinguals and bilinguals by comparing their performance on different levels of the text comprehension process. The aim was to identify linguistic and cognitive discrepancies between L1 and L2 speakers and to investigate how these would affect successive stages of the reading process. Studies 2 and 3 focused exclusively on the processing of isolated words and examined the mechanisms of lexical access. The aim of study 2 was to investigate the processing of linguistic information in L1 and L2 speakers by comparing the impact of linguistic characteristics on lexical access. In study 3, the presence of parallel lexical access in both languages of balanced bilingual children was examined by investigating the processing of cognates and false friends. Further zooming in on the mechanisms of word recognition by focusing on processes prior to lexical access, the aim of study 4 was to explore the detection of language membership in balanced bilingual children. In the following, the goals of the four studies are presented in detail.

5.1 Study 1

Findings from PISA have repeatedly shown that L2 speakers lag behind their native speaking peers on reading comprehension. Widely disseminated by the media, in Germany this gap is particularly pronounced, and remains to be significant even after differences in students' socio-economic background are taken into account (Baumert & Schümer, 2001). Yet, though it is known that in order to achieve high-level text comprehension skills a number of component processes have to be mastered (e.g., Perfetti, Marron, & Foltz, 1996), no study has ever investigated whether the gap in reading comprehension between groups is merely the result of disparities in low-level processes. The first goal of study 1 was to identify the specific locus of reading differences between L1 and L2 speakers by assessing their performance separately for processes on the letter, word, sentence, and text level. We assumed a bottom-up interrelationship of the separate levels, meaning that participants' performance on one level would be most strongly predicted by their performance on the preceding one. We expected that this way the root of deficits on the highest level would become visible. Our second goal was to investigate whether group differences found on specific levels were actually due to participants being L1 or L2 speakers (L2 status), or rather a result of other discrepancies between the groups. To this end, we assessed participants' linguistic and executive functioning skills, which are likely to be relevant for the process of reading and, at the same time, are frequently reported to differ between monolingual and bilingual speakers. We hypothesized that performance differences on specific levels might occur as a function of reading-relevant skills and irrespective of participants' L2 status. In a single self-paced lab session, we administered a battery of tests to 64 L1 speakers and 34 L2 speakers of German, who were attending grades 5, 6, or 7 at a German school. Controlling for socio-economic characteristics, we performed a series of hierarchical regression analyses for each level of reading while examining the impact of participants' linguistic and executive functioning skills.

5.2 Study 2

After the aim of study 1 was to identify the locus of differences in the reading process between L1 and L2 speaking children, study 2 was conducted to zoom in on the mechanisms of lexical access in a second language. These are commonly investigated through within-language factors such as word length, frequency, or orthographic neighborhood size, whose marker effects present key issues in the modelling of visual word recognition. Studies investigating the impact of linguistic characteristics in adult L1 versus L2 orthographic processing found that dissimilarities occurred primarily with respect to frequency related measures (Brysbaert et al., 2016; de Groot et al., 2002; Lemhöfer et al., 2008). The main goal of study 2 was to investigate whether these differences can already be observed at the beginning of reading development and whether child L2 speakers also differ from L1 speakers in the impact of length and neighborhood size. Based on the assumption that language exposure shapes the development of the word recognition system, we hypothesized that due to their reduced exposure bilingual children would differ from their monolingual peers in their sensitivity to linguistic characteristics by showing greater effects. Because of the overall lack of orthographic representations at the very beginning of reading development, we further assumed that initially child L2 speakers would not differ from their L1 speaking peers, but that differences would emerge in the course of reading development. Additionally, given that bilingual children are known to lag behind on vocabulary knowledge and, as a result, L2 reading fluency, we wanted to examine whether potential processing differences were mediated by skills known to vary as a function of language exposure. We conducted a mega study with 800 German elementary school students from grades 2 to 6, who completed an LDT as well as a number of standardized tests during regular school hours. In order to simultaneously access partial effects of several predictors, the data analysis was done by means of mixed-effects models including participants and items as random effects.

5.3 Study 3

Addressing the impact of the manner of bilingual language acquisition, the aim of study 3 was to investigate lexical access in balanced bilingual children. After in study 2 the focus was on processing costs in dominant bilinguals, study 3 was designed to examine potential advantages of the parallel activation of two languages. The common finding that cognates facilitate lexical processing (e.g., Lemhöfer & Dijkstra, 2004) while false friends do not (e.g., Dijkstra, Van Jaarsveld, & Ten Brinke, 1998) has been attributed to the presence of semantic-to-orthographic feedback (Jared, Cormier, Levy, & Wade-Woolley, 2012). In dominant bilingual children, however, cognate facilitation has been found exclusively in their weaker language, and only if cognates were not presented together with false friends (Brenders, van Hell, & Dijkstra, 2011). Assumingly, L2 learners focus more on spelling than on meaning and thus are more affected by orthographic ambiguity compared to more proficient bilinguals, who have the capacity to also pay attention to meaning and thus benefit from semantic co-activation. The purpose of study 3 was to investigate the effect of language proficiency by replicating findings from adults on cognates and false friends in balanced bilingual children. Our first goal was to compare word recognition in both languages and to study whether cognate facilitation would occur as a function of equal language proficiency and, as a result, irrespective of experience with print. Secondly, we wanted to investigate the presence and usage of semantic-to-orthographic feedback in the early stages of the bilingual lexicon. We hypothesized that if both languages were equally well developed, cognate facilitation would occur in both languages and despite the presentation of false friends. Applying a within-subject design, we conducted two LDTs, one in German and one in English, including cognates, false friends, and matched control words. Forty-six balanced bilingual third-graders learning to read concurrently in both languages participated in the study, which took place at a bilingual school. Using mixed-effects models, the data were analyzed separately for cognates and false friends in each language.

5.4 Study 4

After all previous studies focused on processes on the lexical level, study 4 was designed to investigate sub-lexical processing. More specifically, the aim was to explore the mechanism by which a word is associated with a specific language, which has been hardly studied in children so far. As postulated by the BIA+, language detection in bilinguals happens via language nodes, which are connected to the lexical level and feed back information about the language membership after the word has been lexically accessed (Dijkstra & van Heuven, 2002). However, based on the recent evidence that bilingual adults show language selective access if presented with language-specific sub-lexical cues (e.g., Casaponsa, Carreiras, & Duñabeitia, 2014), the BIA+ was extended by a set of sub-lexical language nodes, which enables the detection of language membership already prior to lexical access. Given that knowledge on the sensitivity to orthographic information in children is still scarce, the goal of study 4 was to investigate the presence of such an early language detection mechanism at the beginning of reading development. To this end, we manipulated nonwords according to their word-likeness in English and German and presented them together with only English or only German words in two seemingly monolingual LDTs. We predicted that if children were sensitive to sub-lexical information, in the English LDT, German-like nonwords would be rejected faster and more accurately than English-like nonwords, and vice versa. No performance difference, in contrast, would indicate language-nonselective access and, ultimately, the need for children to process orthographic information on the lexical level in order to detect language membership. To rule out effects of language proficiency and print exposure, the study was conducted as part of the data collection for study 3, using the same group of balanced bilingual third-graders. The data were analyzed using mixed-effects models including nonword language-likeness and language of the LDT as fixed effects.

Chapter 2

Study 1

The Impact of L2 German on Component Processes of Reading

Abstract

In Germany, there is a substantial gap in reading literacy between monolingual children and their L2 speaking peers. Yet, it is still unclear where these performance differences are rooted. We investigated children of grades 5, 6, and 7 with comparable SES, who completed a battery of tests assessing their linguistic and executive functioning skills as well as their reading performance on the letter, word, sentence, and text level. Whereas L1 speakers showed better linguistic skills, there was no difference between groups in executive functioning. After controlling for individual differences on each level of reading, groups only differed in text comprehension. This effect, however, disappeared when participants' linguistic skills were additionally controlled. In sum, results show that reading problems in L2 speakers cannot be attributed to deficits on specific component processes of reading, but to a lack of linguistic skills, which negatively affects reading comprehension.

This chapter has been published in the *Journal of Research in Reading* (see Declaration for reference). Due to copyright restrictions pages 24 to 44 have been removed in the online version of the dissertation.

Chapter 3

Study 2

Differences in Visual Word Recognition between L1 and L2: The Impact of Frequency, Length, and Orthographic Neighborhood Size in German Speaking Children

Abstract

Investigating the impact of linguistic characteristics on visual word recognition in children, we studied whether differences in native (L1) and second language (L2) processing already emerge at the beginning of reading development. German elementary school students in grades 2 to 6 completed a battery of standardized tests and a lexical decision task (LDT). Though L1 speakers outperformed L2 speakers on German skills, groups did not differ in their overall performance on the LDT. However, results from mixed effect models revealed greater effects for word frequency and length in L2 over L1 speakers, indicating qualitative differences in the sensitivity to linguistic information between groups. This distinction persisted across all grades and after controlling for differences in vocabulary size and reading fluency. Findings extend evidence provided for adult L2 processing, suggesting that varying language exposure shapes the development of the word recognition system already in the early stages of reading development.

This chapter has been submitted for publication in *Studies in Second Language Acquisition*.

Introduction

In the field of research on bilingual visual word recognition, evidence has accumulated that bilinguals activate both of their languages when reading in one of them (e.g., Caramazza & Brones, 1979). Consequently, it is widely accepted that lexical processing differs significantly between native (L1) and second language (L2) reading, generally manifesting in greater costs for L2 over L1 (e.g., de Groot, Borgwaldt, Bos, & van den Eijnden, 2002). However, while there is no dearth of studies on L1 to L2 transfer processes, little is known about the differences between L1 and L2 speakers with regard to the general mechanisms underlying the visual word recognition system. These mechanisms are commonly investigated through within-language factors such as word frequency, length, or orthographic neighborhood size, whose marker effects present key issues in the cognitive modelling of reading. Several studies have provided evidence that L2 speakers have more difficulty recognizing low-frequency words than L1 speakers, which suggests that the impact of frequency is greater in L2 over L1 processing. Yet, bilingual participants in these studies were adults who had previously acquired reading skills in their L1. The question that follows is whether they would have shown different effects if they had started reading acquisition in L2 at the same time, i.e. whether it is varying exposure to print or differences in the mechanisms of lexical access that causes dissimilarities between L1 and L2 processing. The present paper aims to answer this question by investigating visual word recognition in L1 and L2 German speaking children, placing special emphasis on differences in the impact of word frequency, length, and orthographic neighborhood size, while controlling for factors associated with language exposure. The goal is to portrait orthographic processing differences between L1 and L2 speakers at the beginning of reading development in order to better understand the mechanisms involved in children’s visual word recognition.

Visual word recognition in bilinguals

As a result of an increasingly multilingual world, in recent years bilingual word recognition has attracted more and more attention in research. Given the wealth of studies, it is of crucial importance to distinguish between different forms of bilingualism, whose characteristics have been shown to have different effects on lexical access. As opposed to balanced bilinguals, who are equally highly proficient in both of their languages, dominant bilinguals, who are usually less proficient in their L2 than in their L1, have been found to lag behind monolinguals on tasks involving lexical access. The costs reported in L2 over L1 include slower RTs in lexical decision tasks (e.g., de Groot, Borgwaldt, Bos, van den Eijnden, 2002; Ransdell & Fischler, 1987), slower RTs and lower accuracy scores on picture naming (Gollan, Fennema-Notestine, Montoya, & Morris, 2005; Gollan, Montoya, Cera, & Sandoval, 2007; Ivanova & Costa, 2008) and category fluency tasks (e.g., Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000), more tip of the tongue experiences (e.g., Gollan & Silverberg, 2001; Gollan & Acenas, 2004), and poorer word identification skills through noise (Rogers, Lister, Febo, Besing, & Abrams, 2006). Taken together, there is reason to assume that speaking two languages has an impact on the development of visual word recognition.

To investigate differences in orthographic processing between L1 and L2, the mechanisms of lexical access need to be examined in detail. Yet, studies exploring the influence of linguistic characteristics on L2 word processing were exclusively carried out on adults, who had started to learn English on average at the age of 12 years. In 2002, de Groot, Borgwaldt, Bos, and van den Eijnden conducted a study with Dutch-English bilinguals, who completed a Dutch (L1) as well as an English (L2) lexical decision task (LDT). The authors found that in both languages frequency variables were the most important predictors, while in English lexical decision was also affected by length. In 2008, Lemhöfer and colleagues compared native speakers of English to three different bilingual populations on L2 English word recognition and found significant differences in the impact of frequency-related measures between L1 and L2 processing, which occurred irrespective of participants' L1. Transferring these findings to beginning readers, we expect the frequency effect to be even more pronounced. Given that the links between phonological, semantic and orthographic representations are naturally weaker in children than in adults, their lexical access should be more affected by differences in language exposure. Also, when learning to read in an orthographically transparent language as opposed to English, effects of word length and neighborhood size should become more salient.

Because of their overall lack of orthographic representations at the very beginning of reading development, initially child L2 speakers should not differ from their L1 speaking peers in orthographic processing. Yet, taking into account that groups differ in their exposure to the target language, it is likely to assume that differences will emerge in the course of reading development. Though groups are equally immersed and exposed to formal reading instruction at school, less oral usage combined with less exposure to print to the target language at home should lead to a disadvantage in orthographic processing in L2 over L1 speakers. In the following, we will elaborate on the three marker effects in visual word recognition research, hypothesizing potential differences between L1 and L2 speaking children.

Word frequency effects

There is large consensus that the most robust predictor for language performance is the frequency of occurrence of a word in a language (for a review, see Brysbaert, Buchmeier, Conrad, Jacobs, Bölte, & Böhl, 2011). The frequency effect (FE), which entails that high frequency words are processed faster and more accurately than low frequency words, is one of the most investigated phenomena in psycholinguistic research. Interactive activation (IA) models (e.g., Dijkstra & Van Heuven, 2002; McClelland & Rumelhart, 1981) suggest implicit learning to be the source of this effect. Accordingly, repeated exposure to a lexical item raises this item's baseline activation, so that the activation threshold is reached earlier and lexical access to that item is executed faster (e.g., Monsell, 1991). However, since the maximum speed of lexical access processes is limited, the effect of facilitation saturates once an item has exceeded a certain amount of exposure (Morton, 1970). It is further assumed that lexical entries are usage-based and that reduced exposure to a language leads to reduced lexical entrenchment, which describes the overall quality of lexical representations in the mental lexicon (Perfetti, 2007). Based on the fact that L2 speakers' L2 representations have accumulated less exposure, the weaker links theory was proposed (Gollan, Montoya, Sera, & Sandoval, 2008), which posits the idea that over time reduced language practice leads to weaker links between orthography, phonology and semantics. This causes greater processing costs in L2 compared to L1 especially for words in the lower frequency range, which are naturally encountered less often and thus are even more affected by reduced exposure.

Several studies have provided evidence for a larger FE in L2 over L1 speakers (e.g., Wijnendaele & Brysbaert, 2002), with the strongest effect in bilinguals' L2, followed by their L1, and the smallest effect in monolinguals (Gollan, Montoya, Sera, & Sandoval, 2008). In a study comparing word identification times of monolingual adults to three different bilingual populations, Diependaele, Lemhöfer, and Brysbaert (2013) could show that the magnitude of the FE depended on participants' vocabulary size and occurred irrespective of their bilingualism, with weaker effects for those with larger vocabularies. Kuperman and Van Dyke

(2013) generalized this finding by suggesting that the FE is a result of individual language exposure and vocabulary size impacting the accuracy of corpus-based frequency measures. Though these findings are based on data of adults with approximately 12 years of exposure to L2, it is likely to assume that already at the beginning of reading development differences in the FE reflect differences in lexical entrenchment. According to the theory of statistical learning, effects of repeated exposure to a word should be especially visible after the word was first acquired, which suggest that the gap between FEs in L1 and L2 processing should be even more pronounced in children than in adults. For the present study, therefore, we hypothesize a much stronger FE in L2 than in L1 speakers.

Word length effects

A vast body of research has shown that in the course of reading development the sensitivity to the length of a word decreases. The length effect (LE), which entails that with an increasing number of letters processing costs for a word become greater, has been taken as the main marker effect for the conversion of orthography to phonology. Designed to explain this conversion, the Dual-Route Cascaded model (DRC; Coltheart, Rastle, Perry, Langson, & Ziegler, 2001) distinguishes between a sublexical letter-by-letter decoding strategy and a lexical strategy in which all letters are processed in parallel. Within this framework, the decrease of the LE is often interpreted as a gradual shift from use of the sublexical to the lexical route, which goes along with increasing reading experience. Already familiar words are stored in the mental lexicon and can be accessed as a whole, whereas unfamiliar words still need to be decoded letter by letter by means of grapheme phoneme conversion (GPC) rules. In other words, the larger the size of the lexicon, the less likely it is for a reader to come across an unknown word and thus to use the sublexical route. As a result, differences in vocabulary size affect the impact of word length on reading.

Within research on bilingualism, it is widely accepted that individuals who speak two languages have smaller vocabularies in each of their languages than monolingual speakers of either language (e.g., Bialystok, Luk, Peets, & Yang, 2010). Assumingly, lexicalised concepts are distributed across a bilingual’s two languages, such that some words are known in one language, some in the other, and only some in both (Oller, 2005). In L2 speakers, who often use their L2 only in a limited context, such as in school or for work, this imbalance is even more pronounced. In a study with Dutch children, Verhoeven and Vermeer (1996) found that at the end of elementary school L2 speakers' vocabulary was one quarter to one third smaller than that of their L1 speaking peers. This finding, commonly known as "the vocabulary gap" within research on L2 acquisition (Thordardottir, 2011), is mainly attributed to the fact that they divide their time between two language environments (e.g., Oller, Pearson, & Cobo-Lewis, 2007). There is ample evidence that the amount of language input strongly influences the degree of general language growth in both L1 and L2 speakers (e.g., Pearson, 2007). Due to their reduced exposure, in the course of reading development L2 speakers are likely to encounter words that are already familiar to L1 speakers but still unknown to them. As a consequence, they have to rely on the sublexical route while their native speaking peers benefit from their greater number of lexical entries by using the lexical route. Differences in the use of routes should become more apparent the more the number of letters in a word increases, which is why we hypothesize a greater LE in L2 over L1 speakers. Especially in orthographically transparent languages, with consistent GPC rules like German, this should be most salient in participants' RTs.

Orthographic neighborhood size effects

Conceptualizing the development of visual word recognition as the growing ability to discriminate between orthographic patterns, orthographic neighborhood size, which is a broad metric of the similarity of a word to other words, also plays an important role. Yet, findings on the impact of the discriminability of a word, i.e. whether there are a lot of words that look orthographically similar, are inconsistent, ranging from inhibitory effects (Grainger, 1990) over facilitatory effects (e.g., Andrews, 1989) to null effects (e.g., Lemhöfer et al., 2008). Several studies have demonstrated that neighborhood size affects word recognition performance depending on the type of orthographic overlap. Exploring the effect of neighborhood size (NE) on form priming, Castles, Davis, Cavalot, and Forster (2007) found that while developing readers in grade 3 showed substantial priming effects for two types of lexical similarity, two years later they only showed effects for one type. In skilled adult readers, the same set of stimuli did not induce any priming effects. The authors interpreted this finding in terms of a tuning of the automatic word recognition system, which develops as a function of vocabulary size. Early in reading acquisition, many of the similar-looking competitors of a target word are not yet known to the reader, which is why the system can afford to be tuned broadly and to also accept orthographically similar words as candidates for the target word.

With growing vocabulary, however, the system must adapt to the presence of more competing words in the lexicon and thus employ a more finely tuned discrimination mechanism to recognize the target word. Based on their findings, Castles and colleagues postulated the lexical tuning hypothesis, which suggests that orthographic representations and thus the recognition system as such will become more precise in the course of reading development. This view is consistent with findings provided by Andrews and Hersch (2010), who investigated the influence of individual differences on neighbor priming in adults. The authors found that while individuals with poor spelling skills showed facilitatory priming effects for high-neighborhood words, better spellers showed inhibitory effects. According to the lexical quality account (Perfetti, 1992), which argues that the precision of lexical representations is crucial for efficient orthographic processing, good spelling skills are an index of finely tuned lexical representations particularly for words with a higher amount of orthographic neighbors. In conclusion, based on the assumption that L2 speakers have a smaller vocabulary size as well as weaker lexical representations, they are likely to show a larger NE than their native speaking peers.

The present study

Most research on L2 word processing is conducted with adults, i.e. late L2 speakers who have prior reading experience in L1. To the best of our knowledge, no study has ever investigated the impact of within-language characteristics on L1 versus L2 visual word recognition in children at the beginning of reading development. To fill this gap, we examined effects of word frequency, length, and neighborhood size on single word reading in German elementary school students. To take into account high inter-correlations between these variables, we used mixed-effect models for our analyses, which enabled us to simultaneously assess partial effects of several predictors while including random effects for items and participants. This way, we were able to estimate the impact of linguistic characteristics separately and simultaneously from the influence of the underlying sample and stimulus material. Our first goal was to find out whether differences reported for the frequency effect in adult L1 versus L2 processing can already be observed in beginning readers. Second, we wanted to investigate whether in contrast to adult L2 speakers child L2 speakers would also differ from L1 speakers in the impact of length and neighborhood size. Third, we were interested in whether these differences were mediated by linguistic skills that are known to develop as a function of language exposure. For this reason, we assessed participants' vocabulary size and reading fluency. If potential differences in the impact of frequency, length, and neighborhood size between L1 and L2 speakers persisted after controlling for these factors, this would serve as evidence that processing differences between L1 and L2 speakers are not due to varying print exposure but to qualitative differences in the mechanisms of lexical access. Fourth, we aimed to study whether these differences would already show at the beginning of reading development or first emerge in the course of elementary school. For this reason, we recruited children from different grades in elementary school, covering different stages of reading development and periods of exposure to print. In summary, with the present study we aimed to address the following four research questions:

1) Can differences reported for the frequency effect in adult L1 versus L2 processing already be observed in beginning readers?
2) Do child L2 speakers also differ from L1 speakers in the impact of length and neighborhood size?
3) Are these differences mediated by vocabulary size or reading fluency?
4) Do differences in L1 versus L2 processing already show at the beginning of reading development or first emerge in the course of elementary school?

Method

Participants

Within the frame of the Developmental Lexicon Project, 621 children in grades 2 to 6 from seven elementary schools in Berlin participated in the study. Data collection was performed during regular school hours and comprised two sessions each lasting 45 minutes. In the first session, which was conducted in a group setting, children completed a battery of standardized tests as well as a questionnaire on their language background and social demographics. Participants who indicated to have bad vision or who had started to learn German later than at the age of 6 years were excluded from all analyses (n = 10). In the second session, which was a computerized single session, children completed an LDT comprising six blocks. Participants who showed high error rates (> 50 %), or performed 2.5 *SD* below their age mean on the LDT were also excluded from all analyses (n = 27). Eventually, data from 189 second-graders, 151 third-graders, 127 fourth-graders, and 117 sixth-graders were analyzed. Children who reported to have never learnt any other language but German were classified as L1 speakers, whereas children who reported to have a different native language were defined as L2 speakers. Altogether, L2 speakers spoke 26 different languages with various writing systems and orthographic depths. The most prevalent L1 was Turkish (29% of participants), followed by Arabic (13%), Russian (9%), English (8%), and Polish (7%). Though for the majority of them their L1 was the dominant language at the time of entering school, due to the growing exposure to L2 in the course of elementary school German became their dominant language.

Overall sample characteristics, which were analyzed using analyses of variance (ANOVAs) with the between subject factor Group (L1 vs. L2 speakers), are provided in Table 1. We assessed children's vocabulary size by administering the vocabulary subtest of the CFT-20R (Weiß, 2006), which is a multiple-choice power test that requires participants to select the closest-matching equivalent for a given target word. As expected, L2 speakers scored significantly lower than their monolingual peers. Reading fluency was measured using the Salzburger Lese-Screening 1-4 (grades 2-4; Mayringer & Wimmer, 2003) and 5-8 (grade 6; Mayringer & Wimmer, 2005), which are speed reading tests that require participants to indicate whether sentences are true or false. Results indicated a significant advantage for L1 over L2 speakers on reading fluency. We also assessed nonverbal intelligence by administering the matrix subtest from the CFT-20R (Weiß, 2006), which is a power test that requires participants to complete a matrix by selecting the missing part. Here, results did not differ between groups.

Stimulus material

The stimulus set consisted of 1152 German content words (769 nouns, 269 verbs, and 115 adjectives) and pseudowords. *Word frequency* measures were taken from the childLex corpus (Schroeder, Würzner, Heister, & Geyken, 2015), which is based on German children's literature and includes 10 million words. Measures refer to normalized type frequency, i.e. the number of occurrences of a distinct word form divided by the total number of words in the corpus, and ranged from 0.1 to 1044 (M = 61.76; SD = 107.55). We transformed frequency to log base 10, so that the size of the FE was not affected by a word's absolute occurrence in the corpus. *Word length* indicates the number of letters in each word, and ranged from 3 to 12 letters (M = 6.0; SD = 1.81). *Orthographic neighborhood size* was operationalized through the mean Levenshtein Distance from a word to its 20 closest orthographic neighbors (OLD20). We considered OLD20 to be the best measure for studying orthographic similarity effects because it enables a larger range of orthographic variability. In contrast to the standard *N* metric, it is not only determined by letter substitution and does not require all neighbors to have the same length, which is especially important in a language with a great number of longer words like German. Measures were derived from the childLex corpus and ranged from 1 to 4.45 (*M* = 1.72; *SD* = .57).

Pseudowords were generated from words using the multilingual pseudoword generator Wuggy (Keulers & Brysbaert, 2010), which is based on an algorithm that replaces subsyllabic elements (i.e. onset, nucleus, or coda) of words with equivalent elements from other words of the same language. All pseudowords were pronounceable and matched the target word on length and capitalization (as in German nouns are always capitalized).

For the LDT we used a multi matrix design. Therefore, we assigned words to lists that differed in their number between grades. We used 4 lists with 288 words for grade 6, 6 lists with 192 words for grade 4, 8 lists with 144 words for the beginning of grade 3 and 6 lists with 192 words for the end of grade 3, and 8 lists with 144 words for grade 2. The same procedure was applied to pseudowords. Stimuli of each list were then randomly assigned to 6 blocks, of which each included a different number of trials between grades, ranging from 96 trials for grade 6 to 64 for grade 4, 48 for the begin of grade 3, 64 for the end of grade 3, and 48 trials for grade 2. The order of stimuli within each block was randomized for every participant.

Table 1

Means, Standard Deviations (in Parentheses), and Results from the ANOVAs of Sample Characteristics for Groups.

	L1	L2	*F*	*df*	*p*
N (% female)	409 (51)	175 (55)			
*A*ge (in years)	8.68 (1.49)	8.75 (1.60)	0.29	1, 582	.59
Vocabulary[a]	13.81 (6.82)	11.67 (6.77)	12.05	1, 580	<.001
Reading fluency[b]	35.77 (11.81)	32.09 (10.59)	12.62	1, 580	<.001
Nonverbal intelligence[c]	5.35 (2.36)	5.08 (2.55)	1.49	1, 580	.22

Note. [a] raw scores: 0-30 (95% CI for L1 [13.14, 14.47] and L2 [10.65, 12.68])

[b] raw scores: 0-70 (95% CI for L1 [34.62, 36.92] and L2 [30.50, 33.67])

[c] raw scores: 0-12 (95% CI for L1 [5.12, 5.58] and L2 [4.70, 5.46])

Procedure

The experimental software and testing apparatus were identical in each grade. Stimuli were presented on a 15-inch TFT monitor (60 Hz refresh rate, resolution 1028 x 768 pixels, placed at a distance of about 60 cm from the participants) on a Windows-compatible laptop (Intel Pentium, dual core 2.x GHz) running Inquisit 3.0. Manual responses were collected using the laptop’s keyboard. Participants were instructed to decide whether or not a presented letter string formed a correct German word, and asked to press a green button on the keyboard for “yes” or a red button for “no” as quickly and accurately as possible. They also completed a practice block with four items and passed buffer items at the beginning of each new block. Each trial began with the presentation of a fixation cross for 500 ms in the center of the screen. After 500 ms, the target item appeared in the same place and remained on screen until the participant responded. There was an inter-stimulus interval of 500 ms after the response was given.

Results

Accuracy scores and RTs were analyzed for words only using mixed-effects models (Baayen, Davidson & Bates, 2008) as implemented in the *lme4* package (version 1.0-4; Bates, Maechler, Bolker & Walker, 2013) in the statistical software *R*. RT data were log-transformed and analyzed using a linear model, while accuracy data were logit-transformed and analyzed using a generalized linear model with a binomial link function. In the main model (Model 1) Words and Participants served as random effects, whereas Group (L1 vs. L2 speakers) and its interactions with linguistic characteristics were included as fixed effects. Frequency, Length, and Neighborhood size were modelled as continuous predictors, centered, and included separately as linear, quadratic and cubic effect components. Contrasts for post-hoc comparisons were estimated using the general linear hypotheses test generated with the *multcomp* package (Hothorn, Bretz, Westfall & Heiberger, 2014). To explore the role of linguistic skills as mediating factors, we fitted two additional models by separately adding Vocabulary (Model 2) and Reading fluency (Model 3) as fixed effects to the main model. To take into account age-related differences in these skills, predictors were generated by z-transforming participants’ raw scores of the tests on reading fluency and vocabulary for each grade. Both predictors were modelled continuously and included in the model as main effects together with their interactions with Group and linguistic characteristics. To investigate whether effects emerge with grade, we fitted a fourth model (Model 4) by adding Grade (grade 2, 3, 4, and 6), its interactions with Group and linguistic characteristics, and their three-way interactions as further fixed effects to the main model. For all models we calculated marginal R^2 values, which represent the proportion of variance explained by the fixed factors alone, and conditional R^2 values, which describe the proportion of variance explained by both the fixed and random factors.

Accuracy

See the first column of Table 2 for participants' mean accuracy scores across grades. Post-hoc comparisons showed that, overall, accuracy did not differ between groups (t = 0.21, p = .42). The first column of Table 3 presents the results of the main analysis. In the following, findings on the impact of Frequency, Length, and Neighborhood size are described separately.

Word frequency. We found a strong main effect of Frequency as well as a significant interaction of Frequency with Group. As expected, the FE was larger in L2 than in L1 speakers. See Figure 1A for the shape of the FE in both groups. In L1 as well as in L2 speakers, the effect was non-linear in nature. The interaction was driven by words in the lower frequency range (-1 standard deviation from mean), which were responded to less accurately by L2 than by L1 speakers, t = -3.9, p < .001. For the higher frequency range (+1 standard deviation), there was no processing difference between groups, t = 1.22, p = .11.

Word length. There was no significant effect of Length in any of the accuracy data. Given the nature of the effect, which typically emerges mainly in RT data, this was not surprising.

Table 2

Model Means and Standard Errors (in Parentheses) for RTs (in ms) and Accuracy Scores (in % correct) for Groups across Grades.

	Accuracy		Reaction Time	
	L1	L2	L1	L2
Grade 2	92 (.6)	91 (1)	1969 (59)	1800 (73)
Grade 3	95 (.4)	93 (.9)	1315 (41)	1260 (66)
Grade 4	96 (.3)	97 (.6)	1029 (34)	1116 (72)
Grade 6	96 (.4)	97 (.4)	772 (30)	807 (39)

Table 3

Main Effects and Interactions with Group for Accuracy and RTs from Model 1.

	Accuracy			Reaction Time		
	χ^2	*df*	*p*	χ^2	*df*	*p*
Fixed effects[a]						
Group	1.26	1	.26	0.03	1	.87
Frequency	426.02	3	<.001	505.50	3	<.001
Frequency × Group	14.62	3	<.01	3.01	3	.39
Length	2.39	3	.49	442.08	3	<.001
Length × Group	1.35	3	.72	36.47	3	<.001
Neighborhood	10.99	3	<.05	5.73	3	.13
Neighborhood × Group	2.91	3	.41	1.91	3	.59
Random effects[b]						
Words	2830			6365		
Participants	3758			108270		

Note. Tests are based on Type II sum of squares and χ^2 values with Kenward-Roger *df*s.
[a] Marginal R^2 values are .06 (Accuracy) and .05 (RT).
[b] Conditional R^2 values are .32 (Accuracy) and .75 (RT).

Neighborhood size. Though we found a significant main effect for Neighborhood size, indicating more errors for words with more neighbors, there was no difference in its impact between groups.

Reaction times

For the RT analysis, incorrect trials and trials that deviated more than 2.5 *SD* from either the participant or item mean were discarded, accounting in sum for 8.3 % of the raw data. Participants' mean RTs across grades are shown in the second column of Table 2. Again, overall, there was no difference in RTs between L1 and L2 speakers (t = 0.05, p = .48). See the second column of Table 3 for the results of the main analysis. In the following, findings on the impact of word length, frequency, and neighborhood size are presented separately.

Word frequency. As expected, we obtained a strong main effect of Frequency. However, there was no significant interaction with Group.

Word length. As often found for visual word recognition in children, there was a strong LE in RTs, which also differed significantly between groups. As expected, planned post-hoc contrasts showed an overall greater LE for L2 over L1 speakers, indicating a processing advantage for L1 over L2 speakers with increasing word length. See Figure 1B for the shape of the LE in both groups. Whereas for words of shorter length (-1 standard deviation from mean) groups did not differ in their processing, $t < 0.03$, $p < .49$, L1 were faster than L2 speakers in their performance on words of longer length (+1 standard deviation), $t = -4.57$, $p < .001$. For L1 speakers, the progression of the LE was quadratic, meaning that the increase in RTs was steeper for words of shorter length and leveled out for words of longer length. For L2 speakers, in contrast, the LE was exclusively linear in nature, characterized by a gradual increase in RT with a growing number of letters. More precisely, L1 speakers showed to be less susceptible to the impact of length after the number of six letters was reached, whereas L2 speakers were impacted gradually by every letter that was added.

Neighborhood size. Though there was a tendency for words to be processed slower the more neighbors they had, we did not find a significant NE in any of the RT data.

Additional Analyses

Vocabulary. Results of Model 2 are presented in Table 4. We found a reliable main effect of Vocabulary in accuracy scores and RTs, suggesting better word recognition skills with increasing vocabulary size. Results further showed significant interactions of Vocabulary with Length, Frequency, and Neighborhood size in both accuracy and RT data, indicating smaller effects for children with a larger vocabulary. Yet, analyses replicated the Group × Frequency interaction in accuracy scores as well as the Group × Length interaction in RTs, which indicated that our findings on L1 and L2 speakers were independent of differences in their vocabulary size.

Reading fluency. See Table 5 for the results of Model 3. Findings revealed a strong main effect for Reading fluency in accuracy scores and RTs, suggesting more efficient word processing skills with increasing reading fluency. In both accuracy and RT data, interactions of Reading fluency with Frequency, Length, and Neighborhood size reached significance, indicating smaller effects for children with higher reading fluency. Yet again, both the Group × Frequency interaction in accuracy scores and the Group × Length interaction in RTs were replicated, which represents further evidence that these effects occur irrespective of participants' reading fluency.

Grade. See Table 6 for the results of Model 4. As expected, there was a strong main effect of Grade in accuracy scores as well as in RT data. Results for accuracy reproduced the

Group × Frequency interaction, but this effect did not interact with Grade. Likewise, RT results replicated the Group × Length interaction, but did not reveal an additional effect of Grade. We interpreted this as evidence that our results on the FE and LE between L1 and L2 speakers did not emerge over time, but were stable throughout the course of elementary school. While in accuracy scores there was only an interaction of Grade with Length, in the RT data we found interactions of Grade with Frequency, Length, and Neighborhood size, suggesting a decline in the size of effects in the course of reading development. The lack of significant interactions with Group, however, indicated that the developmental pattern of L1 and L2 speakers was comparable on all grade levels.

Table 4

Main Effects and Interactions with Group and Vocabulary from Model 2.

	Accuracy			Reaction Time		
	χ^2	*df*	*p*	χ^2	*df*	*p*
Fixed effects[a]						
Group	0.56	1	.45	5.50	1	<.05
Vocabulary	88.52	1	<.001	119.72	1	<.001
Frequency	427.93	3	<.001	514.07	3	<.001
Frequency × Group	17.08	3	<.001	0.99	3	.80
Frequency × Vocabulary	7.34	3	.37	66.67	3	<.001
Length	4.94	3	.18	420.09	3	<.001
Length × Group	1.37	3	.71	18.99	3	<.001
Length × Vocabulary	7.52	3	.06	255.16	3	<.001
Neighborhood	9.35	3	<.05	5.74	3	.13
Neighborhood × Group	3.14	3	.37	6.01	3	.11
Neighborhood × Vocabulary	18.48	3	<.001	53.27	3	<.001
Random effects[b]						
Words	2922			6287		
Participants	2424			99982		

Note. Tests are based on Type II sum of squares and χ^2 values with Kenward-Roger *df*s.
[a] Marginal R^2 values are .08 (Accuracy) and .16 (RT).
[b] Conditional R^2 values are .32 (Accuracy) and .75 (RT).

Table 5

Main Effects and Interactions with Group and Reading Fluency from Model 3.

	Accuracy			Reaction Time		
	χ^2	*df*	*p*	χ^2	*df*	*p*
Fixed effects[a]						
Group	0	1	.99	2.90	1	.09
Reading fluency	92.68	1	<.001	195.18	1	<.001
Frequency	434.86	3	<.001	513.93	3	<.001
Frequency × Group	16.82	3	<.001	1.05	3	.79
Frequency × Reading fluency	7.95	3	<.05	81.76	3	<.001
Length	5.07	3	.17	420.32	3	<.001
Length × Group	1.84	3	.61	23.41	3	<.001
Length × Reading fluency	9.54	3	<.05	334.37	3	<.001
Neighborhood	9.65	3	<.05	5.29	3	.15
Neighborhood × Group	2.52	3	.47	3.08	3	.38
Neighborhood × Reading fluency	8.40	3	<.05	39.11	3	<.001
Random effects[b]						
Words	2892			6294		
Participants	2414			95877		

Note. Tests are based on Type II sum of squares and χ^2 values with Kenward-Roger *df*s.

[a] Marginal R^2 values are .09 (Accuracy) and .22 (RT).

[b] Conditional R^2 values are .32 (Accuracy) and .76 (RT).

Table 6

Main Effects and Interactions with Group and Grade from Model 4.

	Accuracy			Reaction Time		
	χ^2	*df*	*p*	χ^2	*df*	*p*
Fixed effects[a]						
Group	2.19	1	.14	0.40	1	.53
Grade	134.51	3	<.001	571.19	3	<.001
Group × Grade	2.56	3	.46	5.15	3	.16
Frequency	398.71	3	<.001	510.53	3	<.001
Frequency × Group	14.30	3	<.01	3.91	3	.27
Frequency × Grade	11.33	3	.25	77.44	3	<.001
Frequency × Group × Grade	10.44	9	.32	11.42	9	.25
Length	2.43	3	.49	443.43	3	<.001
Length × Group	1.55	3	.67	41.42	3	<.001
Length × Grade	40.83	3	<.001	647.97	3	<.001
Length × Group × Grade	5.87	9	.75	15.87	9	.07
Neighborhood	10.16	3	<.05	5.86	3	.12
Neighborhood × Group	2.25	3	.52	2.69	3	0.44
Neighborhood × Grade	13.04	3	.16	30.10	3	<.001
Neighborhood × Group × Grade	9.99	9	.35	12.55	9	0.18
Random effects[b]						
Words	2509			6341		
Participants	2413			65522		

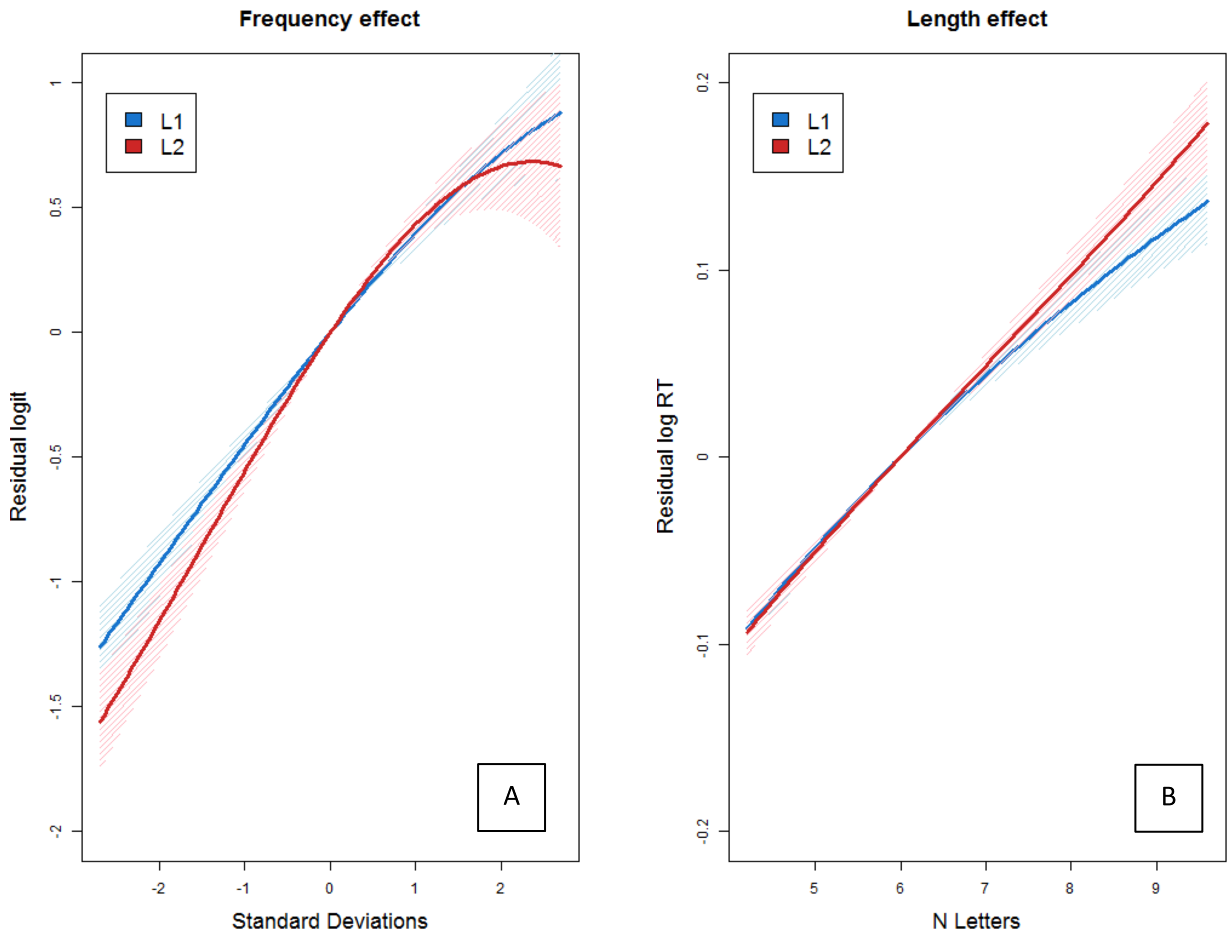
Note. Tests are based on Type II sum of squares and χ^2 values with Kenward-Roger *df*s.

[a] Marginal R^2 values are .09 (Accuracy) and .39 (RT).

[b] Conditional R^2 values are .32 (Accuracy) and .76 (RT).

Figure 1

Differences in the Shape of the FE (A, in residual logits) and LE (B, in residual log RTs) between L1 and L2 Speaking Children.



Discussion

The goal of the present study was to investigate the impact of linguistic characteristics on visual word recognition in L1 and L2 speaking children. We investigated whether differences reported for the frequency effect in adult L1 versus L2 processing can already be observed in beginning readers, and whether child L2 speakers also differ from L1 speakers in the impact of length and neighborhood size. We additionally aimed to study whether these differences were mediated by vocabulary size or reading fluency, and whether they already show at the beginning of reading development or first emerge in the course of elementary school. Within the frame of a cross-sectional mega study, L1 and L2 German elementary school children performed an LDT comprising words that varied in frequency, length and orthographic neighborhood size. Despite their lower scores on vocabulary and reading fluency, results showed that quantitatively L2 speakers did not differ from L1 speakers in their word recognition skills. Across all grades, there was no significant difference between the groups on overall accuracy scores or RTs, indicating that L2 speakers who start reading acquisition in their L2 do not lag behind native speakers on their visual word recognition performance. This is an important difference from findings on adult L2 speakers, whose orthographic word processing in L2 has been shown to be disadvantaged in comparison to their processing in L1 (de Groot et al., 2002; Bos, van den Eijnden, 2002; Ransdell & Fischler, 1987). In more general terms, this serves as evidence that the language in which initial reading acquisition takes place is crucial. Even though they are learning to read in their L2, child L2 speakers' word recognition system seems to be comparable in structure to that of native speakers. Yet, with respect to the impact of within-language characteristics, our data revealed qualitative differences in the mechanisms of lexical access. In the following, we will address the first three of our four research questions by separately discussing our findings with regard to the impact of frequency, length, and neighborhood size, respectively covering the mediating role of vocabulary size and reading fluency.

As expected, groups differed in size and shape of the FE, with a greater disadvantage for low frequency words in L2 compared to L1 speakers. Given that low frequency words, which for beginning readers are likely to be treated like nonwords, are most error prone, it is not surprising that this interaction only showed in accuracy scores and not in RT data. Following studies on the FE in bilingual adults (e.g., Brybaert, Lagrou, & Stevens, 2016; Cop, Keuleers, Drieghe, & Duyck 2015; Diependale et al., 2013), we explain this finding in terms of the lexical entrenchment account. Accordingly, due to their reduced exposure, L2 speakers' links between orthographic, phonological, and semantic representations are weaker, which in turn leads to greater processing costs especially for words that are naturally encountered less often. However, most of these studies have been conducted with adults that had acquired their L2 at the end of childhood, i.e. who had roughly had 10 years of L2 exposure at the time of testing. Thus, our findings show that already a few years of reduced oral exposure seem to be sufficient to cause a greater effect of frequency. Given that the time of print exposure at school is the same for both groups, it seems that differences in the language environment alone suffice to impact children's subjective frequencies. Most interesting, however, is the finding that the Frequency × Group interaction persisted after controlling for vocabulary size and reading fluency. This is in contrast to recent findings on the FE in adults, which show that once vocabulary size is taken into account, differences between L1 and L2 processing disappear (Diependaele et al., 2013). Consequently, our results point to the presence of a qualitative distinction between L1 and L2 processing at the beginning of reading development. Differences in the impact of frequency between child L1 and L2 speakers seem to be imputed to a factor over and above vocabulary size and reading fluency.

Similarly, word length had a greater inhibitory effect in L2 than in L1 speakers, which was primarily driven by words of longer length. While L2 speakers showed to be gradually impacted by length, L1 speakers' sensitivity to length decreased after the number of six letters was reached. Based on assumptions of the DRC model, we interpreted this as a greater reliance on the sublexical route in L2 compared to L1 speakers. Especially for children in the early stages of reading development, many of the words are new and thus treated like nonwords. Presumably, children process a word sequentially until they reach a certain orthographic uniqueness point, at which they switch from the sublexical to the lexical route and process the word as a whole. For L1 speakers, who rely on a large lexicon in their native language, decoding the first few letters of a word could be enough to initiate this switch. L2 speakers, who have less exposure to German, are less likely to detect this point of uniqueness, which is why they continue to process the word sublexically. As this difference becomes more pronounced the more letters there are to decode, this would explain why for short words groups did not differ in their performance. Given that differences in lexical versus sublexical processing are expressed by longer RTs as a function of the increasing number of letters, it is thus not surprising that we found the LE only in RT data and not in accuracy scores. Yet, the fact that the Length × Group interaction persisted after controlling for vocabulary size and reading fluency indicates again that an additional factor must be involved. We presume that given their smaller lexicon size L2 speakers have become accustomed to using the sublexical route to such an extent that even after their lexicon has grown they overly rely on it. Alternatively, L2 speakers' grapheme phoneme mapping could lack in automaticity. Given that they use a different language with a different phonology every day, they are likely to have more difficulties applying GPC rules than native speakers. Both accounts would explain a later shifting from sublexical to lexical processing in L2 compared to L1 speakers, which is reflected by their differences in the LE.

With respect to the impact of orthographic neighborhood size, surprisingly, we did not find a difference between groups. This result is in line with Lemhöfer and colleagues' (2008) findings, who did not observe a difference between monolingual and bilingual speakers in the impact of various measures of orthographic neighborhood either. Based on the inconsistency of findings from previous research on the NE, there are a number of possible explanations for the absence of this interaction in the present study. To begin with, the main effect of neighborhood size was rather small compared to the effects of frequency and length in our data, which indicates little likelihood for a difference between L1 and L2 speakers. Also, most studies reporting a NE manipulated neighborhood size and word frequency at the same time, finding effects mainly for low-frequency words (e.g., Andrews, 1989). Thus, the discrepancy in findings between mega studies and manipulation studies could be due to the modelling of neighborhood as a continuous predictor. In particular, the correlation of neighborhood size and word length is very high. Given that using mixed-effect models we assessed partial effects of length and neighborhood size at the same time, we believe that in our study effects of neighborhood size could be effects of length in disguise. In orthographically transparent languages, like German, readers are known to rely more on smaller units (graphemes, phonemes), whereas in opaque languages, like English, larger units (bodies, rhymes) are more reliable (Ziegler, Perry, Jacobs, & Braun, 2001). Therefore, variations in grain size between German and English could also account for different findings on the impact of neighborhood size. Especially in beginning readers, who do not yet have a large lexicon to rely on and thus depend on sublexical processing much more than skilled readers, word length seems to be of more relevance than neighborhood size.

Turning to our fourth research question, results showed that all effects persisted after the impact of grade was taken into account. After we expected group differences first to emerge in the course of reading development, to our surprise there was no change in the pattern of effects throughout elementary school. Although both groups started initial reading instruction in German at the same time, already in grade 2 differences in the impact of frequency and length were significant. These differences remained stable despite the fact that the lag of German print exposure in L2 speakers was likely to lead to an increasing disadvantage in orthographic processing in L2 over L1 speakers. This finding adds to the assumption that differences in the sensitivity to linguistic information between groups must be ascribed to a factor beyond exposure to print. This, in turn, provides evidence that lexical access in child L2 speakers is profoundly different from L2 speaking adults, who have been shown to perform like native speakers if language exposure is controlled for (e.g., Diependale et al., 2013). Analyzing adult lexical decision data by using a diffusion model, Brybaert, Lagrou, and Stevens (2016) recently found that even after vocabulary size was filtered out similar RTs in L1 and L2 were not achieved in the same way. Though the authors stated that effects were not strong enough to refute the lexical entrenchment hypothesis, they explained this finding by suggesting that lexical information might build up more slowly in L2 than in L1 speakers. Acknowledging the fact that this is open for debate, we would like to adapt this view as a possible explanation for our results. Yet, this raises the question why, on a global level, groups do not differ in their word recognition skills. Despite the fact that L2 speakers were more impacted by frequency and length than L1 speakers, and accordingly should have been disadvantaged on a task involving lexical access, they performed as fast and accurately on the LDT as their native speaking peers. We believe, for that reason, that child L2 speakers might have a way to compensate for their greater susceptibility to within-language characteristics. In line with theories on the advantages of child bilingualism on reading acquisition, such as a better conceptual understanding of language (Bialystok, 2001), we hypothesize that their word recognition system might be more flexible in nature. Although they differ from L1 speakers in the degree of automaticity when processing word frequency and length information, they might, for instance, benefit from orthographic cues that we did not focus on in the present study. Further research is needed to investigate which measures this could possibly be and whether a way of compensation like this can also be observed in other populations.

In summary, results of the present study show that though beginning readers in L2 rely on a word recognition system comparable to that of native speakers, there are significant differences in their sensitivity to linguistic information. In contrast to L2 speakers with prior reading experience in L1, children who start initial reading acquisition in their L2 do not lag behind native speakers in their overall word recognition skills. We could replicate the difference reported for the frequency effect in adult L1 versus L2 processing and further show that child L2 readers are more sensitive to word length information than their native speaking peers. Furthermore, our data provide evidence that in beginning readers differences in the impact of within-language characteristics are not mediated by vocabulary size or reading fluency but seem to be due to qualitative differences in the mechanisms of lexical access between L1 and L2 speakers. Future research needs to investigate what these factors are and why their impact is confined to individuals who start initial reading acquisition in their L2. It would also be of value to study whether bilingual children that simultaneously learn to read in both of their languages show the same effects. For the time being, the data we have provided give further insight into the development of word recognition processes and help to better understand reading acquisition in bilinguals. Especially given the increasing number of bilingual children who start schooling in their non-native language, knowledge as such is essential to foster child L2 speakers' reading skills.

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Chapter 4

Study 3

Orthographic Processing in Balanced Bilingual Children: Cross-Language Evidence from Cognates and False Friends

Abstract

We investigated whether beginning bilingual readers activate orthographic as well as semantic representations in both of their languages while reading in one of them. Balanced bilingual third-graders who were learning to read concurrently in German and English completed two lexical decision tasks, one in each language, including cognates, false friends, and matched control words. Results showed a processing advantage for cognates over controls in both languages, indicating that the facilitation effect is driven by the level of balanced language proficiency rather than by experience with print. Except for lower accuracy scores in German, false friends did not differ in their processing from controls, pointing to the presence of semantic-to-orthographic feedback already in the beginning of reading acquisition. Confirming assumptions by the BIA+ as well as the RHM, findings suggest that in their strategy to resolve orthographic ambiguity balanced bilingual children are more comparable to bilingual adults than to child L2-learners.

This chapter has been published in the *Journal of Experimental Child Psychology* (see Declaration for reference). Due to copyright restrictions pages 76 to 88 have been removed in the online version of the dissertation.

Chapter 5

Study 4

Exploring Early Language Detection in Balanced Bilingual Children: The Impact of Language-Specificity on Cross-Linguistic Nonword Recognition

Abstract

Recent findings on the mechanisms of lexical access suggest that bilinguals are sensitive to the orthographic structure of their languages. Several studies have demonstrated that if presented with language-specific sub-lexical information, bilingual adults use this information to speed up word recognition, which provides evidence for language selective lexical access. In the present study, we investigated the presence of such an early language detection mechanism in children. Forty-six balanced bilingual third-graders performed two seemingly monolingual lexical decision tasks, one in English and one in German, including nonwords with different degrees of word-likeness in each language. Accuracy scores and reaction times were analyzed for nonwords using mixed-effects models with the statistical software R. Results show no impact of language-specific sub-lexical information on children's performance in either task. We argue that bilingual lexical access is initially language-nonselective, and that sensitivity to language-specific orthographic structures first emerges over time. In contrast to bilingual adults, language detection in bilingual children is exclusively based on lexical information. The present study provides first data on the detection mechanism for language membership at the early stages of bilingual reading development. We are the first to demonstrate an important difference in the architecture of the bilingual lexicon between children and adults. Findings contribute to knowledge on the development of lexical access in bilinguals and pose limitations to the generalizability of the BIA+ extended model.

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Introduction

Within research on bilingualism, there is ample evidence that same-script bilinguals activate both of their languages when reading in one of them. Data collected over the past two decades have shown that in balanced bilinguals, who are equally highly proficient in two languages, visually presented words are simultaneously accessed in both of their languages (e.g., van Heuven, Dijkstra, & Grainger, 1998; van Hell & Dijkstra, 2002; Duyck, 2005; van Assche, Duyck, Hartsuiker, & Diependaele, 2009). Widely cited evidence for cross-linguistic activation is the cognate facilitation effect, which refers to the processing advantage for words that are orthographically and semantically identical in both of a bilingual's two languages. Within the frame of Interactive Activation (IA) models (McClelland & Rumelhard, 1981), the effect is commonly attributed to the fact that cognates share their semantic representation in the mental lexicon and thus reach their activation threshold sooner than matched non-cognates (e.g., Lemhöfer & Dijkstra, 2004). In contrast, inter-lingual homographs, which share their form but not their meaning between languages, have been found to cause null or even inhibitory effects effects (e.g., Dijkstra, van Jaarsveld, & Ten Brinke, 1998; Dijkstra, Grainger, & van Heuven, 1999; Dijkstra, Timmermanns, & Schriefers, 2000). Based on these findings, the current model of bilingual word recognition, the Bilingual Interactive Activation Plus model (BIA+; Dijkstra & van Heuven, 2002), postulates that bilingual lexical access is language-nonselective and based on an integrated lexicon. It states that upon the presentation of a visual letter string, sub-lexical orthographic representations are activated, which subsequently activate sub-lexical phonological representations as well as orthographic and phonological entries on the lexical level. These lexical entries, in turn, activate semantic representations and initiate the process of language detection through so-called language nodes. Yet, the mechanism by which a word is associated with a respective language is still unclear.

Supporting the view of language detection postulated by the BIA+, studies with same-script bilinguals have demonstrated that when the language context is ambiguous language information is accessed through the lexical representations of words (Chauncey, Grainger, & Holcomb, 2008; Dijkstra, Grainger, & van Heuven, 1999; Midgley, Holcomb, & Grainger, 2009a, 2009b; von Studnitz & Green, 2002). Language detection, therefore, has been assumed to be the result of top-down modulations from the language nodes feeding information back to the lexical level (Casaponsa, Carreiras, & Duñabeitia, 2015). Latest findings, however, suggest that balanced bilinguals are sensitive to the orthographic structure of their languages prior to word recognition. Recent studies have shown that if presented with language-specific cues – such as unique graphemes, more frequent bigrams, or larger orthographic neighborhood size – bilingual participants show reduced parallel language activation (e.g., Casaponsa & Duñabeitia, 2015; Casaponsa, Carreiras, & Duñabeitia, 2014; Lemhöfer & Dijkstra, 2004; Lemhöfer & Radach, 2009; van Kesteren, Dijkstra, & de Smedt, 2012). For instance, investigating the impact of language-specific versus language-nonspecific sub-lexical information, Casaponsa and Duñabeitia (2015) demonstrated that the absence of such cues promoted language-nonselective lexical access, whereas their presence reduced interference from the non-target language. The authors concluded that bilinguals develop fine-grained sensitivity to language-specific sub-lexical information, which lead to a different organization of lexical representations depending on the degree of language-specificity of the words. They hypothesized that mechanisms of lexical access might be shaped by sub-lexical distributional probabilities within and between languages. While in the absence of sub-lexical cues lexical access is language-nonselective, in their presence language-selective access is enabled. This, however, poses a challenge to the BIA+ as postulated by Dijkstra and van Heuven (2002). Addressing this challenge, van Kesteren, Dijkstra, and Smedt (2012) proposed to extend the model by adding sub-lexical language nodes. Accordingly, in addition to lexical nodes that are connected to the lexical level, there are sub-lexical nodes which can be directly accessed through excitatory connections from sub-lexical levels and then read out by the decision system. This way, depending on the presence or absence of language-specific sub-lexical cues, language detection can also happen prior to lexical access. Oganian, Conrad, Aryani, Heekeren, and Spalek (2015) further proposed the alternative view of a unique set of languages nodes that might accumulate lexical and sub-lexical information in parallel.

Notwithstanding ambiguities on the specific locus of language nodes, there is consensus on the fact that these nodes enable bilinguals to use sub-lexical information in order to detect the language membership of a letter string. Evidence for this account has been provided by reaction time studies using a range of different paradigms, including lexical decision (Lemhöfer & Dijkstra, 2004; Lemhöfer & Radach, 2009; Kesteren, Dijkstra, & Smedt, 2012), masked priming (Casaponsa & Duñabeitia, 2015), progressive demasking (Casaponsa, Carreiras, & Duñabeitia, 2014), and naming (Oganian et al., 2015), as well as by ERP experiments (Casaponsa, Carreiras, & Duñabeitia, 2015). Likewise, different markers for language membership have been studied. Exploring the nature of word-likeness, Bailey and Hahn (2001) compared measures of sequence probability and neighborhood size in their ability to explain empirical word-likeness judgements in English. Their results revealed a superior impact of neighborhood size relative to orthotactic and phonotactic measures. Oganian and colleagues (2015) further stated that in order to investigate language membership decisions in bilinguals, variables that are differently distributed between their two languages are especially relevant. Conducting a corpus analysis based on the German and the English Subtlex databases (Brysbaert, Buchmeier, Conrad, Jacobs, Boelte, & Boehl, 2011), they demonstrated that neighborhood size served as the best source of language membership information. More than 90% of words of each language had more orthographic neighbors in their language than in the respectively other one, whereas the distributions of bigram frequencies showed to have a high overlap between both languages. For the purpose of discriminating between the orthographic structures of German and English, therefore, it seems advisable to select neighborhood size over orthographic frequency measures.

A promising approach to investigate the effect of sub-lexical information is to study the processing of nonwords. A classical finding within this area of research is that in a lexical decision task (LDT) nonwords are rejected the faster the less word-like they are (Coltheart, Davelaar, Jonasson, & Besner, 1977; Forster & Shen, 1996). This observation was first explained by the Multiple Read-Out Model (Grainger & Jacobs, 1996) – an IA-type model which postulates that the more word-like a word is, the more representations (e.g. orthographic neighbors) it will activate. The underlying theory suggests that if at a certain point in time the search for a matching word candidate in the lexicon has remained unsuccessful, the stimulus will be rejected as a word. This temporal deadline is set later the more word-like a stimulus is. Within the framework of leaky competing accumulator models (Usher & McClelland, 2001), Dufau, Grainger, and Ziegler (2012) revised this theory by proposing a dynamic deadline account. Accordingly, the rejection of a stimulus as a word is equal to a constant value that optimizes the speed and accuracy in an LDT minus the activation of the stimulus as a word. Nonword recognition, hence, is a function of the amount of lexical activity generated by a stimulus. Manipulating the word-likeness of nonwords according to German and English neighborhood sizes, Lemhöfer and Radach (2009) asked German-English bilingual adults to perform a seemingly monolingual German, a monolingual English, and a mixed LDT. They found that English-like nonwords were more difficult to reject in the English relative to the German task, and vice versa. The authors concluded that the bilingual word recognition system makes a distinction between languages before their actual recognition or rejection. In line with temporal deadline accounts, German-like nonwords were less word-like in the English task, which is why their temporal deadline for rejection was set earlier than for English-like stimuli. In other words, the more English-like a nonword was in the English task, the harder it was for the recognition system to reject it as a word, and vice versa. In the mixed task, responses were generally slower, but participants reacted faster and more accurately to German-like compared to English-like stimuli. The authors explained this finding by the fact that participants were unbalanced bilinguals with a greater proficiency in German compared to English. They concluded that if stimuli resemble the weaker language, their temporal deadline is set later, which is why they take more time to be processed than stimuli resembling the stronger language. Taken together, Lemhöfer and Radach's findings indicate that rejection criteria for nonwords depend on the language context, which provides further evidence for the view that bilingual lexical access is language-selective if language-specific sub-lexical information is given.

So far, research on language detection in bilinguals has been exclusively conducted with adults. To the best of our knowledge, there is no study that has ever investigated early language detection in bilingual children. Exploring how the degree of cross-linguistic orthographic overlap influences bilingual word recognition at different stages of reading development, Duñabeitia, Ivaz, and Casaponsa (2016) recently demonstrated that the cognate effect as a marker for language co-activation declined as a function of increasing exposure to print. The authors interpreted these findings in terms of different language interference suppression skills of younger and older children. They hypothesized that in a still immature bilingual language control system top-down regulatory activity from the language nodes is impoverished, leading to a lack of inhibitory regulation at the lexical level. Yet, especially with regard to the development of sub-lexical language nodes as postulated by the BIA+ extended model, knowledge on the sensitivity to orthographic information in children is scarce. The goal of the present study was to fill this gap by investigating the presence of an early language detection mechanism at the beginning of reading development. Linking to previous research on nonwords, we conducted two language-specific LDTs, one in German and one in English, and manipulated nonwords according to their word-likeness in both languages. To rule out proficiency effects, we recruited balanced bilingual children who had started reading acquisition in German and English at the same time. We predicted that in a seemingly monolingual context, a fast-operating sub-lexical route sensitive to orthographic information would perceive differences in word-likeness. In other words, if bilingual children were sensitive to language-specific sub-lexical information like adults, lexical access would be language-selective. That is, in the English LDT, German-like nonwords, which activate less word candidates in English than English-like nonwords, should be rejected faster and more accurately than English-like nonwords. In the German LDT, the reverse should be true. If, on the other hand, there was no performance difference between German-like and English-like nonwords, this would be evidence for language-nonselective access. In that case, language-specific sub-lexical information would not be used to speed up the recognition process. This, in turn, would indicate that language detection in bilingual children depends on lexical information, which would argue for the absence of sub-lexical nodes in the early stages of the bilingual lexicon.

Method

Participants

Participants were recruited from a bilingual school in Berlin, in which the language of instruction was 50% German and 50% English. Forty-six third-graders (21 female, M = 7.65 years, SD = 0.48) participated in the study, which was conducted during regular school hours and comprised two sessions each lasting 45 minutes. As part of an admission requirement, all children proved to be fluent speakers of German and English upon entering school. At the time of testing, they had received 2 years of formal reading instruction in each language. All of them reported to use both languages equally on a daily basis and to have normal or corrected-to-normal vision.

To rule out sampling effects, we assessed nonverbal intelligence by administering the CFT 20-R (Weiß, 1998). Participants did not differ from the norm for monolinguals of the same age group (sample: M = 5.04, norm sample: M = 5.4, t < 1, p = .31). To ensure equal language proficiency, we measured vocabulary knowledge using the CFT 20-R Vocabulary Test (Weiß,

1998) for German and the British Picture Vocabulary Scale (Dunn & Dunn, 2009) for English. Both tests consisted of multiple-choice items that required participants to select the closest-matching equivalent for a given target word. The mean percentile was 30.0 (*SD* = 21.6) for German and 26.4 (*SD* = 20.9) for English. As often reported for bilingual children's vocabulary knowledge (Bialystok, Luk, Peets & Yang, 2010), scores were lower than the monolingual norm. Yet, results were comparable in German and English ($t < 1$, $p = .42$), which indicated equal vocabulary knowledge in both languages. Additionally, we assessed children's word and nonword reading fluency in each language through computerized speed reading tests, which require participants to name single words and nonwords as fast as possible. In German, the Salzburger Leserechtschreibtest (Moll & Landerl, 2010) for German revealed a mean raw score of 56.6 (*SD* = 24.3) for words and 36.2 (*SD* = 13.5) for nonwords. In English, the Test of Word Reading Efficiency (Torgeson, Wagner & Rashotte, 1999) yielded a mean raw score of 55.5 (*SD* = 16.8) for words and 36.1 (*SD* = 12.6) for nonwords. We interpreted these results as an indication for participants' equal reading fluency in both languages (all *t*s < 1).

Stimuli

Words for the LDTs were taken from the childLex corpus for German (Schroeder, Würzner, Heister & Geyken, 2015) and from the TASA corpus for English (Zeno, Ivens, Millard & Duvvuri, 1995), which are both solely based on children's literature. We selected 128 English and 128 German nouns that were matched on length and frequency. Nonwords were constructed from these words for each language separately using the multilingual pseudoword generator Wuggy (Keuleers & Brysbaert, 2010), which is based on an algorithm that replaces sub-syllabic elements (i.e. onset, nucleus, or coda) of words with equivalent elements from other words of the same language. To avoid language-unique graphemes, for each word ten nonwords were generated, from which we hand-picked the most optimal one. All nonwords were pronounceable, ranged from 3 to 8 letters ($M = 4.5$, $SD = 1.2$) and did not differ in length between English and German ($t < 1$).

Language-specificity was verified using two measures of orthographic neighborhood. Comparisons of orthographic neighborhood size (*N*; Coltheart, Davelaar, Jonasson, & Besner, 1977) and orthographic Levenshtein distance 20 (*OLD20*; Yarkoni, Balota, & Yap, 2008) for nonwords between the languages showed that nonwords had an overall greater lexical similarity to the language they were supposed to resemble. English-like nonwords had more orthographic neighbors and a smaller Levenshtein distance in English than German-like nonwords, and vice versa, as verified by one-sided *t*-tests (all *p*s < .03). Language-specificity was additionally validated through a rating study performed by respectively twelve adult native speakers of English and German. Participants rated nonwords according to their English- or German-likeness on a 5-point Likert scale in their respective native language. Results showed that English-like as well as German-like nonwords were rated higher in the language they were supposed to resemble (*p*s < .01). Characteristics for the final set of nonwords in both languages are provided in Table 1.

For each language, words and nonwords were randomly assigned to two lists each including 64 words and 64 nonwords. For nonwords, one of the two lists was then replaced with a list from the other language. That is, stimuli for the English LDT consisted of 128 English words, 64 English-like nonwords, and 64 German-like nonwords, while stimuli for the German LDT included 128 German words, 64 German-like nonwords, and 64 English-like nonwords. As in German nouns are always capitalized, English-like nonwords in the German LDT were capitalized, while German-like nonwords in the English LDT were uncapitalized. Due to a technical error, ten words had to be excluded from all analyses, because they were duplicates (3) or existing words (4) in each language. For the complete set of nonwords used in each LDT, see the Appendix.

Table 1

Characteristics of English-like and German-like nonwords.

	English-like nonwords	German-like nonwords
Length	4.6 (1.2)	4.5 (1.1)
Mean *N* in English	7.6 (7.4)	5.6 (6.2)
Mean *N* in German	4.6 (6.0)	7.6 (8.5)
Mean *OLD20* in English	1.7 (0.5)	1.8 (0.5)
Mean *OLD20* in German	1.9 (0.6)	1.7 (0.5)
Mean rating for word-likeness in English	3.2 (0.8)	2.3 (1.1)
Mean rating for word-likeness in German	2.3 (0.9)	3.2 (0.7)

Procedure

Participants performed two seemingly monolingual LDTs in a counterbalanced order. The experiment was conducted using IBM-compatible laptops, which recorded reaction times (RTs) automatically while participants used the keyboard to respond. Items were presented in Courier New font on a 15-inch TFT-screen in white 28-point letters on a black background. Children were instructed to decide whether or not a presented letter string formed a correct word in German (German LDT) or in English (English LDT), and asked to perform as quickly and accurately as possible. To further boost the level of activation of the target language, the language of instruction was English during the English LDT and German during the German LDT. For every language participants completed a practice block with four trials. Words and nonwords were randomly assigned to three blocks of 46 items each. Each trial began with the presentation of a fixation cross for 500 ms, followed by another 500 ms until the item appeared, which remained on screen until a response was given.

Results

Accuracy scores and RTs were analyzed for nonwords only using mixed-effects models (Baayen, Davidson & Bates, 2008) as implemented in the *lme4* package (version 1.0-4; Bates, Maechler, Bolker & Walker, 2013) in the statistical software *R*. RT data were log-transformed and analyzed using a linear model, while accuracy data were logit-transformed and analyzed using a generalized linear model with a binomial link function. Stimuli and Participants served as random effects, whereas Language (German nonwords vs. English nonwords) and Task (German LDT vs. English LDT) were included as fixed effects. Contrasts for post-hoc comparisons were estimated using the general linear hypotheses test generated with the *multcomp* package (Hothorn, Bretz, Westfall & Heiberger, 2014). To control for the impact of vocabulary knowledge and nonword reading fluency, we fitted two additional models by separately adding Vocabulary and Reading fluency as fixed effects. Factors were generated for each language by centering participants' raw scores of the tests on vocabulary knowledge and nonword reading fluency and included as main effects in the model.

Table 2 contains the mean results for English-like and German-like nonwords in both LDTs from the main model. There was a main effect for Task in accuracy data, $\chi^2(1) = 24.67$, $p < .01$, indicating that accuracy scores were higher in the German LDT than in the English LDT, which is a finding usually observed for transparent orthographies. Yet, there was no main effect for Language, $\chi^2(1) = 0.96$, $p = .33$, and no interaction between Language and Task, $\chi^2(1) = 0.04$, $p = .85$. These findings persisted after controlling for vocabulary and reading fluency in each language. For the RT analysis, incorrect trials and trials that deviated more than 2.5 *SD*s from either the stimulus or participant mean were discarded, accounting in sum for 18% of the raw data. There was neither a main effect for Task, $\chi^2(1) = 0.02$, $p = .88$, nor for Language, $\chi^2(1) = 0.46$, $p = .49$, in RT data. Although there was a tendency in the English LDT for German-like nonwords to be processed faster than English-like nonwords, the interaction between Language and Task, $\chi^2(1) = 0.98$, $p = .32$, did not reach significance. Again, these results persisted after controlling for vocabulary and reading fluency in each language.

To test whether the non-significance of our results actually points to the lack of language-specific sub-lexical processing in children, or merely indicates data insensitivity, we calculated the Bayes factor for general linear models. According to Dienes (2014), the Bayes factor compares the null hypothesis to an alternative hypothesis by providing a factor *B* by which the obtained results are more likely under the alternative than under the null. Dienes states that “Bayes factors allow three different types of conclusions: There is strong evidence for the alternative (*B* much greater than 1); there is strong evidence for the null (*B* close to 0); and the evidence is insensitive (*B* close to 1)” (p. 4). We calculated *B* for the RT model including the main effects of Task and Language and the Language × Task interaction while accounting for Participants and Stimuli as random factors. Using the function for general linear mixed effects models as implemented in the *BayesFactor* package (Morey & Rouder, 2015), B_{RT} was 0.02, indicating that our results provide support for the null hypothesis rather than for insensitive data.

Table 2

Mean RTs (in ms) and accuracy scores (in % correct) for nonwords in both LDTs (standard errors are given in parentheses).

	Reaction time		Accuracy	
	English LDT	German LDT	English LDT	German LDT
English-like nonwords	1742 (285)	1708 (279)	87.28 (4.27)	92.90 (2.67)
German-like nonwords	1692 (276)	1717 (280)	85.21 (4.88)	92.31 (2.85)

Discussion

The goal of the present study was to investigate the presence of an early language detection mechanism in balanced bilingual children. German-English bilingual third-graders performed two seemingly monolingual lexical decision tasks, one in each language, which each included German-like and English-like nonwords. We hypothesized that if children were sensitive to word-likeness as a language-specific cue, they would use this information to speed up their recognition process. Accordingly, English-like nonwords would be more easily identified as non-German words in the German LDT, and thus be rejected faster and more accurately than German-like nonwords. Given that participants were equally proficient in both languages, in the English LDT the reverse should be true.

Overall, results suggest that bilingual children are not sensitive to language-specific sub-lexical information. In both tasks, performance did not differ as a function of word-likeness, which indicates that children do not benefit from language-specific information on a sub-lexical level. This finding differs from observations on nonword processing in bilingual adults, who were found to be able to use orthographic cues in order to speed up the recognition process (e.g., Lemhöfer & Dijkstra, 2004; Lemhöfer & Radach, 2009). All results persisted after controlling for vocabulary and reading fluency in both languages, which rules out poor linguistic skills as an explanation for our findings. Also, the pattern of results was the same for German and English, which is what we expected to be the case in balanced bilinguals. We thus interpret our data as evidence for the absence of sub-lexical nodes in the early stages of the bilingual lexicon. With regard to the BIA+ extended model, we propose that initially there are only lexical nodes, and that sub-lexical nodes first emerge in the course of reading development. Accordingly, the fine-grained sensitivity to language-specific orthographic structures found in bilingual adults is the result of their extensive exposure to print in both languages. Based on the theory of statistical learning, beginning readers, in contrast, seem to not yet have the expertise to make use of this kind of information. This finding is in line with observations made by Duñabeitia, Ivaz, and Casaponsa (2016), who demonstrated that cross-language activation on the lexical level diminished in the course of reading development. Young bilingual readers showed a greater reliance on cross-linguistic similarity then their older peers, which the authors ascribed to their still immature language control system.

Our findings further suggest that the word recognition system in bilingual children solely relies on information on the lexical level. Whereas for bilingual adults it is assumed that the mechanisms of lexical access are shaped by sub-lexical stages of orthographic processing (Casaponsa & Duñabeitia, 2015), this view does not seem to hold true for children. In contrast to adults, who show language selective lexical access if language-specific information are given, our data provide evidence that lexical access in children is language-nonselective despite the presence of language-specific cues. This challenges the applicability of the BIA+ extended model for children, which predicts that orthographically salient information immediately activate language nodes, which are then read out by the decision system. Given the absence of sub-lexical language nodes in beginning readers, as we propose, children rely on lexical language nodes only. From this it follows that language detection in bilingual children depends on lexical information and thus can first occur at the (post) lexical stage in the word recognition process.

In sum, based on the present findings, we argue that bilingual lexical access is initially language-nonselective, and that sensitivity to language-specific orthographic structures first emerges over time. In contrast to bilingual adults, who demonstrate the ability to detect language membership at an early stage in the word recognition process, we found that language detection in bilingual children is exclusively based on lexical information. To conclude, the present study provides first data on the detection mechanism of language membership at the early stages of bilingual reading development. We are aware that our findings base on a limited set of nonwords and that replications are urgently needed to confirm results as well as to extend them with regard to different language combinations and age levels. Yet, we demonstrate an important difference in the architecture of the bilingual lexicon between children and adults, which poses limitations to the generalizability of the BIA+ extended model. Further research should therefore include direct comparisons between bilingual and monolingual children as well as adults. Especially given that in today's world more and more children are being raised bilingually, data such as that we have provided are important to better understand the development of bilingual reading.

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Appendix

Nonword Stimuli for LDTs in English and German.

English LDT

English-like nonwords

agleered, ath, bealing, bix, bize, burder, cally, cheems, cian, clissars, clobes, coneme, dag, debroo, doy, ducket, eak, evat, famiday, faquid, fengal, foom, foy, fuds, gath, geason, hant, homp, ith, lew, meaves, mized, moice, mook, mourt, municean, muth, nerm, nood, , palk, pean, phes, pight, pud, pum, rawn, rean, rike, selfand, sloon, sloor, smic, snirge, snode, soa, soat, sosh, sweel, tady, trawn, urage, wuns

German-like nonwords

bage, (bans), bauns, bips, blossig, borz, bute, dauge, fub, gein, gerl, (hams), heet, hehne, helb, hok, imme, japf, kalmt, kawe, keffe, kihi, laum, leed, meife, mims, nekien, nilete, nis, nuge, ogel, ohl, pafe, pahme, pauner, pazo, pids, plad, (pluck), posel, rahl, rak, relm, rolpe, sittam, sokat, sond, sor, spreme, tuwe, ubu, vakke, wehl, weik, woch, wosen, wotz, wuklimus, wutimer, zach, zaffel, zebel, zise, zotter

German LDT

German-like nonwords

Adrille, Baft, (Bags), Biet, Breif, Dage, Dilastor, Dist, Dite, Dond, Firg, Foge, Folz, Gaflik, (Gan), Gane, Gause, Giel, Goks, Henk, (Herk), Hest, Hiser, Hon, Irf, Junter, Kast, Kims, Kland, Kontus, Krock, Lans, Lis, Lumt, Mand, Ming, Moge, Nakafe, Noge, Nolf, Pand, Plie, Plin, Pok, Pulser, (Rit), Sarz, Spirm, Spoch, Stapem, Stebs, Stort, Stralt, Susid, Taf, Tam, Tenribel, Tock, Ulsel, Urm, Wond, Wose, Zafel

English-like nonwords

Angic, Awd, Awn, Bacel, Bame, Baw, Benane, Bestus, Bicer, Blee, Boof, Bove, Broaf, Catter, Crind, Dimaster, Fadric, Fank, Fism, Fobe, (Gan), Gice, Gope, (Herk), Hoke, Hud, Hur, Jit, Kide, Lale, Lape, Mish, Mude, Nace, Nesh, Noke, Nole, Nuncer, Nust, Oppriss, Pault, Plun, Ransible, Rish, (Rit), Rosh, Rudic, Sarn, Sath, Shiple, Snosh, Stape, Stewn, Stoth, Stoze, Strile, Tay, Tob, Toke, Vape, Wagh, Wibs, Woil, Woze

Note. Nonwords in parentheses were excluded from the analyses.

Chapter 6

General discussion

1. Summary of the results

The present dissertation set out to extend previous research on orthographic processing in bilinguals by investigating the impact of bilingualism on reading development in German. The main goals were to identify differences between monolingual and bilingual children in their developmental trajectories of reading, and to study the development of mechanisms specific to the bilingual lexicon. In a top-down manner, the four studies presented followed the process of reading from the surface of text comprehension via lexical processing down to sub-lexical processing. While studies 1 and 2 focused on sequential bilinguals learning how to read in their L2, studies 3 and 4 examined orthographic processing in simultaneous German-English balanced bilingual children. In the following, the results of the studies will be discussed with respect to the two main goals of the present research.

1.1 Developmental trajectories of reading in L1 and L2 speakers

The first goal of this dissertation was to examine whether and how beginning readers in L2 differ from their monolingual peers. Study 1 approached these questions by decomposing the process of reading and comparing L1 and L2 German speaking students on their performance on the letter, word, sentence, and text level. Additionally, the moderating effects of reading-relevant factors known to differ between monolinguals and bilinguals, namely linguistic and executive functioning skills, were taken into account. In study 2, group differences were analyzed for isolated word processing only, with a special focus on the impact of linguistic characteristics that represent benchmark effects in psycholinguistic research. Overall, results show that orthographic processing differences between L1 and L2 speaking children are surprisingly small. In the following, findings will be discussed in detail.

1.1.1 Differences in component processes of reading

Results from study 1 revealed that the gap in reading performance between L1 and L2 speakers frequently reported by international student assessments can be solely ascribed to differences in text processing. Even after controlling for participants socio-economic background, groups did not differ on tasks covering the letter, word, or sentence level. Assuming a bottom-up interrelationship of the separate levels, this means that L2 speakers lag behind their monolingual peers in reading scores because of their lower text representation and model refinement skills. This contradicts theories suggesting that the reason for text comprehension problems are inefficient low-level reading skills (e.g., Perfetti, 1985). Rather, L2 speakers seem to be comparable to poor comprehenders, who score lower on text comprehension tasks in spite of having age-appropriate decoding and parsing abilities. Future research on L2 reading should therefore address the impact of skills known to influence text comprehension beyond decoding and parsing, such as monitoring, inference and integration abilities, or knowledge about text structures (Oakhill, Cain, & Bryant, 2003).

Findings from study 2 did not only replicate the lack of group differences for isolated word processing, but further suggested that there were no changes to this pattern with age. Throughout the whole course of elementary school, L2 speakers did not differ from their monolingual peers in the LDT, neither in their reaction times nor accuracy scores, which implies that there are no quantitative differences in lexical access between L1 and L2 speaking beginning readers. This is in contrast to studies on biliterate adults, which found slower responses at RT tasks in bilinguals over monolinguals (e.g., Gollan et al., 2005) as well as in bilinguals' L2 over L1 (e.g., de Groot et al., 2002). We interpreted these results with regard to the role of initial reading acquisition. In beginning readers, whose mental lexicon is not yet fully developed, orthographic representations are created along with their connections to already existing semantic representations. Thus, even though they are learning to read in their weaker language, child L2 speakers develop a word recognition system comparable in structure to that of their native speaking peers. Adult L2 speakers, in contrast, already have a fully developed lexicon in their L1. As postulated by the RHM, conceptual access in L2 initially happens via their L1, which is reflected by an asymmetry in processing costs between L1 and L2. According to the BIA-d model, in the course of L2 acquisition this asymmetry levels out, until eventually connections between the integrated conceptual system and orthographic representations in L1 and L2 are equally strong. In conclusion, our data provide evidence that L1 and L2 speaking children do not develop differently in their word recognition skills, and that differences between the groups first arise at a later stage in the reading process, when inferences are needed in order to comprehend written language.

1.1.2 The effect of reading-relevant factors

Supporting the general finding that bilinguals have smaller vocabularies in both of their languages than monolinguals have in one of them, descriptive analyses from studies 1 and 2 revealed a gap between L1 and L2 speakers in their German vocabulary knowledge. The data further showed that this gap generalizes to other aspects of L2 use, such as reading fluency, verbal reasoning, and listening comprehension skills. While data from study 2 showed that group differences in the impact of linguistic characteristics were independent of this gap, performance discrepancies in text comprehension were not. After participants' linguistic skills were added as a mediating factor to the regression analyses in study 1, the difference between L1 and L2 speakers in reading on the text level disappeared. Results showed that text processing was almost as strongly impacted by participants' performance on the sentence level as by their linguistic skills. This implies that the decisive aspect for successful reading comprehension is not whether or not children are bilingual, but how well they have mastered the preceding component processes of reading and developed age-appropriate skills in language use. With regard to the interpretation of reading difficulties in L2 speakers, this conclusion is crucial. While other studies only controlled for children's socio-economic background and still found significant group differences (Müller & Stanat, 2006), results from study 1 demonstrate that if more linguistic domains of language use are taken into account, the reputed negative effect of L2 status on reading disappears completely. As a consequence, studies setting out to examine students' reading performance in international contexts would be well advised to assess a broad spectrum of participants' language abilities.

In comparison to linguistic skills, executive functions turned out to have no impact on group differences in reading. Results from study 1 showed that in none of the aspects of executive control, i.e. inhibition, shifting, and updating, L2 speakers differed from their native speaking peers. This finding adds to the growing evidence that the bilingual cognitive advantage in executive functioning does not generalize to individuals who speak two languages fluently. The lack of significant differences between groups in study 1 supports the view that beneficial effects only occur in simultaneous bilingual children who are equally highly proficient in both of their languages. Though the question remains whether improved executive functioning skills found in balanced bilingual children affect their acquisition of reading, results from the present research demonstrate that L2 speakers neither benefit nor suffer from any differences in cognitive skills. Regression analyses from study 1 showed that if the impact of linguistic skills is additionally taken into account, executive functioning only contributes to performance on the most basic, i.e. letter, level of reading, on which, in turn, L1 and L2 speakers do not differ from each other. In conclusion, even if L2 speakers had an advantage on executive functioning, this would not explain the gap found in text comprehension between the groups.

1.1.3 The impact of linguistic characteristics

Though there were no quantitative differences in word recognition between L1 and L2 speakers, results from study 2 revealed qualitative differences in the mechanisms of lexical access. In line with studies on adults, which have found greater effects for frequency measures in L2 over L1 processing (Brysbaert et al., 2016; de Groot et al., 2002; Lemhöfer et al., 2008), L2 speakers showed to be more sensitive to word frequency information than their monolingual peers. This interaction was mainly driven by words in the lower frequency range, which L2 speakers responded to less accurately than L1 speakers across all grades. Given that the time of language exposure at school is the same for both groups, this finding shows that differences in the language environment at home suffice to impact children's subjective frequencies. In contrast to findings on L2 speaking adults, however, differences in the frequency effect persisted after controlling for participants' vocabulary size and ready fluency. By implication, behavioral data from lexical decision in children cannot be merely interpreted in terms of the lexical entrenchment account, which postulates that processing differences between L1 and L2 can be fully explained by variations in language exposure. Though we consent to the authors of adult studies that the greater frequency effect in L2 over L1 can be ascribed to weaker representations in L2 due to reduced exposure, our findings indicate that, in addition, a factor other than vocabulary size and reading fluency must be involved.

As opposed to Lemhöfer et al. (2008), we also found an inhibitory effect for word length, which was greater in L2 compared to L1 speakers across all grades. While for short words groups did not differ in their performance, L2 speakers needed more time to decode longer words. Based on assumptions of the DRC model, we interpret these results in terms of a greater reliance on the sub-lexical route in L2 compared to L1 speakers. Given that at the beginning of reading acquisition many words are new and thus likely processed like nonwords, we assume that children read a word sequentially until they reach a certain orthographic uniqueness point, at which they switch from the sub-lexical to the lexical route and process the word as a whole. While for L1 speakers, who rely on a larger language-specific lexicon than L2 speakers, the first few letters of a word could be enough to initiate this switch, L2 speakers are less likely to detect this point of uniqueness, which is why they continue to process the word sub-lexically. In the course of reading development, they might become accustomed to using the sub-lexical route to such an extent that even after their lexicon has grown they overly rely on it. In other words, the transition from sub-lexical to lexical processing seems to happen earlier for monolinguals than for L2 speakers, which is a crucial finding for research on the developmental trajectories of reading in an orthographically transparent language. Interestingly, group differences in the sensitivity to word length information persisted after controlling for vocabulary size and reading fluency, which adds to the assumption that processing differences between L1 and L2 speakers are of a qualitative nature.

Given that both groups had no orthographic representations at the beginning of reading development, we further assumed that differences in the impact of linguistic characteristics between L1 and L2 speakers would first emerge in the course of reading development. Surprisingly, this was not the case. Despite the fact that the lag of German print exposure in L2 speakers was likely to lead to an increasing disadvantage in orthographic processing, the pattern of effects was stable throughout the course of elementary school. We interpreted this as another piece of evidence that differences in the sensitivity to linguistic information between groups must be ascribed to a factor that goes beyond vocabulary size, reading fluency, and exposure to print. This is in line with a very recent study conducted by Brysbaert and colleagues (2016), who analyzed adult lexical decision data by using a diffusion model and found that even after vocabulary size was filtered out similar RTs in L1 and L2 were not achieved in the same way. Though the authors stated that these effects were not strong enough to refute the lexical entrenchment hypothesis, they explained their finding by suggesting that lexical information might build up more slowly in L2 than in L1 speakers. In order to account for the presence of qualitative differences despite the lag of quantitative differences, we adapted this approach by proposing that L2 speakers lag behind their native speaking peers in their automaticity of orthographic processing. With regard to the length effect, for instance, L2 speakers, who use a different language with a different phonology every day, might have more difficulties applying GPC rules than native speakers, which manifests in longer RTs with longer words.

To explain why yet groups did not differ in their overall word recognition skills, we advocate the idea that child L2 speakers have a way to compensate for their greater susceptibility to linguistic information. In accordance with theories on the advantages of child bilingualism on reading acquisition, such as a better conceptual understanding of language (Bialystok, 2001), we propose that they might benefit from certain orthographic cues which facilitate L2 but not L1 lexical decision. Further research is needed to investigate which cues this could possibly be and whether a way of compensation like this can also be observed in other paradigms or populations.

1.2 The development of the bilingual lexicon

The second goal of this dissertation was to investigate the development of the bilingual mental lexicon, focusing on mechanisms that have been demonstrated to differ in balanced bilingual compared to monolingual adults. More specifically, we wanted to study whether bilingual children activate both of their languages while reading in one of them, and at what point in the word recognition process they associate orthographic information with a specific language. Study 3 investigated the parallel activation of orthographic as well as semantic representations by presenting third graders with German-English cognates and false friends in two seemingly monolingual LDTs. In study 4, we tested the presence of an early language detection mechanism by exploring children's sensitivity to language-specific sub-lexical information. In sum, our findings provide evidence for language-nonselective access on the lexical level as well as on the sub-lexical level, emphasizing the role of balanced language proficiency and time of exposure to print. In the following, the results will be presented in detail.

1.2.1 Parallel language activation

Findings from study 3 provided clear evidence that in balanced bilingual children both languages are activated in parallel and interact during orthographic processing already at the beginning of reading development. In contrast to studies on bilingual adults, we found an advantage for cognates in German as well as in English, which indicates that cognate facilitation does not depend on bilinguals' experience with print but occurs as a function of language proficiency. After the majority of previous research on cognates was conducted with dominant bilinguals, revealing effects of L1 on L2-processing but not vice versa, our data show that if participants are equally highly proficient in both of their languages, cross-linguistic interference works in both directions. This was also the case for false friends, which did not differ in their RTs from controls in either language. In accordance with the explanation put forward by Jared and colleagues (2012), we assumed that their benefit in co-activation on the orthographic level was annulled by their competing representations on the semantic level. Yet, given that at the same time cognates produced a processing advantage, the lack of facilitation for false friends provides evidence for the presence and usage of semantic-to-orthographic feedback in the early stages of the bilingual lexicon. As predicted by the RHM and the BIA-d model, this observation was the same in German and English because in contrast to L2 learners balanced bilinguals benefit from conceptual links that are equally strong in both languages.

Accuracy scores of study 3 revealed a small but significant inhibition effect for false friends in German but not in English, which corresponds to findings from studies with dominant bilinguals, who showed effects only in their stronger language. Despite our participants were controlled for equal proficiency and exposure to print in both languages, they recognized words overall faster and more accurately in German than in English. Given that children were recruited in a German speaking environment, we cannot rule out the possibility that though they reported to use both languages equally on a daily basis they were slightly more exposed to German. Another way to explain this finding goes in line with the orthographic depth hypothesis (Katz & Frost, 1992), which postulates that because of the more consistent letter-sound mapping in orthographically shallow compared to opaque languages, reading acquisition would be easier in German than in English. Taking these two views into account, German words could have either benefited from a higher subjective frequency or from their more transparent mapping between letters and sounds. In either way, faster lexical access in German compared to English would explain why inhibition for false friends only occurred in German accuracy scores. Assuming that the disadvantage for false friends is due to semantic competition, and that lexical access includes semantic-to-orthographic feedback, an inhibition effect arises the more likely the faster a word is lexically accessed. Thus, again, our results point to developmental differences in the mechanisms of lexical access as a function of language proficiency.

The fact that facilitation for cognates occurred despite their presentation together with false friends further demonstrates that as opposed to child L2 learners, whose lexical decision performance has been shown to be impeded by orthographic ambiguity (Brenders et al., 2011), balanced bilingual children have the capacity to simultaneously benefit from orthographic as well as semantic co-activation. This, in turn, provides evidence that with regard to their word recognition system balanced bilingual children are more comparable to bilingual adults than to child L2 learners. In sum, replicating results from studies with adults on language-nonselective access in children, our findings confirm assumptions by the BIA+ on an integrated lexicon and extend existing knowledge about the bilingual mental lexicon by a developmental perspective.

1.2.2 Language membership detection

While recently researchers observed language selectivity in bilingual adults if language-specific sub-lexical cues are available (e.g., Casaponsa & Duñabeitia, 2015), results from study 4 showed that in bilingual children this is not (yet) the case. In contrast to adults, children did not benefit from word-likeness as an orthographic cue to speed up their recognition process. In both LDTs, participants' performance did not differ between German-like and English-like nonwords, which we interpreted as evidence for their lack of sensitivity to language-specific sub-lexical information. Results from the RT and accuracy analyses showed that children were not able to use the language-specific structure of a German nonword to reject it as a word in the English LDT, and vice versa. Given that the pattern of results persisted after controlling for vocabulary size and reading fluency in both languages, we can rule out poor linguistic skills as a possible reason for this finding. This, in turn, indicates that bilingual children do not associate a letter string with a specific language until orthographic processing has reached the lexical level. While bilingual adults demonstrate the ability to detect language membership at an early stage in the word recognition process, language detection in bilingual children seems to be completely based on lexical information. Consequently, data from study 4 provides evidence that an early language detection mechanism such as found in adults does not yet exist in children, which illustrates an important difference in the architecture of the bilingual lexicon between children and adults. Based on the findings from study 3, we conclude that access to the word recognition system in bilingual children is exclusively language-nonselective in nature.

With regard to the BIA+ extended model, we interpret this finding as evidence for the absence of language-nodes on the sub-lexical level in the early stages of the bilingual lexicon. Assumingly, bilingual adults' sensitivity to language-specific orthographic structures is the result of their extensive exposure to print in both languages, in which children at the beginning of reading development naturally lag behind. In other words, sub-lexical language-nodes seem to develop as a function of reading experience, which challenges the applicability of the BIA+ extended model for children. In sum, the results from study 3 and 4 validate assumptions of the BIA+ as well as the BIA-d, but pose limitations to the generalizability of the BIA+ extended model. Future research needs to investigate whether this observation holds true for other bilingual populations with limited reading experience and how much exposure to print is necessary to find evidence for the presence of sub-lexical language nodes.

2. Conclusions

By investigating the source as well as the manifestation of differences between monolingual and bilingual children, the intention of this dissertation was to provide a better understanding of the impact of bilingualism on German reading development. Taken together, our findings indicate that overall bilingualism neither fosters nor impedes the development of word recognition in German. With regard to the first goal, we could show that differences in the trajectories of reading between L1 and L2 speakers are surprisingly small. Concerning the second goal, we could demonstrate that the age of reading acquisition shapes the way in which the bilingual lexicon develops. Summing up the outcomes of the four studies presented, there are three major conclusions. First, and most importantly, L1 and L2 German speaking children seem to acquire orthographic processing skills in largely the same way. Second, word recognition between the groups varies primarily with regard to their sensitivity to word frequency and length. Third, bilingual children differ from bilingual adults in the architecture of their word recognition system. In addition, the dissertation uncovers several methodological issues that should be beard in mind when conducting and interpreting research with bilinguals. In the following, the foundations and implications of these aspects will be elaborated in detail.

Data from studies 1 and 2 showed that, in sum, bilingual children recognize words neither slower nor less accurately than their monolingual peers. Given that for the processing of letters and sentences there are no differences between the groups either, it can be concluded that reduced oral exposure does not lead to a disadvantage in reading acquisition. By implication, schools which offer reading instruction in German only do not have to be concerned that enrolling L2 speaking children in regular German classes automatically makes them lag behind their native speaking peers. Given its shallow orthography, German seems to enable a steep learning curve, so that potential difficulties of children with less oral exposure at the very beginning of reading acquisition are not visible anymore by the time of grade 2. The only difference between L1 and L2 German speaking children draws on their text comprehension ability, which we have shown to be strongly impacted by linguistic skills. Though these are weaker in L2 speakers, they are not confined to the bilingual population. This, in turn, has implications for educational policy in Germany. Interventions to bridge the gap in reading literacy repeatedly reported by international assessments for L1 and L2 German students should target at L2 speakers' vocabulary knowledge and listening comprehension skills. At the same time, measures to improve reading performance should shift their focus from fostering L2 reading acquisition towards monitoring beginning readers more closely and promoting poor reader's development of their linguistic skills regardless of whether they are bilingual or not.

Zooming in on the mechanisms of lexical access, data from study 2 provide evidence that even though there are no differences in their overall word recognition performance, beginning readers in L1 and L2 develop different strategies to decode orthographic information. Differences in the impact of word length and frequency, which are not explained by variations in language exposure, point to the presence of a factor related to bilingualism that causes qualitative dissimilarities between L1 and L2 processing at the beginning of reading development. Though future research is needed to investigate this matter, this could be an indication of a bilingual benefit, such as increased flexibility of the word recognition system through enhanced meta-linguistic abilities. This, in turn, would favor theories on childhood bilingualism which postulate that speaking two languages bears the chance to facilitate reading acquisition, for instance, by means of improved phonological awareness. At the same time, it would refute Cummins' view that in order to benefit from bilingualism both languages have to be equally well developed. In other words, a potential disadvantage in L2 reading acquisition caused by a lower degree of automaticity in the mechanisms of lexical access could be compromised by bilingual children's advantage in the overall processing of language information. At present, it remains to be stated that children who start reading acquisition in their weaker language seem to have found a way to compensate for their greater sensitivity to linguistic characteristics. In conclusion, early bilingualism shapes the way in which mechanisms of lexical access develop.

With regard to the structure of the visual word recognition system, results from this dissertation indicate that the time of L2 reading acquisition as well as the time of experience with print play an important role. Based on the fact that bilingual adults have been shown to perform like native speakers if their differences in language exposure are controlled for, data from study 2 provide evidence that orthographic processing in child L2 speakers is notably different from L2 speaking adults. While late bilinguals, who have acquired reading initially in their L1 and later in their L2, seem to operate by using the same processing mechanisms in both languages, early bilinguals with initial reading acquisition in L2 develop mechanisms that are inherently different from those developed by beginning readers in L1. This limits the generalizability of the lexical entrenchment account, which is frequently used in bilingual research to explain performance discrepancies in comparison to monolinguals. Likewise, the present research poses limitations to the BIA+ extended model, which has recently been proposed to account for bilingual adults' ability to detect language membership in an early phase of the word recognition process. By demonstrating that in bilingual beginning readers access to the mental lexicon is exclusively language-nonselective, data from study 4 demonstrate that the structure of the word recognition system is subject to development, arguably along the lines of experience with print. Yet, replicating effects from studies with bilingual adults on cross-language interference, data from study 3 gives reason to assume that on the lexical level children and adults operate equally. In sum, the present dissertation confirms that the BIA+ is a viable way to explain behavioral word recognition data in children, yet points out several aspects in which orthographic processing mechanisms differ profoundly between bilingual children and adults.

Turning to the methodological implications for bilingual research, our data demonstrate the relevance of controlling for participants' type of bilingualism as well as for their skills in linguistic domains of language use. Results from study 1, which revealed the absence of enhanced executive functioning in dominant compared to balanced bilingual children, point out that when conducting or interpreting bilingual research, especially with a focus on cognitive aspects, special emphasis should be placed on the selection criteria of the sample. In addition to the critical role of language balance, findings from study 3 further show the impact of the manner of bilingual language acquisition. In comparison to studies with child L2 speakers, who have learnt their two languages sequentially (e.g., Brenders et al., 2011), simultaneous bilinguals demonstrated the ability to benefit from semantic information despite the orthographic ambiguity of the stimuli. Moreover, data from study 2 point to the importance of age of acquisition as a decisive factor for the development of the word recognition system, which seems to differ in its architecture between early and late bilinguals. Apart from these variations in the type of bilingualism, psycholinguistic research with bilinguals should place special emphasis on controlling for reading-relevant factors. After previous studies revealed a persisting effect of bilingualism on reading literacy even after accounting for bilinguals' smaller vocabulary size (e.g., Baumert & Schümer, 2001), results from study 1 show that after controlling for performance differences in verbal intelligence and listening comprehension as well, bilinguals did not differ from monolinguals on their text comprehension skills anymore. To endorse the view already proposed by Paap and Greenberg (2013), from this it follows that future research on orthographic processing in bilinguals would be well advised to develop a protocol with refined methodological conditions.

3. Limitations and final remarks

Needless to say, the research presented within the frame of this dissertation is not free from limitations. First, as pointed out previously, bilingualism as such is very hard to define. Though we payed special attention to the selection of our participants, there is no way to ensure that participants in studies 1 and 2 had the same language background concerning their manner and age of L2 acquisition. For instance, given that L2 speakers' native languages were very diverse, they were not controlled for their orthographic similarity to German, which yet has been shown to have an impact on phonological awareness as a key precursor of reading development (e.g., Bialystok, Luk, & Kwan, 2005). With regard to the early balanced bilinguals participating in studies 3 and 4, we are aware that this form of bilingualism is rather the exception than the norm, which, in turn, has implications for the generalizability of the results. Second, in all four studies word recognition was assessed by using the lexical decision paradigm, which presents one of the most established yet not only way to investigate orthographic processing, which leaves the question if results had been the same using different paradigms. Third, study 1 was conducted in the lab, which required children and, consequently, their parents to show greater individual initiative than compared to participants in studies 2, 3, and 4, who were tested in schools during regular class sessions. This fact could have compromised the representativeness of the sample, and also limits the comparability of L2 speakers in studies 1 and 2. Fourth, given the large scale approach of the data collection in study 2, we did not obtain information on individual reading experience prior to school enrollment, which especially in the case of L2 speakers could have accounted for performance differences in the LDT. Fifth, it is important to bear in mind that results from cross-linguistic studies, such as study 3, should be interpreted in view of the fact that languages differ in their orthographic depth and thus in their ease of reading acquisition. Inter-language comparisons, which are often based on tests that are sensitive to linguistic characteristics that, in turn, differ between languages, still pose a challenge to bilingual research and therefore should be treated with caution. Sixth, referring to the lack of significant differences between false friends and controls in study 3 as well as between German-like and English-like nonwords in study 4, we need to acknowledge that null effects do not provide a thorough foundation for drawing conclusions on general orthographic processing mechanisms. Especially given that most aspects of the presented research are strikingly new, replications are necessary to develop a reliable base of knowledge.

In sum, by introducing German language processing as a subject to research on word recognition in bilingual children, the present dissertation makes important contributions to the fields of bilingual development and German as a second language. As in today's world more and more children are growing up bilingually, findings such as the ones presented increase in relevance for a better understanding of the challenges beginning readers of German are faced with, and, ultimately, for the design of educational interventions. Future research needs to investigate whether findings transfer to other, also orthographically opaque, languages, and whether the factors that are still unclear can be identified by means of different methodologies, such as eye-tracking or neuro-imaging techniques. In order to draw a complete picture of the mechanisms of bilingual reading, the development of semantic, phonological, as well as syntactic processes should also become the object of further studies. Concluding from the results of the present dissertation, for the time being it remains to be stated that bilingualism shapes the development of the word recognition system and that therefore bilingual reading is a notable goal for scientific research in the future.

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Declaration

I hereby certify that the research presented in this dissertation is my own original work and has not been submitted for a doctoral degree to any other institution. I further confirm that all sources I have used are indicated and that the assistance I have received for the completion of this dissertation is appropriately acknowledged.

Pauline Schröter

Berlin, July 12, 2016

Chapters 2 and 4 from this dissertation have been published.
The Appendix was omitted in the online version due to copyright restrictions.

Schröter, P., & Schroeder, S. (2016). The Impact of L2 German on Component Processes of Reading. *Journal of Research in Reading.* http://dx.doi.org/10.1111/1467-9817.12078

Schröter, P., & Schroeder, S. (2015). Orthographic Processing in Balanced Bilingual Children: Cross-Language Evidence from Cognates and False Friends. *Journal of Experimental Child Psychology*, *141*, 239-246. http://dx.doi.org/10.1016/j.jecp.2015.09.005

Chapter 5 from this dissertation has been accepted for publication.

Schröter, P., & Schroeder, S. (2016). *Exploring Early Language Detection in Balanced Bilingual Children: The Role of Language-Specificity on Cross-Linguistic Nonword Recognition. International Journal of Bilingualism.*

Chapter 3 from this dissertation has been submitted for publication.

Schröter, P., & Schroeder, S. (under review). *Differences in Visual Word Recognition between L1 and L2: The Impact of Length, Frequency, and Orthographic Neighborhood Size in German Speaking Children.* Manuscript submitted for publication in *Studies in Second Language Acquisition.*

Appendix