The development of orthographic processing skills in children in early French immersion programs

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Children learning to read in two languages are faced with orthographic features from both languages, either unique to a language or similar across languages. In the present study, we examined how children develop orthographic processing skills over time (from grade 1 to grade 2) with a sample of Canadian children attending a French immersion program and we investigated the underlying factor structure of orthographic skills across English and French. Two orthographic processing tasks were administered in both languages: lexical orthographic processing (e.g. choose the correct spelling from people–peeple) and sub-lexical orthographic processing (e.g. which is the more word-like vaid–vayd?), which included both language-specific and language-shared orthographic regularities. Children’s performances in sub-lexical tasks increased with grade but were comparable across languages. Further, evidence for a one factor model including all measures suggested that there is a common underlying orthographic processing skill that cuts across measurement and language variables.

Keywords: orthographic processing; reading; French immersion; bilinguals; second language learners

1. Introduction

Worldwide estimates of multilingualism seem to suggest that there are more multilinguals than monolinguals in the world (Tucker 1999). Among the variety of contexts that can lead an individual to acquire a second language, the case of early immersion educational programs is an interesting situation for understanding reading acquisition in two or more writing systems. In early immersion programs, a second language is learned in both written and oral forms while children are
implicitly exposed to their dominant language in the society at large. The present study focuses on the case of Canadian children in a French immersion program who receive French instruction at school and are exposed to English in their daily life. The goal of the present study was to examine how orthographic processing skills, or “the ability to form, store and access orthographic representations” (Stanovich & West 1989: 414), in English and French change over time. Further, we evaluate whether these skills are developed specifically for a single writing system or in a manner that is shared across writing systems. A longitudinal design in which we followed the children from grade 1 to grade 2 enabled us to evaluate how these skills and their interrelationships might change over time.

The context of biliteracy learning raises the issue of the nature of the underlying processes of reading acquisition. Children in French immersion programs are exposed to multiple orthographic regularities; some of these are common to the two writing systems, while others are specific to one system. Note that here and throughout this manuscript, we use the term writing system to refer to the way in which a specific language is represented on the page.¹ For instance, word endings such as 〈ame〉 are shared across French and English in that they occur in both writing systems. In contrast, word endings such as 〈ough〉 occur in English and not French, and 〈ille〉 occurs at the ends of words in French and not English. Accordingly, these orthographic patterns may be considered to be language-specific since they occur in each of these writing systems only. Children’s sensitivity to language-shared and language-specific orthographic regularities may help them to establish orthographic representations. These might, in turn, support the development of fast, precise, and automatic mechanisms of visual word recognition (Ehri 1995; Perfetti 1992).

1.1 Orthographic processing skills

Orthographic processing skills, as referring to the ability to remember word spellings and regularities in letter sequences that is involved in the acquisition of successful reading² (Cunningham & Stanovich 1990; Juel, Griffith & Gough 1986), has been more and more considered as a multifaceted component that involves orthographic knowledge at various grain sizes (Castles & Nation 2006). Following this view, prior psycholinguistic research has considered two dimensions of orthographic processing skills: lexical and sub-lexical (Deacon, Benere & Castles 2012). Lexical orthographic skills (i.e. at the word level) are commonly assessed via the orthographic choice task which taps into word-level orthographic representations. In lexical tasks, participants are asked to choose the correct spelling between a word and its pseudo-homophone (e.g. rain – rane). The use of homophonic pseudo-word foils is to control for involvement of phonological processing
skills so that responses specifically tap what the participant knows about word spellings. Sub-lexical orthographic skills (i.e. at the sub-word level), which have received growing attention, may be assessed by a word-likeliness judgment task with pseudo-word items. Participants are asked to judge which of two pseudo-words is more word-like in a given writing system (e.g. daik – dayk where only \(<aik>\) may occur as a word ending in English). Ideally, the two pseudo-words used in the sub-lexical task are homophonic so that the task measures sensitivity to orthographic patterns rather than phonological plausibility or ease of decoding of the pseudo-words.

Using sub-lexical orthographic tasks, researchers have shown that both English and French monolingual children are sensitive to the position and identity of doublet consonants as early as in grade 1 (e.g. Cassar & Treiman 1997; Pacton, Perruchet, Fayol & Cleeremans 2001). For instance, Cassar and Treiman (1997) showed that first graders considered nonwords with allowable double consonants (e.g. \(<yill>\) more word-like than those with non-allowable doublets (e.g. \(<yihh>\)). Sensitivity to the letter-context of a given orthographic pattern has also been reported in both English and French (Pacton, Fayol & Perruchet 2005; Hayes, Treiman & Kessler 2006; Treiman & Kessler 2006; see Deacon, Conrad & Pacton 2008 for a review). Orthographic processing skills, as a whole construct, have been reported to predict significant variance in reading outcomes in monolinguals, after controlling for cognitive abilities, phonological awareness, or print exposure (Barker, Torgesen & Wagner 1992; Cunningham, Perry & Stanovich 2001). Nevertheless, it is not clear whether the lexical and sub-lexical dimensions are connected to reading in a similar way. Some researchers argue that lexical orthographic skills may be too closely related to reading outcomes and, in particular, to isolated word reading, leading to a circular relationship between the two skills (Burt 2006; Castles & Nation 2006; see also Deacon, Benere & Castles 2012). By avoiding this circular relationship, sub-lexical orthographic skills have been argued to be a more valid measure of orthographic processing (Castles & Nation 2006). There is increasing evidence that orthographic processing at the sub-lexical level is associated with reading development. And yet the issue of whether lexical and sub-lexical subcomponents of orthographic skills tap the same underlying construct is not clear (see Commissaire, Duncan & Casalis 2011). Cunningham, Perry and Stanovich (2001) examined several measures of orthographic processing of lexical and sub-lexical orthographic processes in children from grade 1 to 4. With a principal component analysis, they showed that all tasks were highly loaded onto one principal component which explained 60% of the variance. This finding suggests that orthographic processing skills could be considered as a unified theoretical construct, at least in monolingual children. This finding inspired us to conduct similar analyses in the present study with the performance of children learning to read two languages.
1.2 Orthographic processing skills across languages

Deacon, Wade Woolley and Kirby (2009) recently uncovered cross-language transfer of orthographic processing skills to reading in bilingual children learning to read in English and French, two languages represented with the same Roman alphabet. Lexical orthographic processing skills in one language predicted significant variance in reading outcomes in the other language, after multiple controls, in a bidirectional manner (see also Deacon, Commissaire, Chen & Pasquarella 2013; Deacon, Chen, Luo & Ramirez 2011). These findings differ greatly from those in prior research; several prior studies of bilinguals learning to read two languages in different scripts, such as Chinese and English, have found no correlation between L1 and L2 orthographic processing skills or transfer to reading across languages (Abu Rabia 2001; Arab-Moghaddam & Sénéchal 2001; Gottardo, Yan, Siegel & Wade-Woolley 2001; Wang, Park & Lee 2006). Taken as a whole, the evidence to date suggests that orthographic skills operate at a writing-system general level, specifically in that they transfer to reading when the languages are within the same script. As assumed by the linguistic interdependence hypothesis (Cummins 1979), this implies that orthographic processing skills might be considered as general metalinguistic processes that are available when learning to read an L2 of a same alphabet (e.g. Roman).

One step forward has been taken by more recent research which has turned to investigating whether sub-lexical dimensions of orthographic processing skills, that is the ability to extract regularities from a written language, are also language-general for children learning to read languages within the same script. In a study with Canadian children attending a French immersion program in grade 1, Deacon, Commissaire et al. (2013) manipulated the language-specificity of the orthographic features examined in a sub-lexical orthographic task (i.e. say which pseudo-word is more word-like). In the language-shared condition, the target orthographic patterns were legal in both French and English (e.g. *plame* – *plahme* where the target pattern *〈ame〉* occurs in both languages); in the language-specific condition, the target orthographic patterns were legal only in the language of the task (e.g. *rouve* – *rouvve* in the French task where the target rime *〈ouve〉* occurs in French and not English; *yead* – *yeadh* in the English task). Children were more accurate with language-shared than language-specific items suggesting that there is benefit of greater exposure. Notably, scores were similar in the French and English versions of the task, suggesting that both explicit and implicit exposure might support the development of orthographic sensitivity. With regard to cross-language transfer, language-shared English sub-lexical orthographic processing skills predicted significant variance in French reading outcomes. This finding adds to the growing body of evidence that orthographic processing skills,
both at lexical and sub-lexical levels, are related to reading outcomes in children learning to read in languages represented with the same alphabet (Deacon et al. 2009; Deacon, Commissaire et al. 2013). And yet, cross-language transfer was not clear-cut when considering the language-specific component of orthographic processing skills, possibly due to the multiple controls that were included in the regression analysis which reduced statistical power.

The findings of transfer of orthographic processing to reading across languages reflect that children who reach high orthographic performances in one language make use of this ability when learning to read in another language. This is underpinned by the idea that the orthographic processing skill itself should be related across languages, at least for children learning two languages that share the same Roman script. Given this, it is perhaps surprising that correlations between performance on orthographic processing tasks across languages are less than reliable. Significant correlations were found across languages for both lexical and sub-lexical (both language-shared and language-specific measures) components of orthographic processing skills in French immersion children attending grade 1 level (Deacon, Commissaire et al. 2013) and for lexical measures in grade 2 French immersion children (Deacon et al. 2009). In contrast, these relationships were not significant in other samples of bilinguals or second language learners (i.e. older children; see Commissaire, Duncan & Casalis 2011; Deacon, Chen et al. 2011). For example, in a study of French-speaking adolescents in grades 6 and 8 who learned English in secondary school, Commissaire and colleagues revealed that only the performance on the lexical measures of orthographic processing was related across languages, after controls for French reading and English vocabulary. In contrast, performance on the two sub-lexical measures did not correlate. This mixed picture of results to date suggests that it is worthwhile to further evaluate whether orthographic processing skill is related across languages for bilingual children.

1.3 The present study

The present study addresses the question of how orthographic processing skills in English and French develop and relate to each other in Canadian children attending a French immersion program. We followed the children longitudinally from grade 1 to 2. In this learning context, the children were learning to read two languages that use the same alphabet, a situation in which cross-language transfer of orthographic processing skills to reading has been observed in previous studies (e.g. Deacon et al. 2009; Deacon, Commissaire et al. 2013; Deacon, Chen et al. 2011). Lexical orthographic skills were assessed by an orthographic choice task (e.g. rain – rane). A word-likeliness judgment task (e.g. vaid – vayd) was used to evaluate sub-lexical orthographic skills. Language-specificity of the orthographic
patterns was manipulated in this task so that language-specific (e.g. 〈ough〉 and 〈ille〉 in English and French, respectively) versus language-shared (e.g. 〈ame〉) orthographic features could be contrasted.

Our first objective was to evaluate the development of sub-lexical orthographic processing skills, for both language-shared and language-specific features, in the two writing systems to which the children were exposed. Our prior findings with this sample in grade 1 showed that sub-lexical orthographic skills have already developed in grade 1, as indicated by the above chance performance of our sample (Deacon, Commissaire et al. 2013). In our prior study, the children were more accurate with the language-shared than the language-specific components at grade 1 (Deacon, Commissaire et al. 2013). In the present study, we tested whether this advantage for processing of the language-shared over language-specific items would still be observed at grade 2. This was expected to be the case given that exposure to language-shared orthographic patterns would still remain higher than for language-specific patterns. Furthermore, our prior research demonstrated comparable levels of sub-lexical skill in the two languages at grade 1 (Deacon, Commissaire et al. 2013). The present study evaluates the rate of development of sub-lexical orthographic processing skills in the two languages from grade 1 to grade 2. If sensitivity to orthographic regularities arises from explicit teaching of a written language, then we would expect French immersion children to perform better on the French as compared to the English sub-lexical orthographic processing task. On the contrary, if sensitivity to sub-lexical orthographic patterns emerges from implicit exposure to a written language (see Deacon, Conrad & Pacton 2008), then one could predict similarity in the development of French and English sub-lexical orthographic processing given the children's exposure to both written languages. To summarize, the present follow-up study enabled us to test the developmental course of sub-lexical orthographic processing skills.

Our second main objective was to evaluate whether orthographic processing skills develop in a general manner, both across lexical and sub-lexical tasks and across two languages represented within the same script. Prior research from Cunningham and colleagues (2001) suggests a single factor for lexical and sub-lexical measures of orthographic processing skills in monolingual English-speaking children and the present study enabled us to test again the degree of unity of these skills. There are no comparable investigations with bilingual children, with substantial variability in the correlations reported to date (e.g. Commissaire et al. 2011; Deacon, Chen et al. 2011; Deacon, Commissaire et al. 2013). The present study also offered the opportunity to test whether orthographic processing skills emerge in a manner that generalizes across a given script with a similar approach; using structural equation modeling (SEM), a powerful statistical approach to determine latent variables, we evaluated whether children's skills in
French and English formed a single factor or two separate factors. There could be two plausible patterns for the factor analysis. We could uncover a single underlying construct for the whole set of measures of orthographic processing skills, both lexical and sub-lexical and both English and French. Such a finding would suggest that the ability to extract orthographic regularities is common to both languages. Another possibility is that only the lexical and language-shared sub-lexical components form a single factor across languages, as suggested by the results of both Deacon, Commissaire et al. (2013) and Commissaire et al. (2011). Further, given that the children were followed longitudinally from grade 1 to grade 2, the developmental course of such underlying factor structure could also be examined.

2. Method

2.1 Participants

Seventy-three children (36 males) enrolled in a Canadian early French immersion program located in Southern Ontario participated in this study in the spring semester of grade 1 (as reported in Deacon, Commissaire et al. 2013) and again in the spring semester of grade 2. Children’s mean age was 6.28 (SD = 0.39) in grade 1. Seven children moved to different schools between testing points and did not participate in the grade 2 testing. In early immersion, children receive all school instruction in French at the beginning of senior kindergarten or grade 1 and they begin to receive part of their instruction in English only from grade 3. Accordingly, the participants’ first formal experience in learning to read was in French. As part of their regular curriculum, the children received direct instruction in phonological awareness as well as in the use of other reading cues. They received no formal instruction in reading or oral language in English in grade 1 or 2.

The majority of the sample (40 of the 73 children) spoke only English at home. Twenty-two children spoke English more than 50% of the time but did occasionally use another language at home. Ten children spoke English less than 50% of the time at home and only one child spoke English at home less than 25% of the time. Of the children who spoke a language other than English at home, the most common home languages were Hebrew, Russian, and Mandarin. Informal conversation (such as on the playground) between the children tended to occur in English, given that English was the first language of most children enrolled in this program. Exposure to English written language began early for all participants. Over 90% of parents reported starting to read with their children in English before 2 years of age. The rest of the parents reported starting to read in English with their children.
between 3 to 5 years of age. All parents read with their children at least once or twice a week, with the majority doing so almost every day. Additionally, 35% of the sample reported that their children read independently every day, where an additionally 40% reported independent reading at least one or twice a week. Finally, the remaining 25% reported reading independently at least once or twice a month. All children whose parents responded (98% of the sample) had at least ten English books in the home, with the majority having more than 100 children’s books. Further, teachers reported informally that the majority of children were enrolled in English kindergartens prior to beginning French immersion. Thus, there was substantial informal learning of English reading both before and after children entered the French immersion program.

2.2 Measures

2.2.1 Lexical orthographic processing

The lexical orthographic task assessed word-specific orthographic skills. Participants were asked to choose between alternative spellings for a target word (based on Olson, Forsberg, Wise & Rack 1994; e.g. dream – dreem for English, jaune – jeaune for French). The alternative spellings were constructed so that they shared phonological overlap with the target word and respected the graphotactic constraints of the language.

In grade 1, the English and French tasks were composed of 29 and 22 items, respectively. Cronbach’s alpha reliability was .69 for the French task and .88 for the English task. In grade 2, more difficult items were added to both the French and English versions so that ceiling effects were avoided. In grade 2, there were a total of 41 and 34 items for English and French tasks, respectively. All of the items are presented in Appendix A (*for the added items). The items in the English and French tasks were matched on length (mean length: 5.64 and 5.73 letters for English and French, respectively), number of syllables (mean number: 1.52 and 1.59 syllables), and size of orthographic neighborhood (mean size: 1.5 and 1.68, respectively). Importantly, according to child-based databases (English: Children’s Printed Word Database; Masterson, Stuart, Dixon & Lovejoy 2003; French: Manulex; Peereman, Lété & Sprenger-Charolles 2007), the words were also matched on printed frequency in the two languages (mean frequency: 131 and 160 occurrences per million for English and French, respectively), t (73) = 1.15, n.s. Cronbach’s alpha reliability was .79 for French and .82 for English.

2.2.2 Sub-lexical orthographic processing

Participants were asked to choose the more likely spelling for pseudo-words in either English or French (based on Cassar & Treiman 1997; Pacton et al. 2001).
In order to evaluate specifically orthographic and not phonological processing, all pseudo-words were homophonic within a pair according to the decoding regularities of the target language of the task (e.g. *doard* – *dowrd* for English and *doeur* – *doeure* for French). The alternative pseudo-word contained an illegal orthographic pattern according to both English and French graphotactic rules, either due to the illegality of a letter string (e.g. *froul* – *fhroul* where ⟨fhr-⟩ does not occur in either languages) or to the illegality of its position in the word (e.g. *caflé* – *ckafle* where ⟨ck-⟩ does not occur at the beginning of a word). Two sets of items were created for both the English and French tasks by manipulating the language-specificity of the target orthographic pattern: (1) language-specific and (2) language-shared.

In the language-specific condition, the target orthographic patterns were legal in the specific target language of the task only. For instance, pairs of items in the English task such as *gook* – *goock* contained the target orthographic pattern ⟨-ook⟩ which is legal in English only. In the French language-specific condition, we used items such as *dreyllle* – *dreyylle* where ⟨eille⟩ is a common body pattern in French.

In the language-shared condition, the target orthographic patterns were legal according to both French and English. For instance, the rime ⟨ame⟩ occurs in both languages and was contrasted to the orthographic pattern ⟨ahme⟩ which is illegal in both languages. Note that the same orthographic patterns (e.g. ⟨ame⟩ vs. ⟨ahme⟩) were used in the English and French tasks although they were combined with different initial consonants to reduce repetitiveness across tasks and to make the items more appropriate for each writing system. All of the items are presented in Appendix B.

Several criteria were followed when creating these pseudo-words. First, as noted earlier, all pseudo-words were homophonic within a pair and therefore, only orthographic processing could help discriminate between the two items. Second, none of the rime patterns corresponded to morphological units (e.g. *quickly*), avoiding multiple influences on participants’ responses. Third, the items were matched on grapheme to phoneme consistency. No difference was found between the language-specific and language-shared items, $F < 1$, n.s., and there was no interaction with the language of the task, $F(1, 52) = 1.693$, n.s. There was, however, a trend for higher grapheme to phoneme consistency in the French than in the English items, $F(1, 52) = 2.68$, $p = .11$, an observation which is consistent with the overall greater grapheme to phoneme consistency of the French than the English script (Ziegler, Jacobs & Stone 1996; Ziegler, Stone & Jacobs 1997).

### 2.2.3 English word reading

The Letter-Word Identification subtest of the Woodcock-Johnson III battery (Woodcock, McGrew & Mather 2001) was administered to assess English word
reading. In total, there are 76 items in the task. The first 16 require children to identify letters and the remaining 60 items corresponding to reading isolated words aloud that increase in difficulty. The task is discontinued when the participants misread six words consecutively.

2.2.4   English vocabulary knowledge
The Peabody Picture Vocabulary Test – Fourth Edition (Form A; Dunn & Dunn 2007) was administered to measure English receptive vocabulary. In this task, four pictures are presented and the participant chooses the picture that best corresponds to a target word that is presented orally. Two practice items are used to ensure the instructions are understood and the task is stopped when students incorrectly answer at least eight items in a set of twelve.

2.3   Procedure
Measures of lexical and sub-lexical orthographic processing were administered in English and French in both grades 1 and 2. Trained research assistants highly fluent in both English and French administered the measures to groups of approximately 20 children. English measures were administered before French measures and lexical measures were administered before sub-lexical measures; this was held consistently across grades 1 and 2.

3.   Results
3.1   Development of lexical and sub-lexical orthographic processing
Table 1 presents descriptive statistics for the lexical and sub-lexical measures of orthographic processing as well as the English word reading and vocabulary measures. Cronbach’s alpha as well as means and standard deviations are displayed for all measures. Means of percentage correct for the orthographic processing measures were used in the following analyses to aid interpretation of comparisons between measures and conditions. Standard scores are also presented for the English word reading and vocabulary measures; these measures have a standardized mean of 100 and a standard deviation of 15. On average, children scored one standard deviation above the mean on the word reading measures, suggesting an above average performance for the group. On the receptive vocabulary measure, the average standard score was at the average, suggesting appropriate grade level performance for this group of students.
Table 1. Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Cronbach’s alpha</th>
<th># of items</th>
<th>Raw (SD)</th>
<th>% Correct (SD)</th>
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<td></td>
<td></td>
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<tr>
<td>English Lexical OP</td>
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<td>28</td>
<td>19.13 (5.54)</td>
<td>.66 (.19)</td>
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<td>14</td>
<td>10.38 (2.81)</td>
<td>.74 (.20)</td>
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</tr>
<tr>
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<td>.65</td>
<td>14</td>
<td>9.64 (2.65)</td>
<td>.69 (.19)</td>
<td></td>
</tr>
<tr>
<td>French Lexical OP</td>
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<td>24</td>
<td>16.61 (3.65)</td>
<td>.69 (.19)</td>
<td></td>
</tr>
<tr>
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<td>14</td>
<td>9.85 (3.39)</td>
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<tr>
<td>French Sub-lexical OP Specific</td>
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<td>9.36 (2.89)</td>
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<tr>
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<td>10.59 (2.64)</td>
<td>.76 (.19)</td>
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*Note: OP = Orthographic Processing; SS = Standard Score*

3.1.1 **Lexical orthographic processing**

A 2 (time: Grade 1, 2) × 2 (language: English, French) repeated measures Analysis of Variance (ANOVA) was used to examine changes in lexical orthographic processing for English and French across grades 1 and 2. There were significant main effects of time, $F(1, 70) = 86.69, p < .001, \eta = .553$, and language, $F(1, 70) = 7.631, p < .001, \eta = .098$, but no significant interaction. Across grades 1 and 2, children’s scores in lexical orthographic processing significantly increased. Moreover, children scored significantly better in French lexical orthographic processing than English lexical orthographic processing.
3.1.2 Sub-lexical orthographic processing

A 2 (time: Grade 1, 2) × 2 (language: English, French) × 2 (condition: shared, specific) repeated measures ANOVA was used to examine changes in sub-lexical orthographic processing for English and French across grades 1 and 2. The only significant main effects were condition, \( F(1, 70) = 42.78, p < .001, \eta = .379 \), and time \( F(1, 70) = 20.26, p < .001, \eta = .224 \). There was no main effect of language or any significant interaction. From grade 1 to grade 2, children significantly improved on the sub-lexical orthographic processing measures in English and French. Children consistently scored higher on shared versus unique conditions of orthographic features in English and French across grades 1 and 2.

3.2 Comparison of factor models of French and English orthographic processing

We used structural equation modeling (SEM) to compare factor models to examine the extent to which orthographic processing in French and English formed multiple factors or a single factor in grades 1 and 2. Using maximum likelihood estimation, four different models were tested in grades 1 and 2. The models tested were: (1) a three factor model with a French orthographic specific factor, English orthographic specific factor, and a shared orthographic factor; (2) a two factor model with French and English orthographic processing as unique factors; (3) a two factor model with lexical and sub-lexical factors across French and English, and (4) a one factor, cross-language orthographic processing factor. Factor models were constructed and tested separately for grades 1 and 2. Theoretical models are shown in Figure 1.5

Table 2 presents fit indices that were used to examine model fit of the four different models. The left side of Table 2 presents grade 1 fit indices and the right side presents grade 2 fit indices. A \( \chi^2 \) to \( df \) ratio < 2 and a Comparative Fit Index (CFI) > .95 suggest good fit. The Root Mean Square Error of Approximation1 (RMSEA) values ≤ .05 suggest good fit and values ≥ .10 suggest poor fit. The Akaike Information Criteria (AIC) was also examined as an additional index where lower numbers are preferred over higher numbers. As the AIC values decrease, the proposed model is a better representation of the data (Arbuckle 2009; Browne & Cudeck 1993; Kenny, Kashy & Cook 2006). All four models had good fit statistics in grades 1 and 2. However, the three factor model (Model 1) and the two factor model with lexical and sub-lexical factors across French and English (Model 3) had correlations among latent factors larger than 1, in both grades 1 and 2. Therefore, these models displayed Heywood Cases making the factor solutions inadmissible. Heywood cases occur when estimates are produced.
Figure 1. Theoretical factor models of orthographic processing

that are outside acceptable (and possible) boundaries, for example, standardized coefficients larger than 1. If a solution cannot be reached, then a model is deemed inadmissible. Often, a solution to Heywood cases is to impose constraints on coefficients so that they are equal; however, these constraints are generally placed on factor loadings (Bollen & Davis 2009; Kenny, Kashy & Cook 2006). Given that the standardized coefficients among latent factors were larger than 1, constraining parameters among the different latent factors is not a logical solution, thus making Models 1 and 3 inadmissible.

Further model comparisons were then made between Models 2 and 4 to determine the most parsimonious model which fit the data best. While Models 2 and 4 displayed good fit statistics, there was an advantage for Model 4 as the $\chi^2/df$ ratio and the AIC were lower than Model 2. The improved fit statistics for Model 4, in comparison to Model 2, suggests that Model 4 is the preferred model as it explains
the data best. Model 4 was consistently a better fitting model in both grades 1 and 2. Additionally, the latent factors in Model 2 where strongly correlated at .79 in grade 1 and .75 in grade 2, suggesting that even when a 2 factor solution was imposed on the data, there is a high degree of alignment between the latent factors of French and English orthographic processing in both grades 1 and 2. Thus, Model 4 (the one factor model) emerged as the preferred model in both grades 1 and 2 as it was the most parsimonious model that best explained the data. The SEM factor analyses described a one factor solution as providing the best fit statistics in comparison to all other models, suggesting that lexical and sub-lexical orthographic processing in French and English form a common latent factor in the early elementary grades.

Table 2. Model fit indices for grades 1 and 2

<table>
<thead>
<tr>
<th>Model</th>
<th>Grade 1</th>
<th>Grade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>χ²</td>
<td>df</td>
</tr>
<tr>
<td>1. Three Factor Model</td>
<td>4.91</td>
<td>4</td>
</tr>
<tr>
<td>2. Two Factor Model</td>
<td>6.16</td>
<td>6</td>
</tr>
<tr>
<td>3. Two Factor Model</td>
<td>6.22</td>
<td>7</td>
</tr>
<tr>
<td>4. One Factor Model</td>
<td>6.22</td>
<td>7</td>
</tr>
</tbody>
</table>

Note: AIC = Akaike Information Criterion, RMSEA = Root Mean Square Error of Approximation, CFI = Comparitative Fit Index

Figure 2 presents the factor loadings of Model 4 for orthographic processing in French and English in grades 1 and 2. Factor loadings ranged from .56 to .87 and variance explained in the observed variables ranged from .31 to .74 in grade 1. Factor loadings ranged from .55 to .94 and variance explained in the observed variables ranged from .33 to .89 in grade 2. Figure 2 also displays the significant correlations between error variances. Correlations among error variances refer to method or measurement effects not captured by the common factor (Eid 2000; Eid, Lischetzke & Nussbeck 2006). Error variances for lexical measures between French and English were significantly correlated in grade 1 (β = .52, p < .001) and grade 2 (β = .43, p < .001). Furthermore, the French sub-lexical language-specific and shared conditions correlated in grade 1 (β = .53, p < .001) and grade 2 (β = .54, p < .001). English sub-lexical error variances were not significantly correlated with each other, possibly because of the high amount of variance captured by the latent orthographic processing factor. No other significant correlations were found between error variances between measures.
Figure 2. One factor model of lexical and sub-lexical orthographic processing in French and English, showing significant paths only.
4. Discussion

This longitudinal study investigated orthographic processing skills in Canadian children attending a French immersion program from grade 1 to grade 2. We evaluated both lexical orthographic skills (i.e. at the word-level, rain – rane) and sub-lexical orthographic skills (i.e. at the sub-word level, vaid – vayd). We had two main objectives. First, we examined the development of sub-lexical orthographic processing skills in English and French. Second, we examined the extent to which commonalities among the whole set of orthographic measures could be observed.

4.1 Development of orthographic processing skills

To address our first objective on the development of sub-lexical orthographic skills, above-chance performance shows early development of sub-lexical orthographic processing skill after only a few months of schooling. That said, children continue to learn about orthographic skills through to grade 2 and likely for several years to come (see also Commissaire et al. 2011; Pacton et al. 2001). Further, children were more accurate with the language-shared items over the language-specific items in the sub-lexical task, across both grade levels. As also demonstrated in our prior study at the grade 1 level (Deacon, Commissaire et al. 2013), children in grade 2 scored higher on items with shared letter patterns across English and French as compared with items with specific letter patterns to an individual writing system. This finding could easily be explained in terms of greater input for the language-shared patterns. More research is needed to further examine how the degree of (dis)similarities among writing systems could also help to highlight the specificities of each language and thus contribute to the development of orthographic skills.

We also compared the rate of development of sub-lexical orthographic processing skills in the children’s two languages. Children reached similar levels of performance across grades 1 and 2 in English and French on the sub-lexical orthographic task. Though a null result should always be interpreted with caution, this result could suggest comparable development of these skills in English and French. In our view, this suggests that explicit exposure to the written language through formal teaching of the language is not the only vehicle through which learning of sub-lexical orthographic regularities occurs; orthographic learning at the sub-lexical level might also occur through implicit exposure. This interpretation is in line with statistical approaches of orthographic learning which suggest that implicit exposure to the written input leads to progressive extraction of the regularities of the orthographic system (Deacon, Conrad & Pacton 2008; Pacton et al. 2001).

As we discuss language similarities in sub-lexical orthographic processing skill, we also need to address our finding that the children scored higher on the
French as compared to the English lexical orthographic task. Though the items in this task were matched on several dimensions including printed frequency, this matching was based on English and French as L1 databases that possibly do not reflect printed frequencies in immersion programs. So, this advantage that we found for the French as compared to the English task might be explained by other factors such as differences in the familiarity or regularity of the grapheme to phoneme mappings of the items, entailing different levels of difficulty for the two tasks. Further, the advantage in the French lexical task could also be due to the explicit nature of French learning at school. By emphasizing decoding skills, the formal teaching of the French written language would possibly enhance orthographic skills at the word-level (Share 1995), more than when implicitly exposed to a written language as is the case for English. So, it is possible that explicit learning, and associated larger decoding experiences, is important when considering the development of word-level orthographic skills while not for sub-lexical aspects of orthographic skills. Future studies should explore the underpinning processes of orthographic learning in immersion program contexts and compare the processes (e.g. successful decoding, prior letter knowledge) between the two writing systems to which bilingual children are exposed.

4.2 Relationship of orthographic processing across languages

Our next goal in the present study was to evaluate the relationships between the different components of orthographic processing across the two languages. A common factor analysis (Widaman 1993, 2007) was used in order to assess the latent factors underlying orthographic processing skills in English and French, at both lexical and sub-lexical levels. We conducted two analyses, one at each grade, to capture potential developmental trends. The best fitting model at both grades was a one factor model for which the pattern of relationships among the measures were similar for grade 1 and grade 2. This pattern suggests that orthographic skills in English and French, the two writing systems that children are exposed to, are at least partly underpinned by similar processes, a result which indirectly supports the finding of cross-language transfer from orthographic processing to reading for children learning to read languages within the same script (Deacon et al. 2009; Deacon, Commissaire et al. 2013). Indeed, the fact that orthographic processing skills in one language may significantly contribute to reading outcomes in another language might be conceived as in part reflecting the commonalities between orthographic skills across languages. As for the precise level at which cross-language transfer may occur, i.e. knowledge and/ or skill levels (Koda 2000), our data suggest that what transfers across languages is not only knowledge of specific individual features shared between writing systems but also at a more general
skill level, partly independent of the orthographic features at stake – though within the same script.

Interestingly, measures of orthographic processing skills at both the lexical and sub-lexical level significantly loaded onto this single latent factor. Further, this was observed for language-shared items as well as language-specific ones in the sub-lexical task. These results seem to suggest that comparable processes underlie the different sub-components of orthographic processing even when the orthographic regularities under investigation are specific to a single writing system. Retrieving word-level orthographic information and recognizing word-likeliness of sub-lexical orthographic patterns might require, to some extent, the same underlying processing skills. This observation, congruent with findings from Cunningham and colleagues (2001) with monolingual children, presents a unified concept of orthographic skills. However, in a study that examined older English (L2) learners attending grades 6 and 8, Commissaire et al. (2011) found correlations across languages for the lexical but not sub-lexical orthographic measures. Such diverging results need to be addressed by future inquiry into orthographic patterns across different second language learning contexts.

The correlations of error variances between English and French lexical measure and the French shared and specific sub-lexical conditions point to measurement effects between lexical and sub-lexical items. Children might be using slightly different strategies when completing the lexical and sub-lexical measures. Vocabulary knowledge and word recognition can aid decisions on the lexical tasks, as many of these words were known by children, while sub-lexical tasks may rely on finer-grain knowledge of orthographic patterns and decoding in French. Although lexical and sub-lexical measures of orthographic skills load onto a single latent factor in the present study, future studies might investigate possible method and task level differences.

4.3 Limitations and implications

Limitations in our study must be considered in relation to the measures that were used and the sample under investigation. Our orthographic measures have some strengths and some weaknesses, too. Our finding of improvement on the sub-lexical tasks between grades 1 and 2, along with the satisfactory psychometric quality of the measures, provides a validation of the sub-lexical tasks used in the present study. These appear to capture orthographic skills and their development over time, without reaching ceiling levels, at least through to grade 2. Further, the sub-lexical tasks were well controlled on a number of dimensions. That said, some variables could not be controlled, especially due to stimuli constraints and the type of exposure the children received from each language. In the lexical orthographic
tasks, it is possible that there were subtle differences in the familiarity and frequency of the items between English and French, leading to better performance in the French task than the English task. With respect to the sample, the multicultural nature of the Canadian society led to the inclusion of children for whom English was not their first language in the French immersion program. Yet, both reading and vocabulary scores of these children were comparable with English first language children and multiple statistical controls were embedded into the SEM models which ensured that our findings were not biased by this particular aspect of our data.

Despite the limitations, our study has important theoretical implications. Findings of the present study confirm our prior study (Deacon, Commissaire et al. 2013) by showing that learners of two languages rapidly develop multiple orthographic skills and this happens at a younger age than predicted by theories of reading acquisition (Ehri 1995). Not only do children quickly learn to decode new words but they also acquire orthographic processing skills rapidly, at both the lexical and the sublexical dimensions (see Martinet, Valdois & Fayol 2004 and Pacton et al. 2001 for additional evidence in monolinguals). This observation is in line with monolingual research by Share (1995) suggesting that relatively little exposure to a visual input is necessary for developing an orthographic representation. The extent to which these orthographic skills may be dependent upon decoding skills remains unanswered. Future research should address this issue by examining the relationships between decoding and/or phonological skills with both lexical and sub-lexical dimensions of orthographic skills, in both languages of immersion children.

Further, our findings of a one factor model of orthographic processing skill seem to be in favour of a language-general view of orthographic skills, specifically one that emerges across two languages that share the same alphabet. As previously described for other metalinguistic skills such as phonological awareness (see Koda 2007 for a review), orthographic skills might be considered as a common skill underlying both dominant and nondominant literacy experiences, at least in the context of learning two languages represented by the same alphabet. The finding that even language-specific conditions of the sub-lexical orthographic measure loaded onto one single factor seems to suggest that common skills are required to extract orthographic regularities, whether they are shared between the two writing systems or are specific to one of the writing systems. This unified factor structure also increases our understanding of the nature of cross-language transfer of orthographic processing skills to reading (Deacon et al. 2009; Deacon, Chen et al. 2011; Deacon, Commissaire et al. 2013). As previously discussed, the connection between orthographic processing in one language and reading in the other language may be partially based on the association between orthographic processing across the two languages.
In terms of educational implications, our finding of early development of orthographic processing skills suggests that it might be useful for teachers to help the children extract the orthographic regularities of each of writing systems in which they are learning to read. Emphasizing these orthographic features might help children extract the similarities and dissimilarities between the two languages, thereby improving their awareness of the formal aspects of the languages. The findings of commonalities between orthographic skills in English and French also suggest that it might be worthwhile to make explicit connections between formal teaching of these two languages, once English is introduced in the curriculum. These suggestions are speculative and require confirmation with intervention studies.

Notes

1. Note that in our previous work (Deacon, Commissaire, Chen & Pasquarella 2013), we used the term ‘writing system’ to refer to the way in which a group of languages that share the same representational system is represented on the page (e.g. English and French are within the same writing system as they are both represented with Roman characters). Here, following a distinction more common in the study of written language, we use the term ‘writing system’ to refer to the specific manner in which a single language is represented on the page.

2. Note that the term ‘orthographic processing’ (also called ‘orthographic coding’) may also refer to the on-line process involved during reading isolated words which involves the fast and automatic mapping of the written input to representations of letters, bigrams, and words. The extent to which this on-line reading process is related to the metalinguistic skills or knowledge that are assessed with off-line tasks remains unfortunately little addressed in the field (see Burt 2006).

3. Examination of the English and French lexical orthographic performances led to removing some of the items when too difficult (see Deacon, Commissaire et al. 2013).

4. Phoneme to grapheme consistency of the items was also checked (Ziegler et al. 1996, 1997). Yet, given the items were presented visually, this variable was of less relevance than that of grapheme to phoneme consistency. Items in the French and English task were matched on this criterion, with no interaction between the language of the task and language-specificity, all Fs < 1, n.s. Given strong constraints on item selection, we could not avoid having the items in the language-shared items more consistent in terms of phonology to orthography conversion than those in the language-specific condition, F(1, 52) = 4.024, p < .05.

5. The four models were tested for the influences of English word reading and vocabulary knowledge on the measures of lexical and sub-lexical orthographic processing. Given that these variables did not impact on the fit statistics, factor loadings, or parameter estimates, these were not included in the figures or the models presented below to simplify the results.

The pattern of error variance correlations was identical across all versions of the factor models tested in Table 2.
6. We thank an anonymous reviewer for pointing out another explanation to this advantage for the language-shared patterns over the language-specific patterns. It could be that language-shared patterns were more common than language-specific ones within each of the writing systems under study. Using the Lexique and the CPWD databases in French and English, we checked our stimuli by examining the properties of the monosyllabic words that contained the target pattern in both English and French. We found that although more words contained the language-shared as compared to the language-specific patterns ($p < .05$ in both languages), language-shared and language-specific target patterns were matched within a language according to the summed frequency of all words that contained the target patterns ($p > .10$, n.s) and according to the frequency of the higher frequent word that contained that specific target pattern (that could have been reminded to perform the task, $p > .10$, n.s.). This good matching would tend to support our interpretation of this advantage as reflecting a greater input for the language-shared patterns in bilinguals.

References


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Appendix A

Items in the lexical orthographic processing tasks. Note that *represents those items that were added to the task in grade 2

**English Task**


**French Task**


Appendix B

Items in the sub-lexical orthographic processing tasks

**English task**


**French task**


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