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Reading and Spelling Development Across Languages Varying in Orthographic Consistency: Do Their Paths Cross?

IN PRESS

CHILD DEVELOPMENT

Abstract

We examined the cross-lagged relations between reading and spelling in five alphabetic orthographies varying in consistency (English, French, Dutch, German, Greek). Nine hundred forty-one children were followed from Grade 1 to Grade 2 and were tested on word and pseudoword reading fluency and on spelling to dictation. Results indicated that the relations across languages were unidirectional: earlier reading predicted subsequent spelling. However, we also found significant differences between languages in the strength of the effects of earlier reading on subsequent spelling. These findings suggest that, once children master decoding, the observed differences between languages are not related to the direction of the effects but to the strength of the effects from reading to spelling. Theoretical and practical implications are discussed.

Keywords: reading, spelling, orthographic consistency, longitudinal, cross-linguistic.

Reading and Spelling Development Across Languages Varying in Orthographic Consistency: Do Their Paths Cross?

There is little doubt that reading and spelling are interrelated skills (e.g., Ehri, 2000; Fitzgerald & Shanahan, 2000; Furnes & Samuelsson, 2011; Juel, 1988; Moll et al., 2014; Vaessen & Blomert, 2013) relying on similar linguistic skills, such as letter knowledge (e.g., Georgiou, Torppa, Manolitsis, Parrila, & Lyytinen, 2012), phonological awareness (e.g., Caravolas et al., 2012), orthographic knowledge (e.g., Apel, 2009), and morphological awareness (e.g., Apel, Wilson-Fowler, Brimo, & Perrin, 2012). Evidence in support of the strong connection between reading and spelling has been provided by correlational (e.g., Shanahan & Lomax, 1986), intervention (e.g., Conrad, 2008), neuroimaging (e.g., Rapp & Lipka, 2011), and behaviour genetic (e.g., Bates et al., 2004) studies. In their meta-analysis, Swanson, Trainin, Necoechea, and Hammill (2003) estimated the average observed correlation between real word reading and spelling to be .70 (.80 after correcting for restriction of range).

Despite the acknowledged connection between reading and spelling, most previous studies examining their relationship have analyzed concurrent correlations. Unfortunately, this kind of analysis fails to determine the direction of impact and whether the direction changes over time. In addition, the few studies that employed a cross-lagged analysis were conducted in single languages (English: Abbott, Berninger, & Fayol, 2010; Finnish: Leppänen, Niemi, Aunola, & Nurmi, 2006) and used different reading and spelling tasks, which makes it difficult to draw any conclusions as to which associations are universal and which more language specific. Thus, the purpose of this study was to examine the cross-lagged relations between reading and spelling in five languages varying in orthographic

consistency (English, French, Dutch, German, and Greek; Borgwaldt, Hellwig, & De Groot, 2004; Seymour, Aro, & Erskine, 2003).

The Nature of the Reading-Spelling Relationship

There are two competing hypotheses regarding the developmental relations between reading and spelling. On the one hand, Frith (1985) proposed that reading and spelling take turns in influencing each other in distinct phases of literacy development. According to Frith (1985), improved spelling of simple letter-sound correspondences leads to improved reading of the words that follow simple letter-sound correspondence rules during the early stages of literacy development (the 'alphabetic' stage in Frith's theory of literacy development). In turn, improved reading of words capturing more complex orthographic patterns leads to improved spelling of these patterns (the 'orthographic' stage in Frith's theory of literacy development; see Ellis, 1997, for a visual on the cross-domain influences and the time they are expected to occur). On the other hand, Ehri (1995) proposed that reading and spelling have a reciprocal relationship and a learner's progression through the different phases of reading and spelling acquisition occurs simultaneously. According to Ehri (1995), reading and spelling instruction and experiences help children build up their word-specific knowledge, which, in turn, facilitates reading and spelling development.

Although it is tempting to endorse the view that since reading and spelling are highly correlated they must also be reciprocally related, the underlying nature of such a relationship remains unclear. A possible explanation can be traced to the self-teaching hypothesis (Share, 1995) and its more recent version (Shahar-Yames & Share, 2008), according to which the process of converting graphemes to phonemes (for reading) and phonemes to graphemes (for spelling) both fulfil a self-teaching function, enabling children to independently acquire

orthographic knowledge. High-quality orthographic representations are crucial not only for spelling, but also for skilled word recognition because they allow the immediate activation of the phonological form of the word in long-term memory (e.g., Barker, Torgesen, & Wagner, 1992; Cunningham, Perry, & Stanovich, 2001). An alternative explanation relates to the lexical quality hypothesis (Perfetti, 1997; Perfetti & Hart, 2002). Words with high lexical quality mental representations contain information not only about their pronunciation but also about their spelling, and higher lexical quality may contribute to greater efficiency. Finally, according to the phonological coherence model (Bosman & Van Orden, 1997), there is a network of reciprocal relations between phonemic, graphemic and semantic information that supports reading and spelling, respectively. However, because there are in general more graphemes to choose from to represent a phoneme than there are phonemes to pronounce a grapheme, spelling is more difficult than reading. The asymmetry between the grapheme-to-phoneme versus the phoneme-to-grapheme conversions has an important implication: with increasing asymmetry between reading and spelling, it is likely that the development of the two abilities will diverge as spelling is increasingly being affected by different factors and is more dependent on specific instruction. This should translate to smaller effects of reading on spelling. To our knowledge, no cross-linguistic studies have been conducted to test this hypothesis.

To date, only a handful of studies have tested the developmental relations between reading and spelling and provided mixed findings (e.g., Abbott et al., 2010; Ahmed, Wagner, & Lopez, 2014; Caravolas, Hulme, & Snowling, 2001; Davis & Bryant, 2006; Leppänen et al., 2006; Lerkkanen, Rasku-Puttonen, Aunola, & Nurmi, 2004; see also Ellis, 1997; Tierney & Shanahan, 1996; for reviews of earlier studies). For example, Abbott et al. (2010)

examined the cross-lagged relations between word reading accuracy and spelling in two cohorts of American children (Cohort 1 was followed from Grade 1 to 5 and Cohort 2 from Grade 3 to 7). Their results were in line with Ehri's hypothesis showing that, with one exception (Grade 1 word reading failing to predict spelling in Grade 2), word reading and spelling were reciprocally related all the way until Grade 7. In turn, Davis and Bryant (2006) examined whether the ability to use the conditional split-digraph rule (the final –e) in reading precedes and causes the ability to spell this pattern. Year 2 and 3 children from UK (ages 7 and 8, respectively) were followed for two years and tested on their ability to read and spell pseudowords that followed the split-digraph rule (the final –e). The results of cross-lagged analysis with the first cohort of children revealed unidirectional relations: reading split-digraph words at ages 7 and 8 predicted the ability to spell such words at ages 8 and 9, respectively. In contrast, the results with the second cohort of children that covered ages 8 to 10 showed no cross-lagged relations between reading and spelling. Although the findings with the first cohort provide some support for Frith's hypothesis, the nature of their data allowed Davis and Bryant to test only the last part of Frith's hypothesis (that children first acquire orthographic knowledge through reading and only after they have become relatively adept in using orthographic strategies they can transfer and apply this knowledge to spelling). Finally, in a longitudinal study that spanned Grades 1 to 4, Ahmed et al. (2014) found that only word reading (operationalized with word/pseudoword reading fluency tasks) was predictive of spelling (operationalized with spelling to dictation tasks) in every subsequent time point. Ahmed et al. concluded that the ability to read words correctly may facilitate writing them correctly via mastery of phoneme-grapheme relations that are learned through reading. Unfortunately, the use of different reading and spelling tasks in these studies makes

it difficult to draw any firm conclusions. In addition, all aforementioned studies were conducted in English, which is known for its low forward (from graphemes to phonemes) and backward (from phonemes to graphemes) consistency (e.g., Borgwaldt et al., 2004; Landerl, 2005; Seymour et al., 2003). The natural follow-up question is whether similar findings can be obtained in orthographies in which the connection between letters and sounds is less ambiguous.

Examining the prospective relations between reading and spelling in orthographically consistent languages (e.g., Finnish, Greek, German) is interesting because the relatively high correspondence between graphemes and phonemes coupled with phonics instruction in these languages should allow children to decode any given word without previously spelling it. The opposite would also be true: children should be able to spell any given word without previously reading it.[1] In line with this hypothesis, Georgiou et al. (2012) showed that in Finnish, letter knowledge in kindergarten was the only significant predictor of nonword reading and spelling in Grade 2. In contrast, in English, letter knowledge, rapid naming, and phonological awareness all predicted nonword decoding and letter knowledge and rapid naming predicted spelling. In addition, because the 'logographic' stage in Frith's theory is relatively short in consistent orthographies (same applies to the 'partial alphabetic' phase in Ehri's theory; see e.g., Coenen, van Bon, & Schreuder, 1997; Porpodas, 1999; Rau, Moeller, & Landerl, 2014; Wimmer & Hummer, 1990), the proposed spelling-to-reading effects in English (assuming Frith's hypothesis is correct) should take place earlier in consistent orthographies. On the other hand, if Ehri's (1995) hypothesis is correct, reading and spelling should be reciprocally related irrespective of when children are assessed.

[1] This of course rests on the assumption that the consistency is similar in both directions (from graphemes to phonemes and from phonemes to graphemes).

To our knowledge, only three studies have examined the developmental relations between reading and spelling in a consistent orthography (all were conducted in Finnish) and they have some important limitations. In the first study, Lerkkanen et al. (2004) examined the developmental relations between reading and writing (they reported though separate analyses for spelling) in a sample of 83 Finnish children who were assessed four times during Grade 1 (at the beginning of October and December, and at the end of January and March). Reading was operationalized with word/sentence-picture matching and reading comprehension, and writing with spelling and writing fluency (children were asked to write as many words or sentences as they could about a given picture). The results of cross-lagged analyses showed that reading (sum of word reading and comprehension scores) and spelling were reciprocally related from October to December, spelling in December predicted reading in January, and reading in January predicted spelling in March. Thus, the results from October to December supported Ehri's hypothesis and the results from December to March supported Frith's hypothesis. However, apart from their relatively small sample size, the reported means in spelling show that their task suffered from ceiling effects and there was no improvement over time. In the second study, Leppänen et al. (2006) followed 207 Finnish children from preschool to Grade 2 and assessed them five times (beginning and end of preschool, beginning and end of Grade 1, and beginning of Grade 2) on reading (reading words/ sentences and sentence comprehension) and spelling (spelling of words and sentences). In line with Frith's hypothesis, the results of cross-lagged analyses showed first that spelling at the beginning of kindergarten predicted reading at the end of kindergarten and at the end of Grade 1. In addition, reading at the end of kindergarten and Grade 1 predicted subsequent spelling. Unfortunately, Leppänen et al. (2006) did not run separate analyses for word reading

and word spelling and we do not know what scores may have been driving their findings. This is important in light of evidence showing that different levels of language (word vs. sentence vs. passage) may produce different results (Ahmed et al., 2014). Finally, Mäki, Voeten, Vauras, and Niemi (2002) followed 171 Finnish children from Grade 2 to Grade 3 and assessed them twice on a lexical decision task (the response times were used to index word recognition speed) and on spelling (number of errors in a composition task). Their results showed that word recognition speed in Grade 2 was predictive of spelling in Grade 3 (and only when the correlation between word recognition speed and spelling in Grade 3 was excluded from the model). However, the use of non-conventional reading and spelling tasks limits the generalizability of these findings. Notice also that Frith's theory assumes an orthographic stage that is needed to master complex words, but such words do not really exist in Finnish (the words get longer, but they are not orthographically more complex).

The Present Study

The purpose of this study was to examine the cross-lagged relations between reading and spelling from the end of Grade 1 to the end of Grade 2 across a wide range of alphabetic orthographies that were purposefully selected to vary in consistency (English being the most inconsistent, Greek being the most consistent, and French, Dutch, and German lying in between English and Greek in the orthographic consistency continuum; Borgwaldt et al., 2004; Seymour et al., 2003).[2] Examining the cross-lagged relations between reading and

[2] Borgwaldt et al. (2004) quantified the word-initial letter-to-phoneme and phoneme-to-letter ambiguity (by calculating an entropy value) in five languages (English, French, German, Dutch, and Hungarian). In terms of the word-initial letter-to-phoneme mappings, English was found to be the most ambiguous orthography, followed by, in descending order, German, French, and Dutch, with Hungarian having the most predictable orthography. In terms of the word-initial phoneme-to-letter mappings, English was again found to be the most ambiguous orthography, closely followed by French and then German, Dutch, and Hungarian. Closely matching the methodology used by Borgwaldt et al. (2004), Protopapas and Vlahou (2009) found that Greek is equally ambiguous in the direction of reading and spelling, being similar to Dutch in the direction of reading and similar to French in the direction of spelling. More specifically, when letter-to-phoneme mappings are concerned, Greek

spelling from the end of Grade 1 to the end of Grade 2 is important because this time window is crucial for the acquisition of literacy skills. In addition, it allows us to test specific hypotheses (see below) that are directly related to the two competing hypotheses (Ehri, 1995; Frith, 1985).

More specifically, our study examined the following two questions:

1) How is the development of children's reading ability associated with that of spelling? If Frith's (1985) hypothesis is correct, we should observe unidirectional relations between reading and spelling. Reading at the end of Grade 1 and at the beginning of Grade 2 should predict spelling at the beginning and end of Grade 2, respectively. This rests on the assumption that by the end of Grade 1 (the first time point in our study) our participants should be entering the 'orthographic' stage in Frith's stage theory of literacy development. Assuming that from Grade 2 onward children do not spell orthographically-complex words before they actually read them (children also do not spell unless they are asked to, but they read all sorts of materials in their environment), reading should always predict future spelling. In contrast, if Ehri's (1995) hypothesis is correct, we should observe reciprocal relations between reading and spelling.

2) Does orthographic consistency influence the relations between reading and spelling? Ehri (1995) pointed out that reading and spelling development relies on the accumulation of word-specific orthographic knowledge. If phonological recoding acts as a self-teaching mechanism for the development of orthographic knowledge (Share,

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is less transparent than Hungarian and more transparent than French, German, and English. When phoneme-to-letter mappings are concerned, Greek is less transparent than Hungarian, Dutch and German, and more transparent than English.

1995) and phonological recoding is easier in consistent orthographies (because of the close to 1:1 correspondence between letters and sounds), one would expect a stronger effect of reading on spelling in consistent orthographies. However, a different pattern would be expected if we consider the orthographic depth hypothesis (e.g., Frost, Katz, & Bentin, 1987; Katz & Frost, 1992). This proposes that whereas readers of consistent orthographies continue to use nonlexical reading strategies (i.e., phonological recoding), those reading in inconsistent orthographies are pressured to recruit lexical strategies given the less transparent grapheme-to-phoneme mappings. Assuming reading and spelling development relies on word-specific orthographic knowledge (Ehri, 1995) and that readers of consistent orthographies remain insensitive to word-specific details for a relatively long time (Share, 2004), one would expect a stronger effect of reading on subsequent spelling in inconsistent orthographies.

Reading and Spelling Instruction

Although reading and spelling instruction in all languages included in this study starts in Grade 1, reading and spelling practices vary as a function of the orthographic characteristics of each language.[3] In Alberta, Canada (where our English-speaking participants were recruited), teachers use a synthetic phonics approach to teach reading, which emphasizes letter-sound correspondences and sound blending. Spelling is taught through the identification of common spelling patterns in words, the use of word walls, and by directly teaching orthographic rules.

In Quebec, Canada (where our French-speaking children were recruited), the program that was designed by the Ministry of Education recommends a communicative approach

[3] Unfortunately, we did not collect any specific information from the teachers in each site on how they were teaching reading and spelling.

based on authentic and varied texts for the teaching of reading and spelling akin to the whole language approach. The explicit teaching of grapheme-phoneme and phoneme-grapheme correspondences is to be restricted only to struggling learners. Teachers, however, have the freedom to adopt the teaching model they find most effective. Most teachers in our sample made extensive use of explicit teaching of letter-sound correspondences, orthographic rules, and spelling patterns.

In the Netherlands, teachers use a synthetic phonics approach to teach reading. In turn, instruction in spelling emphasizes the conversion of the sounds heard in a spoken form into letters and eventually the written form of the word. Reading and spelling instruction starts with transparent words. Thereafter, inconsistent words, which include mostly rule-based inconsistencies, are taught.

In Austria (where our German-speaking children were recruited) children are first introduced to letter-sound correspondences and learn to write the letters at the same time. Sounding out letter sequences is heavily practiced. Spelling instruction also starts with encouraging children to segment spoken words into their sounds and translate these sounds into letters. In Grades 1 and 2, spelling attempts are mostly phonologically adequate. Eventually, children are expected to spell words orthographically correct. From Grade 3 on, spelling instruction focuses on introducing typical spelling patterns and regularities of the German orthography.

Finally, in Greece, teachers use a synthetic phonics approach to teach reading. Spelling is taught in parallel with reading with an emphasis placed initially on phoneme-grapheme correspondences and from Grade 2 onward on spelling patterns based on the morphological rules of Greek orthography. Although by the end of Grade 1 Greek children

have been taught all letter-sound correspondence rules and can decode any given word, learning of all spelling rules is not achieved before Grade 3.

Method

Participants

The data used in the present study are part of a larger longitudinal project examining the role of cognitive and non-cognitive predictors of literacy development in five European languages. Our sample consisted of 941 children followed from the end of Grade 1 (April/May) until the end of Grade 2 (April/May). One hundred and seventy children (82 girls; mean age = 79.12 months at the first measurement point) were native speakers of English and were recruited from six public elementary schools in Edmonton [city's name removed for blind review], Canada, 254 children (136 girls; mean age = 78.12 months at the first measurement point) were native speakers of French and were recruited from eight public elementary schools in Gatineau, Canada, 113 children (63 girls; mean age = 78.52 months at the first measurement point) were native speakers of Dutch and were recruited from five public elementary schools in Amsterdam, Netherlands, 175 children (85 girls; mean age = 79.11 months at the first measurement point) were native speakers of German and were recruited from five public elementary schools in Graz, Austria, and 229 children (120 girls; mean age = 76.10 months at the first measurement point) were native speakers of Greek and were recruited from six public elementary schools in Heraklion, Greece. Our participants were recruited on a voluntary basis (letters of information were sent to the parents of all children attending Grade 1 in the participating schools) and were tested three times: at the end of Grade 1 and at the beginning and end of Grade 2. By the end of Grade 2, our sample consisted of 157 English-speaking (8% attrition), 237 French-speaking (7% attrition), 107

Dutch-speaking (6% attrition), 167 German-speaking (5% attrition), and 219 Greek-speaking (5% attrition) children. The children in each site came mostly from families of middle socioeconomic background (based on the location of the schools and on parents' education) and none were experiencing any intellectual, emotional, or sensory difficulties. Parental and school consent was obtained prior to testing.

Measures

Reading. To assess reading ability we administered a word and a pseudoword reading fluency task. We did not assess reading accuracy because it reaches ceiling before the end of Grade 1 in Greek, German, and Dutch (Seymour et al., 2003). Furthermore, because deriving comparable word/pseudoword lists for the languages included in our study is almost impossible unless we violate important orthographic characteristics of each language, we adapted existing reading fluency tasks in each language (English: Torgesen, Wagner, & Rashotte, 1999; French: Authors, 2012; Dutch: Brus & Voeten, 1995; van den Bos, lutje Spelberg, Scheepstra, & de Vries, 1994; German: Authors, 2010; and Greek: Authors, 2012) by arranging their items in four columns on two separate pages (one for words and one for pseudowords) and by using a similar discontinuation rule. Children were asked to read as many words or pseudowords as possible within a 60-second time limit. A practice trial with 8 words/pseudowords preceded timed testing to allow children to familiarize themselves with the task demands. In both tasks, the child's score was the total number of syllables in the correctly read words within the specified time limit. This scoring procedure was necessary because of differences in the length of the words or pseudowords included in each task across languages. Test-retest reliability has been reported to be higher than .85 for elementary school children (Authors, 2010, 2012; Brus & Voeten, 1995; Torgesen et al., 1999).

Spelling. To assess spelling ability, we adopted an existing spelling to dictation task in each language (English: Wechsler, 2001; French: Wechsler, 2005; Dutch: Geelhoed & Reitsma, 1999; German: Authors, 2010; and Greek: Mouzaki, Protopapas, Sideridis, & Simos, 2007). The tester would first say a target word followed by a sentence in which the target word was embedded, and then s/he would repeat the target word. Children were then asked to write the target word in the space provided. The items in each language were ordered in terms of increasing difficulty and a discontinuation rule of six consecutive errors was applied. A participant's score was the total number of correct responses. Internal consistency has been reported to be higher than .90 for elementary school children (Authors, 2010; Mouzaki et al., 2007; Wechsler, 2001; 2005).

Procedure

All tasks were administered in a quiet room in the child's school during school hours by trained research assistants. The tests were administered in one session lasting about 25 minutes. Administration and scoring was standardized across all children and languages.

Statistical Analyses

First, we examined the distributional properties of the measures and winsorized the few outliers' scores to reduce their potential effect on the results (Tabachnick & Fidell, 2007). Second, we performed a principal axis exploratory factor analysis (EFA) to test if a two-factor model (one for reading and one for spelling) would fit the data in each language and if a similar amount of variance and similar factor loadings would emerge across languages. The result of EFA with direct oblimin rotation yielded a reading factor and a spelling factor in each language. The rotated factor loadings for each measure in each language are reported in Table 1. The factor solution suggested clearly separate factors with high loadings across all

languages. The correlation between the factors was .63 in Dutch, .84 in English, .66 in French, .66 in German, and .70 in Greek. The two-factor solution also explained a large proportion of variance in each language: 83.41% in Dutch, 88.39% in English, 84.30% in French, 87.84% in German, and 81.24% in Greek. Because the two reading fluency tasks loaded on the same factor across languages, we created a composite score for reading by first transforming the raw scores to *z*-scores within each language and then by averaging the two *z*-scores. Both spelling and reading composite scores were approximately normally distributed. There were only few missing values in each orthography (see Table 2) and there was no indication of systematic missingness.

Next, we performed a cross-lagged analysis with the models built separately in each language. All models were estimated with the maximum likelihood (ML) estimator using Mplus 7.3. A basic cross-lagged model was the basis of this phase including the stabilitity estimates (within-domain) to each time point from the previous timepoint and the cross-lagged (cross-domain) paths to each time point from the previous time point. In order to have well-fitting models we had to add two additional stability paths in each language: from the end of Grade 1 to the end of Grade 2 in both reading and spelling. These were added based on the modification indices provided by Mplus 7.3. After the identification of the best fitting model in each language, we performed multigroup analyses to examine if the model estimates (stability estimates, cross-lagged paths, error covariances, and the reading-spelling Grade 1 correlation) were identical across languages by first imposing equality contraints across languages. Finally, pairwise comparisons between languages were conducted by setting each of the model estimates equal one-by-one while estimating other parts of the model freely in each of the language pairs. Model comparison was based on a chi-square difference testing.

The model with all paths estimated freely served as the baseline model against which the other models' fit were compared to.

Results

Descriptive Statistics and Correlations

Table 2 reports the sample sizes, means, and standard deviations of the raw scores in reading and spelling measures separately for each language. Table 3 reports the zero-order correlation coefficients between the reading composite and spelling separately for each language.

Cross-Lagged Models Between Reading and Spelling in Each Language

Figure 1 depicts the model and provides standardized estimates, separately for each orthography. The models fitted the data well in each language: Dutch: χ^2 (2) = 3.22, p = .20, CFI = 1.00, RMSEA = .07, SRMR = .01; English: χ^2 (2) = 7.54, p = .02, CFI = .99, RMSEA = .13, SRMR = .01; French: χ^2 (2) = .94, p = .63, CFI = 1.00, RMSEA = .00, SRMR = .00; German: χ^2 (2) = 1.68, p = .43, CFI = 1.00, RMSEA = .00, SRMR = .00; and Greek: χ^2 (2) = .92, p = .63, CFI = 1.00, RMSEA = .00, SRMR = .01. In each language, reading was highly stable and there were stronger cross-lagged path estimates from reading to spelling than the other way around.

Model Comparisons Between Languages

Next, we examined if the model paths were identical across languages using chi-square difference testing. We first examined if all estimates between reading and spelling were equal in all languages (stability estimates, cross-lagged paths, error covariances, and reading-spelling Grade 1 correlation) and found that such a model did not fit the data well (χ^2

(58) = 114.67, p = .001) and that the change in the model fit was significant ($\Delta\chi^2$ (48) = .97.06, p < .001).

Because of the presence of significant differences in the estimates across languages, we then conducted pairwise comparisons between languages. The comparisons revealed that the stability estimates of reading were similar across languages, but there were significant differences between languages in spelling stability as well as in the cross-lagged paths and in the Grade 1 correlation between reading and spelling. All model estimates were equal between English and Dutch, but there were differences in all other comparisons.

First, comparisons of the stability estimates of spelling from the end of Grade 1 to the beginning of Grade 2 suggested lower stability in Greek than in any other language. Model fits decreased significantly when the end of Grade 1 to the beginning of Grade 2 spelling stability estimate was set equal between Greek and Dutch ($\Delta\chi^2$ (1) = 4.48, p = .034), between Greek and English ($\Delta\chi^2$ (1) = 6.48, p = .011), between Greek and French ($\Delta\chi^2$ (1) = 14.65, p < .001), and between Greek and German ($\Delta\chi^2$ (1) = 22.50, p < .001). In addition, the end of Grade 1 to the beginning of Grade 2 spelling stability was lower in English than in German ($\Delta\chi^2$ (1) = 4.34, p = .037). In turn, comparisons of the spelling stability estimates from the beginning of Grade 2 to the end of Grade 2 suggested stronger stability in German than in Dutch ($\Delta\chi^2$ (1) = 4.96, p = .026) or in French ($\Delta\chi^2$ (1) = 5.86, p = .015).

Second, comparisons of the cross-lagged paths from spelling to reading suggested no differences across languages between the beginning of Grade 2 and the end of Grade 2. In all languages, this path was non-significant and close to zero. Similarly, the path from the end of Grade 1 spelling to the beginning of Grade 2 reading was weak in all languages (it reached significance only in Greek). However, comparisons across languages revealed that the path

coefficient in French was significantly smaller than that of English ($\Delta\chi^2$ (1) = 5.80, p = .016), German ($\Delta\chi^2$ (1) = 6.15, p = .013), and Greek ($\Delta\chi^2$ (1) = 7.52, p = .006).

In contrast to the spelling-to-reading paths, comparisons of the reading-to-spelling paths across languages revealed several differences. The end of Grade 1 reading was a weaker predictor of the beginning of Grade 2 spelling in French ($\Delta\chi^2$ (1) = 4.90, p = .027) and German ($\Delta\chi^2$ (1) = 9.87, p = .002) than in Greek. The path in German was also weaker from that in English ($\Delta\chi^2$ (1) = 5.88, p = .015). The beginning of Grade 2 reading was again a weaker predictor of the end of Grade 2 spelling in French ($\Delta\chi^2$ (1) = 7.52, p = .006) and in German ($\Delta\chi^2$ (1) = 7.21, p = .007) than in Greek. Furthermore, in comparison to Dutch, the beginning of Grade 2 reading was a weaker predictor of the end of Grade 2 spelling in French ($\Delta\chi^2$ (1) = 8.15, p = .004) and German ($\Delta\chi^2$ (1) = 4.96, p = .026).

Discussion

The purpose of this study was to examine the cross-lagged relations between reading and spelling from the end of Grade 1 to the end of Grade 2 in five alphabetic orthographies that were selected to vary in consistency. First, we speculated that if Frith's (1985) assumptions were correct, we should observe unidirectional effects between reading and spelling: earlier reading should predict future spelling. In contrast, if Ehri's (1995) assumptions were correct, we should observe reciprocal effects between reading and spelling (this would also be expected based on Perfetti's, 1997, lexical quality hypothesis). With one exception (the reciprocal relations between reading and spelling in Greek between the end of Grade 1 and the beginning of Grade 2), our findings were in line with Frith's hypothesis. This pattern of relations is similar to those of previous studies (see Ahmed et al., 2014; Caravolas et al., 2001; Davis & Bryant, 2006; Mäki et al., 2002) and suggests that, once children master

some basic decoding skills, their ability to read words correctly facilitates their subsequent ability to spell words correctly. Spelling may be important for subsequent reading only in earlier phases of literacy development (see e.g., Caravolas et al., 2001; Leppänen et al., 2006; for supporting evidence), or among children in later grades who continue to experience reading/spelling difficulties (e.g., Conrad, 2008), but neither of these assumptions were examined in this study.

From a theoretical point of view, our findings support Share's early version of self-teaching hypothesis (see Share, 1995) according to which successful phonological recoding builds up children's orthographic knowledge, but not his most recent one (Shahar-Yames & Share, 2008) advocating for the superiority of spelling over reading in building children's orthographic representations.[4] As spelling relies on precise orthographic knowledge, earlier reading (phonological recoding) should predict future spelling (what we found). On the other hand, children can probably read accurately a word (e.g., *bread*), even if they do not have access to a precise orthographic representation (e.g., *bred*).[5] Evidence in support of this argument can be drawn also from studies examining the double dissociation between reading and spelling (e.g., Frith, 1980; Manolitsis & Georgiou, 2015; Moll & Landerl, 2009). Frith (1980) was the first to report a group of children who were adequate readers but 'atrocious' spellers. She argued that the poor performance of this group of children in spelling was due to inefficient orthographic processing during reading. Frith (1980) further showed that good readers/poor spellers deployed different reading strategies than good readers/good spellers:

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[4] We acknowledge though that this proposal may be valid in Hebrew for reasons related to the characteristics of that orthography and which are beyond the scope of this study.

[5] Short, monosyllabic pseudowords (or even longer pseudowords that have been created after replacing a letter in real words) do not appear to engage a different mechanism than the one used for reading real words; see e.g., van den Boer, Georgiou, & de Jong, 2016). We mention this because one of our fluency tasks involved reading pseudowords.

whereas good readers/good spellers used all the cues available in a word, good readers/poor spellers relied on ‘partial cues’ to read. She concluded that poor spellers do not pay attention to all details in words (e.g., the correct sequence of letters). If minimal cues are used for reading, reading may be efficient, but at the same time, limited information becomes available for later spelling of the words.

An alternative explanation could relate to print exposure, whose role in reading and spelling appears to be independent from that of phonological recoding. More specifically, researchers have shown that greater print exposure (achieved via reading) may also help children build high-quality orthographic representations of words (e.g., Cunningham et al., 2001; Cunningham & Stanovich, 1990, 1991) that are then used for spelling. Cunningham and Stanovich (1991), for example, showed that print exposure predicted spelling even after controlling for general cognitive ability and phonological processing.

Our second hypothesis pertained to the role of orthographic consistency in the reading-spelling developmental relations. More specifically, we speculated that if Frith’s (1985) hypothesis was correct we should see a different pattern of relations across languages, particularly between Greek, German, and Dutch on the one hand, and French and English, on the other hand. This is because Greek, German, and Dutch are considerably more consistent in the direction of reading than French and English (Borgwaldt et al., 2004; Seymour et al., 2003). Our findings failed to support this hypothesis; earlier reading predicted subsequent spelling in all languages. In addition, the effects of earlier reading on subsequent spelling were stronger in Greek than in German or French (Dutch also produced stronger effects from the beginning of Grade 2 to the end of Grade 2 than German or French). This would be expected based on the phonological coherence model (Bosman & Van Order, 1997). If

greater asymmetry leads to weaker effects from reading to spelling, this should be apparent in French and German (the two languages with the greatest asymmetry in our study; Borgwaldt et al., 2004).

The differences in the strength of the effects from reading to spelling across languages may have been brought about by differences across languages in the stability of spelling from one time point to another. For example, from the end of Grade 1 to the beginning of Grade 2 the lowest stability was found in Greek. In contrast, the highest stability was found in German and French (see Figure 1). Lower stability (as in the case of spelling) allows other variables (e.g., reading) to make a significant contribution. The lower stability in Greek may be due to the fact that during this time period children in Greece are introduced to spelling rules (e.g., spelling of verbs ending in /i/ with <*ɛɪ*>, but spelling of nouns in plural ending in /i/ with <*oɪ*>) that violate the 1:1 phoneme-grapheme correspondences that they were used to when reading and spelling simple words at the beginning of Grade 1. Taken together, these findings suggest that orthographic consistency alone may not be adequate to produce significant differences between languages (at least not in the period covered in this study) in the direction of the relations between reading and writing, but unique orthographic features (along with instructional practices in each language) can influence the strength of the relationships across languages.

Some limitations of the present study are worth mentioning. First, because developing strictly comparable reading and spelling measures across such as diverse group of languages is extremely difficult given the unique features of each language, we decided to use existing measures of reading and spelling that follow the same administration and scoring procedures across languages. For example, there is a large body of short single syllable words in English,

whereas there is only a small number of such words in Greek. Given the number of single-syllable words used in existing reading tests in English (see e.g., Test of Word Reading Efficiency; Torgesen et al., 1999), it is not possible to construct word reading tasks in Greek that would be strictly parallel in terms of length and word frequency to the English tasks. Using more multi-syllabic words in English would not resolve the problem either because of significant differences in the syllabic structures between Greek and English. In addition, matching the items across languages in one dimension (e.g., length) does not guarantee matching in all dimensions (see Caravolas, in press, for an example). Thus, although we cannot rule out the possibility that some of the observed differences in the cross-lagged relations between reading and spelling in our study might be due to the characteristics of the items used in each language, we also acknowledge that fully controlling for the effect of item characteristics across five diverse languages is almost impossible. Second, our study spanned only two grade levels (Grades 1 and 2) and we do not know if a similar pattern of relations would be observed in later grades. For example, some researchers have argued that the relationship between reading and spelling is stronger in earlier grades than in later grades (e.g., Vaessen & Blomert, 2013). Third, as mentioned above, we did not obtain specific information regarding the instructional practices in each site. Relatedly, the instructional practices used in Alberta and Quebec are likely not the same across the English- or French-speaking world. We acknowledge that more comprehensive instructional information could help us understand our results in a more nuanced manner than what is now possible. Fourth, we acknowledge that Ehri's or Frith's theories are not attached to specific ages/grade levels and that problems may arise when age or grade groups are assigned to certain levels within developmental models. It is possible that the same child is in different "stages" for different

words – some words s/he just knows, others s/he can process with effort, and others are beyond his/her skill level. In addition, the same classroom may have children working on average at very different levels. When we presented information on the age or grade level of the participants in previous studies (see Introduction), we did it in order to allow readers of our paper to compare our findings to those of previous studies and not to use the developmental models to clasify classroom groups. Fifth, we operationalized reading and spelling with word-level tasks. Our findings could have been different had we administered sentence- or passage-level measures. For example, Ahmed et al. (2014) found reciprocal relations between reading and spelling when both skills were operationalized with passage-level tasks. Finally, although our spelling task assessed accuracy, our reading tasks assessed efficiency (number of words read correctly in a minute). This was necessitated by the fact that reading accuracy reaches ceiling in transparent orthographies (i.e., Greek, Dutch, German) already by the end of Grade 1. A solution to this problem would have been the use of a spelling fluency measure. Unfortunately, this comes with its own limitations. Spelling fluency is typically assessed with a recognition task (e.g., Which of the following *rane* – *rain* is the correct spelling of the word?) that allows researchers to obtain response times for each item. Nevertheless, children appear to be better spellers when their knowledge of words' spelling is assessed with a recognition task. Recognizing the correct spelling then becomes more similar to reading because children can see the letters of the correct spelling (see Bosman & Van Order, 1997, for a similar argument). To control for the possible effects of speed in reading fluency, we reran our analyses using measures of rapid naming (Colors and Digits) as predictors of reading and the results remained essentially the same.[6]

[6] The results of these analyses can be obtained from the corresponding author upon request.

To conclude, our findings add to a growing body of research examining the developmental relations between reading and spelling (e.g., Abbott et al., 2010; Ahmed et al., 2014; Leppänen et al., 2006; Lerkkanen et al., 2004). In support of Frith's ideas and Share's early ideas, we found that, irrespective of the language studied, the effects were unidirectional (earlier reading predicted subsequent spelling). This suggests that, at least among alphabetic orthographies and once children have mastered some basic decoding skills, any differences between languages do not impact the direction of the effects, but may impact the strength of the effects. Our findings further suggest that orthographic learning at this point in literacy development is driven by implicit learning from decoding and exposure rather than explicit learning from spelling.

References

Abbott, R. D., Berninger, V. W., & Fayol, M. (2010). Longitudinal relationships of levels of language in writing and between writing and reading in grades 1 to 7. *Journal of Educational Psychology, 102*, 281–298.

Ahmed, Y., Wagner, R. K., & Lopez, D. (2014). Developmental relations between reading and writing at the word, sentence and text levels: A latent change score analysis. *Journal of Educational Psychology, 106*, 419-434.

Apel, K. (2009). The acquisition of mental orthographic representations for reading and spelling development. *Communication Disorders Quarterly, 31*, 42–52.

Apel, K., Wilson-Fowler, E. B., Brimo, D., & Perrin, N. A. (2012). Metalinguistic contributions to reading and spelling in second and third grade students. *Reading and Writing, 25*, 1283-1305.

Authors (2010).

Authors (2012).

Barker, T. A., Torgesen, J. K., & Wagner, R. K. (1992). The role of orthographic processing skills on five different reading tasks. *Reading Research Quarterly, 27*, 335–345.

Bates, T. C., Castles, A., Coltheart, M., Gillespie, N., Wright, M., & Martin, N. G. (2004). Behaviour genetic analyses of reading and spelling: a component processes approach. *Australian Journal of Psychology, 56*, 115–126.

Borgwaldt, S. R., Hellwig, F. M., & De Groot, A. M. B. (2004). Word-initial entropy in five languages: Letter to sound and sound to letter. *Written Language and Literacy, 7*, 165–184.

Bosman, A. M. T., & van Orden, G. C. (1997). Why spelling is more difficult than reading. In C. A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: Research, theory, and practice across languages* (pp. 173–194). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brus, B., & Voeten, B. (1995). *Eén minuut test vorm A en B. Verantwoording en handleiding* [one-minute-test manual]. Lisse, The Netherlands: Swets & Zietlinger.

Caravolas, M. (in press). Growth of word and pseudoword reading efficiency in alphabetic orthographies: Impact of consistency. *Journal of Learning Disabilities*. doi:10.1177/0022219417718197

Caravolas, M., Hulme, C., & Snowling, M. (2001). The foundations of spelling ability: Evidence from a 3-year longitudinal study. *Journal of Memory and Language, 45*, 751–774.

Caravolas, M., Lervåg A., Mousikou P., Efrim C., Litavský M., Onochie-Quintanilla E., . . . Hulme C. (2012). Common patterns of prediction of literacy development in different alphabetic orthographies. *Psychological Science, 23*, 678–686.

Coenen, M. J. W. L., van Bon, W. H. J., & Schreuder, R. (1997). Reading and spelling in Dutch first and second graders: Do they use an orthographic strategy? In C. K. Leong & R. M. Joshi (Eds.), *Cross-language studies of learning to reading and spell* (pp. 249-269). Dordrecht, Netherlands: Kluwer Academic Publishers.

Conrad, N. J. (2008). From reading to spelling and spelling to reading: Transfer goes both ways. *Journal of Educational Psychology, 100*, 869-878.

Cunningham, A. E., Perry, K., & Stanovich, K. E. (2001). Converging evidence for the concept of orthographic processing. *Reading and Writing: An Interdisciplinary Journal, 14*, 549-568.

Cunningham, A. E., & Stanovich, K. E. (1990). Assessing print exposure and orthographic processing skill in children: A quick measure of reading experience. *Journal of Educational Psychology, 82*, 733- 740.

Cunningham, A. E., & Stanovich, K. E. (1991). Tracking the unique effects of print exposure in children: Associations with vocabulary, general knowledge, and spelling. *Journal of Educational Psychology, 83*, 264-274.

Davis, C., & Bryant, P. (2006). Causal connections in the acquisition of an orthographic rule: a test of Uta Frith's developmental hypothesis. *Journal of Child Psychology and Psychiatry*, 47, 849-856.

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18*, 116-125.

Ehri, L. C. (2000). Learning to read and learning to spell: Two sides of a coin. *Topics in Language Disorders, 20*, 191–236.

Ellis, N. (1997). Interactions in the development of reading and spelling: Stages, strategies, and exchange of knowledge. In C. A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: Research, theory and practice across languages* (pp. 271-294). Mahwah, NJ: Lawrence Erlbaum Associates.

Fitzgerald, J., & Shanahan, T. (2000). Reading and writing relations and their development. *Educational Psychologist, 35*, 39–50.

Frith, U. (1980). Unexpected spelling problems. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 495-516). London: Academic Publishers.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading (*pp. 301-330). London: Lawrence Erlbaum Associates.

Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 104-114.

Furnes, B., & Samuelsson, S. (2011). Phonological awareness and rapid automatized naming predicting early development in reading and spelling: Results from a cross-linguistic longitudinal study. *Learning and Individual Differences, 21*, 85-95.

Geelhoed, J., & Reitsma, P. (1999). *PI-dictee*. Lisse: Swets & Zeitlinger.

Georgiou, G., Torppa, M., Manolitsis, G., Lyytinen, H., & Parrila, R. (2012). Longitudinal predictors of reading and spelling across languages varying in orthographic consistency. *Reading and Writing: An Interdisciplinary Journal, 25*, 321-346.

Juel, C. (1988). Learning to read and write: A longitudinal study of 54 children from first through fourth grades. *Journal of Educational Psychology, 80*, 437–447.

Katz, L., & Frost, R. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning (*pp. 67-84). Amsterdam: Elsevier North Holland Press.

Landerl, K. (2005). Reading acquisition in different orthographies: Evidence from direct comparisons. In M. Joshi & P. G. Aaron (Eds.), *Handbook of orthography and literacy* (pp. 513-530). Hove: Erlbaum.

Leppänen, U., Niemi, P., Aunola, K., & Nurmi, J.-E. (2006). Development of reading and spelling Finnish from preschool to Grade 1 and 2. *Scientific Studies of Reading, 10*, 3-30.

Lerkkanen, M., Rasku-Puttonen, H., Aunola, K., & Nurmi, J. (2004). The developmental dynamics of literacy skills during the first grade. *Educational Psychology, 24*, 793–810.

Mäki, H. S., Voeten, M. J. M., Vauras, M. M. S., & Niemi P. (2002). Relationships between reading and writing skills in the intermediate grades. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.) *Precursors of functional literacy* (pp. 215-228). Amsterdam: John Benjamins.

Manolitsis, G., & Georgiou, G. (2015). The cognitive profiles of good readers/poor spellers and poor readers/good spellers in a consistent orthography. *Preschool and Primary Education, 3*, 103-116.

Moll, K., & Landerl, K. (2009). Double dissociation between reading and spelling deficits. *Scientific Studies of Reading*, *13*, 359-382.

Moll, K., Ramus, F., Bartling, J., Bruder, J., Kunze S., Neuhoff, N., ... Landerl, K. (2014). Cognitive mechanisms underlying reading and spelling development in five European orthographies. *Learning and Instruction, 29*, 65-77.

Mouzaki, A., Protopapas, A., Sideridis, P., & Simos, G. (2007). Psychometric properties of a new test of spelling achievement in Greek. *Επιστήμες της Αγωγής-Educational Science*, *1*, 129-146.

Perfetti, C. A. (1997). The psycholinguistics of spelling and reading. In C. A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: Research, theory and practice across languages* (pp. 21-38). Hillsdale, NJ: Lawrence Erlbaum Associates.

Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 189-213). Amsterdam: John Benjamins.

Porpodas, C. D. (1999). Patterns of phonological and memory processing in beginning readers and spellers of Greek. *Journal of Learning Disabilities, 32*, 406–416.

Protopapas, A., & Vlahou, E. L. (2009). A comparative quantitative analysis of Greek orthographic transparency. *Behavior Research Methods, 41*, 991–1008.

Rapp, B., & Lipka, K. (2011). The literate brain: the relationship between spelling and reading. *Journal of Cognitive Neuroscience, 23*, 1180–1197.

Rau, A. K., Moeller, K., & Landerl, K. (2014). The transition from sublexical to lexical processing in a consistent orthography: An eye-tracking study. *Scientific Studies of Reading, 18*, 224–233.

Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*, 143–174.

Shahar-Yames, D., & Share, D. L. (2008). Spelling as a self-teaching mechanism in orthographic learning. *Journal of Research in Reading, 31*, 22–39.

Shanahan, T., & Lomax, R. G. (1986). An analysis and comparison of theoretical models of the reading-writing relationship. *Journal of Educational Psychology, 78*, 116–123.

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55*, 151–218.

Share, D. L. (2004). Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *Journal of Experimental Child Psychology, 87*, 267–298.

Swanson, H. L., Trainin, G., Necoechea, D. M., & Hammill, D. D. (2003). Rapid naming, phonological awareness, and reading: A meta-analysis of the correlation evidence. *Review of Educational Research, 73*, 407-440.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Boston: Allyn & Bacon.

Tierney, R. J., & Shanahan, T. (1996). Research on the reading-writing relationship: Interactions, transactions, and outcomes. In R. Barr, M. L. Kamil, P. B. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research* (Vol. 2; pp. 246–280). Mahwah, NJ: Lawrence Erlbaum Associates.

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *Test of Word Reading Efficiency*. Austin, TX: PRO-ED.

Vaessen, A., & Blomert, L. (2013). The cognitive linkage and divergence of spelling and reading development. *Scientific Studies of Reading, 17*, 89–107.

van den Boer, M., Georgiou, G., & de Jong, P. F. (2016). The naming of short words is (almost) the same as the naming of alphanumeric symbols. *Journal of Experimental Child Psychology, 144*, 152-165.

van den Bos, K. P., lutje Spelberg, H. C., Scheepstra, A. J. M., & de Vries, J. R. (1994). *De Klepel: een test voor de leesvaardigheid van pseudowoorden* [Klepel manual]. Lisse, The Netherlands: Swets & Zeitlinger.

Wechsler, D. (2001). *Wechsler individual achievement test – Second edition (WIAT-II)*. New York: Pearson.

Wimmer, H., & Hummer, P. (1990). How German-speaking first graders read and spell. Doubts on the importance of the logographic stage. *Applied Psycholinguistics, 11*, 349.

Table 1

The Rotated Factor Loadings for the Reading and Spelling Measures in Each Language

	Dutch		English		French		German		Greek	
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
Word reading, Grade 1S	**.72**	.25	**.73**	.24	**.71**	.28	**.77**	.18	**.80**	.16
Word reading, Grade 2F	**.79**	.20	**.82**	.14	**.91**	.07	**.82**	.19	**.78**	.23
Word reading, Grade 2S	**.84**	.11	**.95**	-.03	**.88**	.04	**.76**	.25	**.80**	.17
Phonemic decoding, Grade 1S	**.85**	.05	**.88**	.01	**.75**	.18	**.87**	.02	**.89**	-.05
Phonemic decoding, Grade 2F	**.96**	-.08	**.92**	.03	**.99**	-.10	**.99**	-.08	**.92**	-.02
Phonemic decoding, Grade 2S	**1.00**	-.16	**1.00**	-.10	**.95**	-.11	**1.00**	-.15	**.96**	-.12
Spelling, Grade 1S	.01	**.83**	-.08	**.98**	-.05	**.92**	.03	**.86**	.04	**.62**
Spelling, Grade 2F	.01	**.84**	.09	**.85**	.04	**.84**	-.01	**.95**	-.06	**.90**
Spelling, Grade 2S	.41	**.51**	.14	**.76**	.08	**.74**	.05	**.84**	.13	**.72**

Table 2

Descriptive Statistics Within Each Orthography

	Dutch			English			French			German			Greek		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Word reading															
Grade 1 Spring	113	38.82	26.61	170	56.16	29.37	254	60.26	25.73	175	45.72	26.66	229	58.78	25.89
Grade 2 Fall	108	64.12	35.08	161	72.11	33.20	238	77.18	26.76	170	65.26	33.38	224	77.61	34.29
Grade 2 Spring	107	85.09	34.04	157	91.52	30.22	237	101.95	28.37	167	85.45	37.77	219	104.15	39.68
Phonemic decoding															
Grade 1 Spring	113	19.51	13.09	170	23.30	17.11	254	42.19	16.63	175	45.42	18.04	229	45.35	16.65
Grade 2 Fall	108	28.29	17.71	159	30.13	19.44	238	51.94	17.22	170	59.07	20.28	223	49.99	17.53
Grade 2 Spring	107	37.79	17.68	157	36.85	19.47	237	65.06	17.53	167	70.17	23.94	219	65.39	22.37
Spelling															
Grade 1 Spring	113	13.32	5.98	170	18.99	3.07	255	16.96	4.54	175	9.55	5.11	231	13.57	5.00
Grade 2 Fall	108	17.90	6.76	159	20.47	3.61	238	18.23	4.12	170	12.61	5.90	224	16.83	5.21
Grade 2 Spring	106	27.92	6.75	157	23.73	5.01	239	21.85	4.20	167	17.24	5.10	219	22.99	7.10

Table 3

Correlation Coefficients (Pearson) Between Reading and Spelling Within Each Orthography

	Spelling, Grade 1S	Spelling, Grade 2F	Spelling, Grade 2S	Reading, Grade 1S	Reading, Grade 2F
Dutch					
Spelling, Grade 2F	.714				
Spelling, Grade 2S	.637	.686			
Reading Grade 1S	.631	.576	.694		
Reading Grade 2F	.571	.564	.692	.888	
Reading Grade 2S	.467	.497	.735	.819	.867
English					
Spelling, Grade 2F	.845				
Spelling, Grade 2S	.786	.824			
Reading Grade 1S	.755	.787	.736		
Reading Grade 2F	.717	.796	.772	.875	
Reading Grade 2S	.667	.758	.746	.887	.926
French					
Spelling, Grade 2F	.774				
Spelling, Grade 2S	.718	.711			
Reading Grade 1S	.667	.623	.590		

	Reading Grade 2F	.530	.581	.545	.862	
	Reading Grade 2S	.502	.524	.532	.798	.894
German						
	Spelling, Grade 2F	.836				
	Spelling, Grade 2S	.767	.834			
	Reading Grade 1S	.636	.610	.571		
	Reading Grade 2F	.615	.638	.613	.858	
	Reading Grade 2S	.584	.621	.622	.844	.952
Greek						
	Spelling, Grade 2F	.560				
	Spelling, Grade 2S	.523	.696			
	Reading Grade 1S	.471	.571	.572		
	Reading Grade 2F	.495	.603	.649	.853	
	Reading Grade 2S	.425	.533	.636	.806	.893

Note. All correlation coefficients were significant at $p < .001$ level.

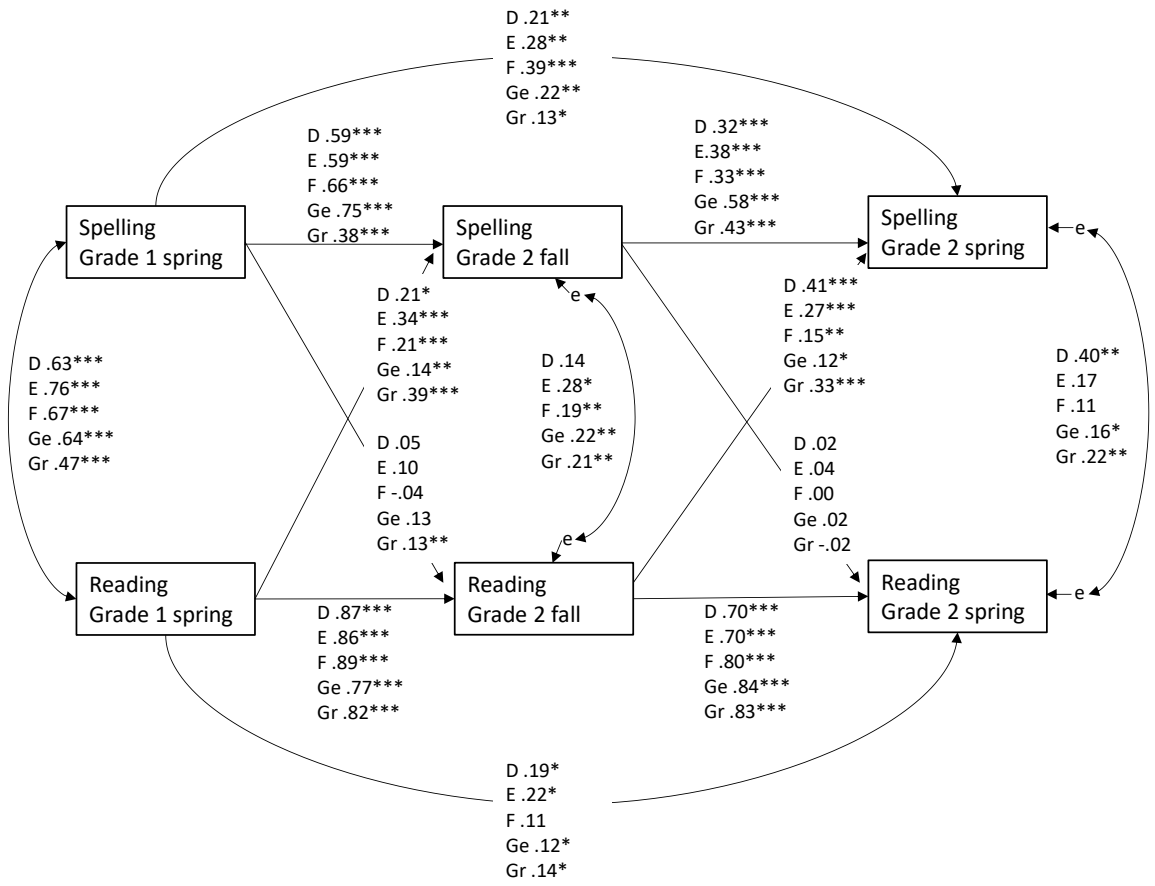

*Figure 1. Cross-lagged models for each orthography separately. Note. D=Dutch, F=French, E=English, Ge=German, and Gr=Greek. The numbers represent standardized beta coefficients. * p < .05; ** p < .01; *** p < .001.*

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