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Phonological Awareness and Rapid Automatized Naming Predicting Early Development in Reading and Spelling: Results from a Cross-Linguistic Longitudinal Study

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Abstract

In this study, the relationship between latent constructs of phonological awareness (PA) and rapid automatized naming (RAN) were investigated and related to later measures of reading and spelling in children learning to read in different alphabetic writing systems (i.e., Norwegian/Swedish vs. English). 750 U.S./Australian children and 230 Scandinavian children were followed longitudinally between kindergarten and 2nd grade. PA and RAN were measured in kindergarten and Grade 1, while word recognition, phonological decoding, and spelling were measured in kindergarten, Grade 1, and Grade 2. In general, high stability was observed for the various reading and spelling measures, such that little additional variance was left open for PA and RAN. However, results demonstrated that RAN was more related to reading than spelling across orthographies, with the opposite pattern shown for PA. In addition, tests of measurement invariance show that the factor loadings of each observed indicator on the latent PA factor was the same across U.S./Australia and Scandinavia. Similar findings were obtained for RAN. In general, tests of structural invariance show that models of early literacy development are highly transferable across languages.

Keywords

cross-linguistic; measurement and structural invariance; phonological awareness; RAN; literacy development

1. Introduction

Studies of children learning the opaque English orthography have shown that phonological awareness (PA), the sensitivity to and the ability to manipulate sounds in spoken words, and rapid naming (RAN), the amount of time needed to name stimuli (e.g., digits and letters), are among the best predictors for reading and spelling (Caravolas, Hulme, & Snowling, 2001; Muter, Hulme, Snowling, & Stevenson, 2004; Parrila, Kirby, & McQuarrie, 2004; Scarborough, 1998; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Wagner, Torgesen, & Rashotte, 1994; Wolf & Bowers, 1999). In recent years, however, emerging data from cross-linguistic comparisons have shown that learning to read and spell proceeds faster in more transparent orthographies (e.g., Czech, Dutch, Finnish, German, Greek,

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Norwegian, or Swedish). In addition, the pattern of predictions from language and cognitive skills to reading and spelling acquisition is possibly different in transparent orthographies compared to English (Caravolas, 2005; Harris & Hatano, 1999; Seymour, Aro, & Erskine, 2003). Such findings raise doubts about whether models of early literacy development can be generalized across alphabetic writing systems (Share, 2008).

In this article, the main aim was to study the relationship between individual differences in PA and RAN and early development in reading and spelling across transparent and opaque orthographies. The study reported is part of an ongoing large-scale International Longitudinally Twin Study (ILTS) of early language and literacy growth conducted in Australia, the United States, Norway, and Sweden (Byrne et al., 2008; Byrne et al., 2002; Byrne et al., 2006; Byrne et al., 2007; Byrne et al., 2005; Samuelsson et al., 2008; Samuelsson et al., 2005; Samuelsson et al., 2007). In the ILTS, tests measuring PA and RAN are administered at the end of kindergarten and Grade 1 and tests of reading and spelling are administered at the end of kindergarten, Grade 1, and Grade 2 across the four test sites. In the following, current theoretical assumptions as well as empirical evidence on how PA and RAN relates to reading and spelling ability in different orthographies will be reviewed.

1.1. Phonological Awareness

PA is consistently found to predict reading and spelling development in the normal range as well as reading and spelling difficulties in many alphabetic writing systems studied to date (e.g., Bast & Reitsma, 1998; Caravolas, 2004, 2005; Høien, Lundberg, Stanovich, & Bjaalid, 1995; Lundberg, Olofsson, & Wall, 1980; Muter, et al., 2004; Müller & Brady, 2001; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wagner, et al., 1994; Wimmer, Landerl, Linortner, & Hummer, 1991; Öney & Durgunoglu, 1997). However, while PA appears to be related to reading in English-speaking children across several grades, studies conducted *within* transparent orthographies report that PA is either marginally related to early literacy development (Harris & Giannouli, 1999; Holopainen, Ahonen, & Lyytinen, 2001; Aarnoutse, van Leeuwe, & Verhoeven, 2005), or diminishes as a reliable predictor after the first two grades (de Jong & van der Leij, 1999, 2002; Landerl & Wimmer, 2000; Leppänen, Niemi, Aunola, & Nurmi, 2006; Lervåg, Bråten, & Hulme, 2009; van den Bos, 1998; Verhagen, Aarnoutse, & van Leeuwe, 2008; Wimmer, 1993; Wimmer, Mayringer, & Landerl, 2000).

The few studies that have attempted to *directly* compare patterns of prediction of early development in reading *across* orthographies have provided contradictory findings. Some of these studies seem to confirm that PA is a long-term predictor in English, but it is not to the same extent in examples of transparent orthographies (i.e., Greek vs. English as in Georgiou, Parrila, & Papadopoulos, 2008; German vs. English as in Mann & Wimmer, 2002). This pattern of predictions was also recently confirmed in a study distinguishing between normal readers and children with reading difficulties in Norwegian/Swedish compared to English at Grades 1 and 2 (Furnes & Samuelsson, 2010). In that study, PA contributed to identifying poor readers in English at both Grades 1 and 2, whereas PA was related to reading difficulties only in Grade 1 among the Norwegian/Swedish children. In contrast, there are three studies claiming that PA predicts individual differences in reading similarly in transparent orthographies and English (Caravolas, Volin, & Hulme, 2005, compared Czech and English; Furnes & Samuelsson, 2009, compared Norwegian/Swedish and English; Patel, Snowling, & de Jong, 2004, compared Dutch and English). It should be noted that the study by Furnes and Samuelsson (2009) do not contradict previous research suggesting that PA accounts for individual differences in reading at the initial phase in transparent orthographies. That is, in their study reading was predicted with the last assessment being conducted at Grade 1. Note also that the studies by Caravolas et al. (2005), Patel et al.

(2004), and Mann & Wimmer (2002) are based on concurrent assessments, and thus, not designed to study how patterns of prediction may *change* over time.

Although findings within and across orthographies are mixed, the general pattern seem to be that the association between PA and reading is more pronounced in opaque orthographies than in several transparent European orthographies. One possible explanation is the time needed to establish reliable grapheme-phoneme recoding procedures in different alphabetic writing systems (Goswami, Ziegler, & Richardson, 2005; Seymour, et al., 2003). In transparent orthographies, this is a relatively effortless challenge for most readers where one letter or letter cluster is normally pronounced in the same way. In contrast, a less transparent orthography such as English, where letters can have multiple pronunciations, places heavier demands on PA when reading develops. Thus, given that a close correspondence between letters and sounds secures children’s recoding skills at a relatively early stage in transparent orthographies, it is expected that PA should be a less reliable predictor of reading in Norwegian and Swedish compared to English after the first grade.

Most cross-linguistic research has focused on the prediction of individual differences in reading. However, recent studies have reported that PA is more closely associated with spelling than reading in transparent orthographies (Furnes & Samuelsson, 2010; Landerl & Wimmer, 2008; Moll, Fussenegger, Willburger, & Landerl, 2009; Nikolopoulos, Goulandris, Hulme, & Snowling, 2006; Verhagen, Aarnoutse, & van Leeuwe, 2010). It has been argued that transparent orthographies are generally more consistent and redundant in the correspondence between letters and sounds (i.e., reading) than in the correspondence between sounds and letters (i.e., spelling) (Landerl & Wimmer, 2008). Thus, PA might contribute to spelling for a longer period of time compared to reading. However, to date there has been no study conducted longitudinally to examine if and how the prediction of PA to later spelling development in the normal range might change over time as well as *across* orthographies (but see Furnes & Samuelsson, 2010, predicting spelling difficulties at Grades 1 and 2 measuring PA at preschool and kindergarten). Similar to Dutch (Bosman & van Orden, 1997; Verhagen, et al., 2010), German (Landerl & Wimmer, 2008; Moll, et al., 2009), and Greek (Protopapas & Vlahou, 2009), in Norwegian and Swedish orthographies grapheme-phoneme correspondences are also more predictable than corresponding associations between phonemes and graphemes (for more details see Appendix). Consequently, it can be expected that PA should be a more reliable predictor for spelling compared to reading beyond the first grade in Norwegian and Swedish, and also that PA might predict spelling development in a similar way across orthographies.

1.2. Rapid Automatized Naming

Several studies have shown that RAN predicts later literacy performance in both transparent (e.g., de Jong & van der Leij, 1999; de Jong & van der Leij, 2002; Lervåg, et al., 2009; van den Bos, 1998; Wimmer, et al., 2000) and opaque orthographies (e.g., Georgiou, Parrila, Kirby, & Stephenson, 2008; Kirby, Parrila, & Pfeiffer, 2003; Wagner, et al., 1994; Wolf & Bowers, 1999). The pattern of prediction from RAN to reading across orthographies seems to be the opposite compared to PA. While RAN remains as a predictor of reading in transparent orthographies across grades (de Jong & van der Leij, 2003; van den Bos, Zijlstra, & Lutje Spelberg, 2002), it appears to be time-limited in English (Parrila, et al., 2004; Roman, Kirby, Parrila, Wade-Woolley, & Deacon, 2009; Wagner et al., 1997; Walsh, Price, & Gillingham, 1988). Much less is known about the association between RAN and spelling. The few studies that have investigated this relationship in English report that RAN predict spelling concurrently (Savage, Pillay, & Melidona, 2008; Strattman & Hodson, 2005). However, in two longitudinal studies involving children learning Greek and German (Landerl & Wimmer, 2008; Nikolopoulos, et al., 2006; Wimmer & Mayringer, 2002) no association between RAN and subsequent spelling skills were found.

In the studies designed for direct comparison *across* orthographies, all but one (Caravolas, et al., 2005), have included assessments of RAN. Georgiou et al. (2008) and Furnes and Samuelsson (2009, 2010) reported that RAN was a significant predictor of reading across orthographies. However, Mann and Wimmer (2002) showed that RAN was a significant predictor of reading in German but not in English. In the Patel et al. study (2004), RAN was not associated with reading in English or Dutch. A direct comparison of how RAN relates to spelling across orthographies has only been investigated in previous studies by Furnes & Samuelsson (2009, 2010). They showed that RAN was a significant predictor of spelling in both Norwegian/Swedish and English.

Despite a substantial number of studies over the past three decades, it is still debatable exactly *how* RAN is related to reading and spelling. One view sees RAN as tapping into the phonological system measuring the rate of access to phonological information in long-term memory (Share, 1995; Snowling & Hulme, 1994; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). This view is supported by studies showing moderate to high correlations between PA and RAN, and that the association between RAN and reading is mediated through PA (Torgesen, et al., 1997; Wagner, et al., 1994). If this suggestion is correct, then RAN should be more strongly related to literacy development in Norwegian and Swedish than English. The theoretical underpinnings being that, beyond the preciseness or accuracy of the phoneme-grapheme representations itself, rapid access to phonological representations is the main prerequisite to develop automaticity in reading a transparent writing system. A second view acknowledges that RAN has phonological components (e.g., retrieving and articulating various symbol names), but suggests that RAN also taps a distinct process unrelated to PA, namely, the ability to form orthographic representations (Manis, Seidenberg, & Doi, 1999; Wolf & Bowers, 1999). This view is supported by studies showing moderate to low interrelationships between PA and RAN, and that each component contributes independently to the variance in specific literacy subskills (see Wolf & Bowers, 1999, for a review). If this is correct, then it can be expected that RAN should be a more important predictor of literacy development in English than in Norwegian and Swedish because *multiple* strategies, such as children's ability to form orthographic representations, are more important for reading to be effective in opaque orthographies.

In addition to explanations related to orthographic regularity, it might also be that the link between PA, RAN, and literacy development depends on the way reading and spelling is measured in different studies as well as across orthographies. That is, most studies from English-speaking countries generally favour the prediction of reading accuracy, whereas researchers in transparent orthographies have been more concerned with the prediction of reading speed (cf. Share, 2008). Being aware that PA is normally assessed with tasks focusing on accuracy, and RAN on speed, this could partly explain why RAN seems to be a stronger predictor in transparent orthographies whereas PA might be a better predictor in English. In fact, several English-speaking studies measuring reading speed have shown that RAN is a more reliable longitudinal predictor of reading compared to PA (Georgiou, Parrila, & Papadopoulos, 2008; Schatschneider, et al., 2004; Torgesen, et al., 1997; Wolf & Bowers, 1999).

1.3. The present study

Because alphabetic languages vary in the degree to which letters represent sounds, it has been questioned whether models of early literacy development can be generalized across orthographies (Aro & Wimmer, 2003; Harris & Hatano, 1999; Share, 2008). For this reason, the primary aim of the present study was to examine the relative contribution of PA and RAN to early development in reading and spelling across transparent and opaque orthographies (Norwegian/Swedish vs. English). In an initial study, the impact of a range of cognitive and language skills on reading and spelling in the normal range from preschool to the end of kindergarten and Grade 1 was examined (Furnes & Samuelsson, 2009). In a second study, the importance of the same preschool and kindergarten cognitive and language skills in distinguishing between poor and normal readers at Grades 1 and 2 was examined (Furnes & Samuelsson, 2010). In the present study, assessments of PA and RAN in Grade 1 were included. The main aim addressed was whether PA and RAN would remain as significant predictors of individual differences in reading and spelling when controlling for the autoregressive effects from prior reading and spelling skills. More specifically, in both orthographies, the impact of PA and RAN at the end of kindergarten and Grade 1 on reading and spelling skills at the end of Grades 1 and 2 was examined.

Previous cross-linguistic studies have all used observed rather than latent variables in their analysis. This is a methodological and statistical shortcoming because one takes for granted that the developmental conceptualization of the construct of interest is identical across samples. In addition, a latent variable represents the common variance of its indicators and, consequently, specific method variance of an indicator is excluded (cf. de Jong & van der Leij, 1999). In the present study, the observed measures of PA and RAN served as indicators for latent variables of each construct. Thus, one additional aim was to determine whether PA and RAN can be seen as invariant constructs across orthographies.

2. Methods

2.1. Participants

The total sample for the present analyses was 750 same-sex twin pairs from Australia and the United States and 230 pairs from Norway and Sweden. However, the use of twins for these analyses potentially represents a methodological problem because the scores of the twins in each pair might not fully represent independent observations, that is, twins share genes, home and preschool/school environment. Therefore one child from each pair was selected by removing Twin 1 from Pair 1, Twin 2 from Pair 2 and so forth. Since this study is still in progress in Sweden, Australia, and the United States, some of the children have not at the time of writing been tested at Grade 1 and Grade 2. Actual attrition because of families leaving the project is virtually zero. Mean age, total sample sizes, and gender distribution in each sample across grades are given in Table 1. Only participants for whom the predominant language of their country was the first language spoken at home were selected (i.e., Norwegian, Swedish, or English). There were no significant differences in parents' mean years of education in Norway/Sweden (M = 13.9, SD = 2.9) and U.S./ Australia (M = 14.0, SD = 2.1).

There are some cultural as well as educational differences between Norway/Sweden (henceforth denoted Scandinavia), on the one hand, and Australia and the United States, on the other hand, that needs comment. In Scandinavia, there is an established tradition among parents that teaching literacy should take place in school, and that children receive literacy instruction at 7 years of age (i.e., Grade 1). That is, reading is not directly taught in kindergarten but children learn about letter names and letter sounds. Note that Norwegian children entering school from 2006 and onwards received formal literacy instruction in kindergarten, that is, at 6 years of age (this change in the curriculum was made after data collection in the present study). Both Australia and the United States generally favour earlier and more gradual instruction, and the culture of home and preschool training is such that most children have already learned about letter names and letter sounds by the time they enter kindergarten and receive formal literacy instruction. In sum, these differences across countries suggest that U.S./Australian children might perform better than Scandinavian children on tests measuring reading and spelling skills at Grades 1 and 2.

2.2. Tests and Materials

At the end of kindergarten and Grade 1, the children were administered measures of PA, RAN, word recognition, phonological decoding, and spelling. At the end of Grade 2, only measures of word recognition, phonological decoding, and spelling were administered. All tests were English in origin and have been translated and adjusted into the Scandinavian languages for this project (see Samuelsson, et al., 2005, for further details). Based on data available for the U.S. sample, Cronbach's alpha estimates of reliability are high for all measures. In addition, monozygotic twin correlations provide lower-bound reliability estimates for the measures, and these have been reported to be reasonably high and comparable for most tests across test sites (Byrne, et al., 2007; Byrne, et al., 2005).

As the present study is part of a larger study that addresses a wide range of questions, only variables that specifically relate to the current research questions are presented here. Children's verbal ability was mainly measured in preschool and was included as a control variable in the current study.

2.2.1. Vocabulary—The Vocabulary subtest from the WPPSI-Revised battery (WPPSI-Revised; Wechsler, 1989) and the Hundred Picture Naming Test (HPNT; Fisher & Glenister, 1992) were used to measure preschool vocabulary. In these two tasks the children were asked to either provide verbal definitions of words or to name pictures (no time restriction was used). Score is total number correct, maximum = 22 for WPPSI vocabulary and 100 for the HPNT. Mean age for test administration at preschool was 58 months (*SD* = 2.8) in U.S./Australia and 61 months (*SD* = 1.7) in Scandinavia.

2.2.2. Phonological awareness—Two subtests from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) were used to measure phonological awareness at kindergarten and Grade 1. In the syllable and phoneme blending test children were required to amalgamate segments into words, as in /I/ + /t/ to make *it* in English, or /A/ + /t/ to make *at* in Norwegian. Score is total number correct, maximum = 20. In the syllable and phoneme elision task children were required to say part of a word after eliding a segment, as in *cup* without /k/ in English or *kopp* without /k/ in Norwegian. The score is total number correct, maximum = 20.

2.2.3. Rapid naming—Rapid Digit Naming and Rapid Letter Naming from the CTOPP (Wagner, et al., 1999) were used as measures of rapid automatized naming at kindergarten and Grade 1. Six digits and letters were presented randomly in each test, and the tests included a total of 72 digits and letters. Time in seconds was recorded.

2.2.4. Reading—The sight word reading and the phonological decoding subtests from The Test of Word Reading Efficiency(TOWRE; Torgesen, Wagner, & Rashotte, 1999), with both forms A and B administered, were used to measure word recognition and phonological decoding in kindergarten, Grade 1, and Grade 2. In each form, children read a list of words and a list of nonwords as quickly as possible in 45s. Score is total number correct after 45s.

2.2.5. Spelling—At kindergarten, spelling was measured by a test developed by Byrne and Fielding-Barnsley (1993). Scoring was based on correct representation of the individual phonemes in each word and nonword. There were ten words and four nonwords in the test. In Grades 1 and 2, spelling was measured by the Wide Range Achievement Test (WRAT; Jastak & Wilkinson, 1984) spelling subtest. In this test, children spell words until they make ten consecutive errors and the score is the total number of words spelled correct out of the maximum of 45.

2.3. Procedure

All participants were tested individually in either their homes or schools by trained research assistants. Testing at each grade level (i.e., kindergarten, Grade 1, and Grade 2) was administered in a single session of 1 hour between March and June each year in Scandinavia, or in the summer (U.S./Australia).

2.4. Data Analyses

For this study, structural equation modelling (SEM) was utilized to examine the relationship between individual differences in PA and RAN and later development in reading and spelling. All analyses were based on variance/covariance matrices, and maximum-likelihood algorithms were used to estimate parameters (Mplus 5.2; Muthén & Muthén, 1998–2007). Model fit was evaluated with the chi-square statistics and by means of the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean square Residual (SRMR). Indicative of good model fit are CFI > .95, RMSEA ≤ .06, and SRMR ≤ .08 (Hu & Bentler, 1999).

SEM was performed within each sample with phonological decoding, word recognition, and spelling at the end of Grades 1 and 2 as the dependent variables. Multigroup-SEM analyses were used to compare the equivalence of the factor structure and structural paths across orthographies. The first step in determining the comparability of the models was to arrive at a baseline model that fit the data for each sample letting all parameters be free. If this holds, then it was established that the models had the same paths and the same fixed and free parameters across samples. The next step was to compare the baseline model with a nested model, where factor loadings were held equal across samples. If the difference in chi-square value ($\Delta\chi^2$), with degrees of freedom (*dfs*) equal to the number of constrained parameters, was significant, then this indicated that measurement invariance at this level was not detected. If the hypothesis of equal factor loadings was not rejected, however, then the invariance of structural path coefficients across samples was evaluated.

Because the chi-square difference test “has substantial power in large samples to detect small discrepancies between groups that may be of no theoretical or practice consequence” (Chen, Sousa, & West, 2005, p. 487), Cheung and Rensvold (2002) recommended that a decrease in the CFI greater than .01 should be considered to indicate a meaningful decrement in fit. Given that the tests was based on large sample sizes (N = 980), both the chi-square difference test and change in CFI was used to evaluate model fit.

3. Results

Descriptive statistics for all measures are displayed in Table 2. Most tasks were registered as total number correct, with higher scores indicating better performance. The RAN tasks were reported in terms of seconds, that is, shorter times indicated better performance.

As can be seen in Table 2, there were no floor or ceiling effects across test occasions in the tests measuring PA and RAN at kindergarten and Grade 1. However, the distributional properties of the variables indicated that the RAN tasks revealed some skewness, but there were no obvious outliers in the two samples. At kindergarten, word recognition and phonological decoding was positively skewed in both samples. The score distribution of the reading and spelling tests in Grades 1 and 2 were approximately normal, except for phonological decoding in Scandinavia at Grade 1. The subsequent raw score analyses of these measures were repeated with appropriately logarithmically transformed scores (Tabachnick & Fidell, 2007). However, although transformations of variables that deviate from normality improved their distributions, it did not change the results. Therefore, analyses were performed on raw scores.

Means and standard deviations across the U.S./Australian and the Scandinavian sample are comparable for most of the measures except for some of the reading and spelling tasks (see Table 2). The Scandinavian children were superior in spelling and comparable with the U.S./Australian children in phonological decoding (possibly accounted for by a more transparent orthography), but their word recognition scores were significantly lower (most likely due to later start of formal reading instruction in Norway and Sweden).

3.1. Correlations Among All Variables in U.S./Australia and Scandinavia

Table 3 displays the correlations between all measures used in preschool (vocabulary only), kindergarten, Grade 1, and Grade 2 with the Scandinavian sample above the diagonal and the U.S./Australian sample below the diagonal. All correlations were statistically significant and ranged from low to high.

PA and RAN were weakly correlated within each sample at kindergarten (mean correlation of −.36 in U.S./Australia and −.41 in Scandinavia) and Grade 1 (mean correlation of −.28 in U.S./Australia and −.30 in Scandinavia). These results confirm research from a variety of orthographies showing that RAN and PA are only weakly related (see Wolf & Bowers, 1999, for a review). Both PA and RAN showed moderate stability from kindergarten to Grade 1 across samples. More specifically, mean correlation for PA was .44 in the U.S./Australian sample and .51 in the Scandinavian sample. Comparable results for RAN were .64 in U.S./Australia and .58 in Scandinavia.

Mean correlation between reading and spelling skills at kindergarten were .73 in the U.S./Australian sample and .74 in the Scandinavian sample. A similar pattern of findings was seen among reading and spelling skills in Grade 1 (.82 in the U.S./Australian sample and .78 in the Scandinavian sample) and Grade 2 (.80 in the U.S./Australian sample and .76 in the Scandinavian sample). The stability of word recognition and phonological decoding between kindergarten and Grade 1 was high, with a mean correlation of .69 and .68 in the U.S./Australian and Scandinavian sample, respectively. These correlations were even more substantial between Grades 1 and 2 (.82 in U.S./Australia and .78 in Scandinavia). A similar pattern of findings was seen for spelling across languages as well as across grades. Together, these findings indicates that reading and spelling skills become more manifest once children have received some years of formal instruction in reading.

Finally, the relationship between PA in kindergarten and reading and spelling skills in Grade 1 yielded a mean correlation of .49 and .51 in the U.S./Australian and the Scandinavian sample, respectively. Corresponding findings between Grade 1 and Grade 2 were somewhat lower, .38 in U.S./Australia and .41 in Scandinavia. Measures of RAN in kindergarten and Grade 1 were moderately correlated with reading and spelling skills in Grade 1 (mean correlation of −.50 and −.48 in U.S./Australia and Scandinavia, respectively) and Grade 2 (mean correlation of −.52 and −.50 U.S./Australia and Scandinavia, respectively). To summarize, a similar pattern of correlations was obtained in both orthographies between PA and RAN at kindergarten and Grade 1, between reading and spelling skills at kindergarten, Grade 1, and Grade 2, and also between PA and RAN and later reading and spelling skills. In addition, the stability of the different variables ranged from moderate to high. Note also that preschool vocabulary was only weakly related with all other measures across samples as well as across grades.

3.2. PA and RAN in Kindergarten and Grade 1 Predicting Reading and Spelling Skills at the End of Grade 1 and Grade 2 across Orthographies

Structural equation modelling for the U.S./Australian and the Scandinavian samples was performed to assess the influence of individual differences in PA and RAN in kindergarten

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and Grade 1 on reading and spelling skills in Grades 1 and 2, respectively. Before conducting longitudinal analyses the scores were standardized by regressing age and sex onto the raw scores for each variable within each sample and time of assessment. Because of indications of collinearity between some of the predictor variables, a method for computing hierarchical regressions in the context of latent variables was used to partition out the unique variance in reading and spelling predicted by PA and RAN at each grade level. According to Bentler and Satorra (2000, p. 287), "The essence of this approach is to decompose the predictor variables in the regression into orthogonal components based on a Cholesky decomposition and to regress the dependent variable on these orthogonal components. The components may be conceived of as phantom factors that do not have their own indicators" (see also de Jong, 1999).

In all analyses, the autoregressive variable was entered at the first step. Vocabulary was entered as a control variable at the second step. Step 3 shows the proportion of variance in reading and spelling that was explained by PA and RAN beyond the impact of the autoregressor and vocabulary. Finally, Step 4 shows the unique variance accounted for by PA and RAN. Note that, in all analyses, PA, RAN, and vocabulary are latent variables whereas reading and spelling consist of observed variables.

3.2.1. Predicting reading and spelling skills at the end of Grade 1—In the first analyses, the relationship between PA and RAN in kindergarten and reading and spelling skills in Grade 1 was examined. As can be seen in Table 4, the model-fit indices appear to range from good to excellent. All loadings from the latent variables (i.e., PA, RAN, and vocabulary) to their observed indicators were strong and significant, indicating good reliability. The squared parameter estimates from these analyses are displayed in Table 5.

As can be seen in Table 5, the four predictor variables together accounted for 60%, 55 %, and 49 % of the variance in word recognition, phonological decoding, and spelling in the U.S./Australian sample, respectively. A similar amount of variance in word recognition (57 %), phonological decoding (48 %), and spelling (57 %), was accounted for in the Scandinavian sample. As expected, there was a strong autoregressive path from literacy skills in kindergarten to subsequent literacy skills in Grade 1 across samples (36 % to 52 % in U.S./Australia and 39 % to 48 % in Scandinavia). However, even after controlling for the autoregressive effect, PA and RAN were significant predictors of word recognition, phonological decoding, and spelling in Grade 1 in the U.S./Australian sample. On the one hand, RAN was the strongest predictor for word recognition and phonological decoding, accounting for two to three times more variance than PA. On the other hand, PA was a stronger predictor for spelling, accounting for about five times as much variance compared with RAN. In Scandinavia, RAN was the only significant predictor for word recognition and phonological decoding in Grade 1. Both RAN and PA were significantly associated with spelling, but the amount of variance accounted for by PA was five times higher compared with RAN. Note that the contribution from PA and RAN did not change noticeably when considered first (Step 3) or last (Step 4) in the model in neither U.S./Australia nor in Scandinavia. This finding further indicates that PA and RAN account independently for individual differences in reading and spelling. Note also that given the strong autoregressive effect in this model, the evaluation of PA and RAN as additional longitudinal predictors of reading and spelling is quite conservative. Although the analyses presented above might indicate some differences in the prediction of reading across orthographies, we have still not evaluated such potential differences in a proper statistical way.

To ensure that valid comparisons can be made between samples, the assumption of measurement and structural invariance of the models was tested. As can be seen in Table 6, the baseline model provided an excellent fit to the data for word recognition, phonological decoding, and spelling. The next step was to compare the baseline model with a more restrictive model where factor loadings were constrained to equality across samples. In these analyses, the decrease in the CFI value was at the highest .001. These values are well below the criteria for model comparison suggested by Cheung and Rensvold (2002). As the present analyses performed Cholesky decomposition, it was also necessary to constrain the loadings between the latent constructs and their phantom factors. At this step, the decrease in the CFI value was significant for word recognition (.024) and spelling (.032), but not for phonological decoding (.002). Given these strict rules for comparing models across groups, only structural path coefficients in the model predicting phonological decoding could be tested for invariance. When this was performed as a final step, the decrease in the CFI value was only .006. The total decrease in CFI from the baseline model to the last structural model with constraints in all parameters was .008, and thus, well below the criteria for model comparison. To summarize, tests of measurement and structural invariance showed that (a) the latent constructs of PA and RAN in kindergarten were reliable across samples, (b) PA and RAN predict phonological decoding in the same way and at similar levels across orthographies, and finally, (c) strictly statistical criteria were not fulfilled for sample comparison in predicting word recognition and spelling in Grade 1. However, given that estimated variances accounted for in word recognition and spelling by PA and RAN were reasonable similar across samples, it is quite safe to conclude that there are no reliable differences across orthographies in predicting basic reading and spelling skills.

3.2.2. Predicting reading and spelling skills at the end of Grade 2—In a second set of analyses the extent to which PA and RAN in Grade 1 were able to predict reading and spelling in Grade 2 across orthographies was examined. The model-fit indices and the squared parameter estimates from these analyses are displayed in Table 7 and Table 8, respectively. Again, in all analyses, the loadings from the latent variables to their indicators were reasonably high and significant and the model-fit indices appear to range from good to excellent.

As can be seen in Table 8, the predictor variables accounted for 78 %, 75 %, and 73 % of the variance in word recognition, phonological decoding, and spelling in the U.S./Australian sample, respectively. A similar amount of variance in word recognition (67 %), phonological decoding (61 %), and spelling (68 %), was accounted for in the Scandinavian sample. Once again, a strong autoregressive effect of previous literacy skills was obtained (72 % to 74 % in U.S./Australia and 56 % to 66 % in Scandinavia), making it difficult for PA and RAN to explain additional variance. The amount of variance accounted for by the autoregressive variable have increased on average 10 % to 20 % compared to the analyses from kindergarten to Grade 1 reading and spelling. After controlling for the autoregressive path, RAN was a significant predictor of both word recognition and phonological decoding in U.S./Australia, but only for phonological decoding in Scandinavia. PA did not predict word recognition in either sample. Although significant in the U.S./Australia sample, PA was not a reliable predictor of phonological decoding across samples, on average more than five times less important compared to RAN. Both PA and RAN accounted for a small amount of variance in spelling in U.S./Australia, whereas PA was the only significant predictor of spelling in Scandinavia. The contribution from PA and RAN did not change noticeably when considered first (Step 3) or last (Step 4) in the model across samples.

As in the previous analyses between kindergarten and Grade 1, the present analyses showed that the baseline model provided an excellent fit to the data (see Table 9). In addition, when factor loadings were constrained to equality the decrease in the CFI value was well below .01. When constraining loadings between the latent constructs and their phantom factors the decrease in CFI was .011 for both phonological decoding and spelling, and .006 for word recognition. Thus, testing the invariance of structural path coefficients across samples was only possible in the model predicting word recognition. In this final step, the CFI value did not result in an additional decrease. Thus, total decrease in CFI from the first baseline model to the final model was .009. These analyses suggest that the latent constructs of PA and RAN in Grade 1 were again reliable across orthographies. In addition, the strength of the structural paths when predicting Grade 2 word recognition from Grade 1 PA and RAN were similar in the U.S./Australian and Scandinavian samples. Although the models for phonological decoding and spelling across samples were not fully comparable in a strict statistical sense, the pattern of prediction from Grade 1 PA and RAN to decoding and spelling was almost identical across orthographies, with the only possible exception that Grade 1 PA might be a stronger predictor to Grade 2 spelling in Scandinavia compared to U.S./Australia.

4. Discussion

4.1. Predicting reading within orthography

This study examined the longitudinal relationship between latent constructs of PA and RAN at kindergarten and Grade 1 and measures of reading and spelling in Grade 1 and Grade 2 across transparent and opaque orthographies. Controlling for previous reading skills and vocabulary, analyses showed that kindergarten RAN accounted for a small but significant amount of variance in word recognition and phonological decoding in Grade 1 in both the U.S./Australian and the Scandinavian samples (3 % to 7 %). One year later, Grade 1 RAN continued to predict word recognition and phonological decoding in Grade 2 in U.S./Australia (2 % to 3 %). In Scandinavia, Grade 1 RAN was only a predictor of phonological decoding in Grade 2 (3 %). The contribution of PA to early development in reading was somewhat different. In U.S./Australia, kindergarten PA was significantly related to word recognition and phonological decoding in Grade 1 only (1 % to 2 %). The contribution from Grade 1 PA to word recognition and phonological decoding in Grade 2 was virtually zero. In Scandinavia, neither kindergarten PA nor Grade 1 PA accounted for significant variance on measures of reading at Grades 1 and 2, respectively. These findings replicate research from a variety of transparent orthographies in that RAN is a stronger predictor of early reading development than PA (e.g., de Jong & van der Leij, 1999; Georgiou, Parrila, & Papadopoulos, 2008; Lervåg, et al., 2009; Mann & Wimmer, 2002). In fact, the present analyses suggest that PA is not at all a reliable predictor of reading skills beyond kindergarten in transparent orthographies here represented by Norwegian and Swedish. More surprisingly, a similar pattern of findings concerning the impact of PA on reading was found in the U.S./Australian sample in that PA diminishes as a significant predictor beyond Grade 1. Research conducted within English-speaking countries has shown that PA is a longitudinal predictor of individual differences in reading up to Grade 4 (e.g., Wagner, et al., 1997). In addition, several reports from English-speaking countries suggest that RAN diminish as a predictor of reading after the first grades in school (e.g., Meyer, Wood, Hart, & Felton, 1998; Wagner, et al., 1994; Walsh, et al., 1988). The present study suggest that kindergarten and Grade 1 RAN continue to predict reading in Grades 1 and 2, and that RAN seem to contribute to reading in a very similar way across orthographies. Thus, the overall impression from the present analyses is that there are more similarities than dissimilarities in the prediction of reading from PA and RAN in different languages.

4.2. Predicting spelling within orthography

The relationship between PA, RAN and early development in spelling was somewhat different compared to the pattern found for reading across orthographies. After the effects of earlier spelling ability and vocabulary had been controlled, analyses showed that kindergarten PA explained a significant amount of variance in Grade 1 spelling in both the U.S./Australian and the Scandinavian samples (10 %). Kindergarten RAN was also significantly related to spelling in Grade 1 across orthographies but to a lesser extent compared with PA (2 % to 3 %). One year later, both PA and RAN in Grade 1 were weakly related to Grade 2 spelling in U.S./Australia (< 1%). In Scandinavia, Grade 1 PA continued to predict spelling in Grade 2 (5 %), while the contribution from Grade 1 RAN to spelling in Grade 2 was close to zero. These findings replicate recent studies suggesting that PA is a stronger predictor of early spelling development than RAN in transparent orthographies (e.g., Landerl & Wimmer, 2008; Moll, et al., 2009; Verhagen, et al., 2010).

4.3. Predicting reading and spelling across orthographies

In addition to these findings on the prediction of early reading and spelling skills in different languages, the design of this longitudinal study also allowed to determine the extent of measurement and structural invariance of the models across samples. Analyses of measurement invariance at kindergarten and Grade 1 showed that the factor loadings of each observed indicator (i.e., blending and elision) on the latent PA factor was not statistically different across the U.S./Australian and the Scandinavian samples. Similar results were obtained for RAN. These findings confirm that the constructs of PA and RAN are similar and highly reliable across languages. However, given the strict statistical criteria for comparing structural path coefficients across groups, analyses of structural invariance (i.e., comparing structural paths between PA and RAN at kindergarten and Grade 1 and reading and spelling in Grades 1 and 2) was only possible in two out of six models. These analyses showed that the contribution from PA and RAN in kindergarten and Grade 1 to phonological decoding in Grade 1 and word recognition in Grade 2 were the same in U.S./Australia and Scandinavia. In addition, the remaining four models also indicate that the pattern of prediction from PA and RAN at kindergarten and Grade 1 to reading and spelling skills in Grades 1 and 2 were highly comparable across orthographies.

The present results are not in accordance with research claiming that PA is a long-term predictor in English compared to transparent orthographies (cf. Mann & Wimmer, 2002). In a previous study, it was shown that PA in preschool is a reliable predictor in the initial phase of learning to read across languages (Furnes & Samuelsson, 2009). It seems, however, that when children have established some very basic grapheme-phoneme recoding skills the importance of PA on further development in reading is fully accounted for by the component that it has in common with reading skill itself (cf. Hogan, Catts, & Little, 2005; Lervåg, et al., 2009). As has been shown by the present study, this role of PA in relation to early reading skills is more similar across different writing systems than previously reported.

In contrast to what have been shown for reading, PA seems to be a reliable predictor in the first stages of spelling development across orthographies. With the reservation that PA in Grade 1 seems to be a stronger predictor of Grade 2 spelling in Scandinavia than in U.S./ Australia, PA continues to be a significant predictor in both samples. This finding fits well with previous research in different orthographies suggesting that spelling imposes higher demands on PA than reading (e.g., Bradley & Bryant, 1983; Caravolas, 2004; Frith, 1985; Landerl & Wimmer, 2008; Verhagen, et al., 2010). One possible explanation is that the consistency of correspondences between phonemes and graphemes is generally less predictable than between graphemes and phonemes in both transparent and opaque orthographies (Savage, et al., 2008; Wimmer & Mayringer, 2002; Ziegler, Stone, & Jacobs, 1997).

This study provides no clear support to the view that RAN mainly reflects the speed of access to phonological representations, as suggested by Wagner and colleagues (Torgesen, et al., 1997; Wagner, et al., 1994; Wagner, et al., 1997), or RAN as a marker of orthographic representations, as suggested by Manis et al. (1999) and Wolf & Bowers (1999). Although, the present study does not provide a fair test for distinguishing between these two views of

RAN (i.e., none of the reading and spelling tasks were pure measures of phonological and/or orthographical skills), the fact that RAN as a predictor of reading and spelling was not affected by orthographic regularity seem to suggest that RAN is a compound skill that consists of several sub-processes that are related to early literacy development. These processes might very well imply both orthographical and phonological skills (cf. Bell, McCallum, & Cox, 2003). However, further investigation is certainly needed to more fully understand what RAN measure and why RAN is related to reading and spelling.

It has also been suggested that the divergent importance of PA and RAN across orthographies seen in previous research might be an artefact of tests measuring reading (cf. Share, 2008). In this study, however, PA and RAN as well as tests of reading and spelling were the same across orthographies with the test measuring reading emphasizing fluency and the test measuring spelling emphasizing accuracy. Thus, one additional explanation for the similar findings across orthographies seen in this study is that parallel versions of tests have been used in both samples.

4.4. Limitations

There are some limitations that should be borne in mind in evaluating this work. First, the findings may generalize only to orthographies with similar characteristics as Norwegian, Swedish and English and mainly for the ages of the participants involved. Second, the present study did not control for the possible influences of verbal memory on the relations between PA, RAN, and early development in reading and spelling. However, in previous reports, verbal memory measured at preschool was not significantly related to early reading and spelling development when considered along with PA and RAN (Furnes & Samuelsson, 2009, 2010). In addition, cultural as well as educational differences are inevitable when conducting cross-linguistic studies. However, the ILTS took all the necessary precautions to ensure that the tasks and the administration procedures would be as similar as possible across languages.

4.5. Conclusions

To sum up, the results of this study show that RAN is a reliable predictor of early reading development across orthographies, whereas PA is more related to the development of spelling. In addition, tests of measurement invariance clearly indicated that PA and RAN are reliable constructs across different languages. Although tests of structural invariance were not possible in most analyses, it might be concluded that structural models illustrating the relationship between PA, RAN, and early literacy development appear highly transferable across transparent and opaque orthographies. However, without evidence for the invariance of core cognitive and language skills (e.g., PA and RAN) in reading research across languages, the interpretation of possible differences on features related to the development of reading and spelling is problematic.

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Appendix

Key features of the Norwegian and Swedish orthographies

Norwegian and Swedish belong to the North-German group of the Indo-European languages with many similarities in phonology, morphology, vocabulary and syntax. Both languages consists of about 40 phonemes, 29 letters of the alphabet (20 consonants, and 9 vowels), and between 33 and 38 graphemes. The vowels /æ/ and /ø/ in Norwegian are written differently in Swedish (/ä/ and /ö/). Norwegian and Swedish are described as semi-regular, similar to German and Dutch, and located between Finnish and English (Elley, 1992; Seymour, et al., 2003). Norwegian and Swedish shares some basic rules for phonology and orthography with English in that the languages stem from the same Germanic root. That is, they are similar with respect to phonology (complex syllable structures, consonant clusters etc.) but differ with respect to both grapheme-phoneme and phoneme-grapheme regularity. To illustrate, in the Norwegian words *Land*, *Ball*, *Hage*, and *Katt* the grapheme /*a/* is normally pronounced the same, while in the corresponding English words *hand*, *ball*, *garden*, and *cat* the grapheme /*a/* is pronounced differently. In addition, Norwegian and Swedish adhere to the principle of morpheme regularity, that is, the root morphemes are preserved in different word forms (think: tenke, tenker, tenkte). Although Norwegian and Swedish are regular orthographies, there are some pitfalls for beginning readers and spellers. In Norwegian, for example, one grapheme may contain several letters: kj/tj [Ç], skj [ʃ], and ng [ŋ]. The principle for doubling consonants is another problem for beginning spellers (e.g. hatt [hat]; katt [cat]; buss [bus]). Typically, both Norwegian and Swedish have consonant clusters in initial, middle as well as final positions in words and this seems also to be somewhat problematic for beginning readers. For example, Hagtvet, Helland, and Lyster (2006), report that combinations such as oftest [most often], nifst [scary], and kringkasting [broadcasting] are often misspelled by children early in school. Note, however, that Norwegian and Swedish seem more consistent in the grapheme-phoneme direction (i.e., reading) than in the phoneme-grapheme direction (i.e., spelling) making it easier to learn to read than learn to spell. For example, identical word spellings with different pronunciations do not exist in these languages. Instead, words with similar pronunciation that are spelled differently (e.g., the Norwegian words hjerne [brain], gjerne [gladly]; hjort [deer], gjort [done]; skal [shall], skall [shell]; halv [half], hall [hall]; hjul [wheel], jul [christmas]) are quite common. Although accurate quantitative assessments of such ambiguities are not available in Norwegian and Swedish, this asymmetry has also been reported for other relatively transparent European orthographies such as Dutch, German, and Greek (Bosman & van Orden, 1997; Landerl & Wimmer, 2008; Protopapas & Vlahou, 2009; Verhagen, et al., 2010).

Table 1

Mean Age (standard deviation), Total Sample Size, and Sex Distribution in U.S./Australia and Scandinavia at the End of Kindergarten, Grade 1, and Grade 2.

Characteristics	U.S./Australia	Scandinavia
End of Kindergarten		
Age (in months)	74.4 (4.0)	81 (3.5)
Total sample size	750	230
Girls (%)	51	49
End of Grade 1		
Age (in months)	87.3 (4.6)	92.9 (3.7)
Total sample size	735	182
Girls (%)	49	50
End of Grade 2		
Age (in months)	99.6 (4.8)	105.1 (3.6)
Total sample size	686	140
Girls (%)	51	50

Table 2

Means and Standard Deviations of All Measures across U.S./Australia and Scandinavia

	U.S./Australia		Scandinavia	
Measures	***M***	***SD***	***M***	***SD***
Preschool				
WPPSI Vocabulary	19.7	6.9	18.3	5.4
Picture naming	78.0	9.2	78.2	9.9
End of Kindergarten				
Elision	6.2	3.7	4.7	4.0
Blending	8.9	4.1	7.2	4.8
RAN-digits	79.8	33.0	92.7	36.4
RAN-letters	86.6	36.7	104.1	39.6
Word Recognition	29.6	27.0	10.9	18.6
Phonological Decoding	12.6	13.7	8.4	13.6
Spelling	55.5	19.6	44.1	30.4
End of Grade 1				
Elision	10.5	4.7	9.7	5.6
Blending	12.5	3.6	14.0	3.9
RAN-digits	50.5	18.4	54.6	16.8
RAN-letters	56.5	23.3	64.3	22.4
Word Recognition	82.7	33.1	49.4	29.5
Phonological Decoding	35.5	22.7	30.2	17.6
Spelling	13.0	5.2	16.5	7.1
End of Grade 2				
Word recognition	110.5	29.5	85.0	29.9
Phonological decoding	51.2	25.0	45.2	19.5
Spelling	18.2	5.8	23.7	6.5

Note. WPPSI = Wechsler Preschool and Primary Scale of Intelligence.

Table 3

Correlations between All Measures Across Scandinavia (above diagonal) and U.S./Australia (below the diagonal)

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Preschool																			
1 WPPSI Vocabulary	-	.53	.23	.25	−.24	−.19	.24	.25	.20	.28	.29	−.21	−.24	.27	.17	.32	.22	.18	.27
2 100 picture naming	.57	-	.27	.33	−.23	−.22	.27	.29	.27	.28	.24	−.20	−.25	.34	.30	.35	.39	.30	.40
End of Kindergarten																			
3 Elision	.25	.31	-	.63	−.35	−.43	.70	.68	.65	.55	.43	−.21	−.30	.51	.46	.61	.33	.37	.58
4 Blending	.31	.35	.57	-	−.40	−.44	.58	.59	.75	.52	.55	−.30	−.35	.49	.38	.62	.37	.35	.58
5 RAN-digit	−.20	−.15	−.36	−.31	-	.60	−.39	−.39	−.49	−.31	−.34	.67	.53	−.46	−.40	−.45	−.44	−.42	−.36
6 RAN-letter	−.22	−.22	−.39	−.36	.84	-	−.52	−.51	−.54	−.33	−.21	.49	.61	−.56	−.51	−.48	−.40	−.41	−.28
7 Word recognition	.35	.37	.63	.51	−.49	−.53	-	.96	.62	.43	.36	−.26	−.38	.71	.66	.66	.50	.54	.56
8 Phonological decoding	.31	.31	.65	.54	−.45	−.48	.88	-	.64	.44	.38	−.27	−.40	.69	.65	.64	.51	.51	.56
9 Spelling	.38	.43	.64	.66	−.48	−.56	.67	.65	-	.55	.54	−.40	−.49	.58	.45	.66	.42	.36	.59
End of Grade 1																			
10 Elision	.19	.21	.54	.44	−.30	−.31	.42	.47	.45	-	.41	−.29	−.37	.51	.47	.59	.42	.42	.57
11 Blending	.11	.11	.31	.46	−.16	−.20	.21	.28	.35	.42	-	−.26	−.26	.33	.17	.54	.33	.25	.49
12 RAN-digit	−.22	−.14	−.24	−.22	.67	.61	−.33	−.31	−.36	−.36	−.22	-	.78	−.50	−.45	−.44	−.55	−.51	−.41
13 RAN-letter	−.20	−.14	−.26	−.20	.64	.62	−.33	−.32	−.37	−.34	−.18	.89	-	−.65	−.58	−.54	−.55	−.57	−.43
14 Word recognition	.25	.29	.52	.43	−.56	−.58	.72	.63	.61	.55	.26	−.55	−.54	-	.92	.74	.82	.80	.70
15 Phonological decoding	.25	.25	.54	.42	−.48	−.49	.71	.71	.55	.56	.28	−.48	−.46	.88	-	.67	.73	.76	.64
16 Spelling	.23	.25	.56	.45	−.43	−.44	.69	.67	.60	.60	.35	−.45	−.44	.80	.79	-	.65	.60	.80
End of Grade 2																			
17 Word recognition	.24	.27	.46	.35	−.56	−.58	.58	.51	.54	.48	.22	−.61	−.59	.86	.74	.67	-	.87	.71
18 Phonological decoding	.25	.26	.50	.36	−.49	−.51	.62	.60	.51	.53	.24	−.53	−.50	.83	.85	.73	.86	-	.69
19 Spelling	.17	.19	.52	.41	−.44	−.45	.62	.59	.56	.55	.24	−.44	−.43	.80	.78	.84	.75	.79	-

Note. WPPSI = Wechsler Preschool and Primary Scale of Intelligence; Elision = Syllable and phoneme elision; Blending = Syllable and phoneme blending.

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Table 4

Model Fit of the Hierarchical Latent Variable Regression Models Predicting Reading and Spelling Skills at Grade 1 across a) U.S./Australia and b) Scandinavia

Dependent variable	**N**	χ^2	***df***	***p***	**CFI**	**RMSEA**	**SRMR**
a)							
WR_G1	750	37.810	12	.000	.991	.054	.019
PD_G1	750	33.961	12	.001	.992	.049	.018
S_G1	750	37.630	12	.000	.991	.053	.018
b)							
WR_G1	230	15.930	12	.195	.994	.038	.023
PD_G1	230	14.265	12	.284	.997	.029	.021
S_G1	230	8.879	12	.713	1.000	.000	.015

Note. WR_G1 = Word recognition – Grade 1; PD_G1 = Phonological decoding – Grade 1; S_G1 = Spelling – Grade 1; χ^2 = chi-square test statistic; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual.

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Table 5

Incremental R^2 of the Hierarchical Latent Variable Regression Models Predicting Reading and Spelling Skills at Grade 1 across U.S./Australia ad Scandinavia.

	U.S./Australia			Scandinavia		
Steps	**WR_G1**	**PD_G1**	**S_G1**	**WR_G1**	**PD_G1**	**S_G1**
1 Autoregressor_KG	.516***	.496***	.364***	.477***	.419***	.391***
2 Vocabulary[b]	.000	.000	.000	.020[a]*	.001	.062***
3 RAN_KG	.071***	.038***	.025***	.066***	.053**	.026*
4 PA_KG	.011**	.013**	.097***	.004[a]	.008[a]	.097***
3 PA_KG	.021***	.023**	.102***	.000	.000	.107***
4 RAN_KG	.061***	.029***	.019***	.071***	.061***	.017†
Total R^2	.60	.55	.49	.57	.48	.57

Note. WR_G1 = Word recognition – Grade 1; PD_G1 = Phonological decoding – Grade 1; S_G1 = Spelling – Grade 1; Autoregressor_KG = the same reading and spelling variable measured at Kindergarten; RAN_KG = Rapid naming – Kindergarten; PA_KG = Phonological awareness – Kindergarten;

[a] Negative regression weight;

[b] Vocabulary was only assessed in preschool.

† $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

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Table 6

Measurement and Structural Invariance Tests of the Hierarchical Latent Variable Regression Models Predicting Reading and Spelling Skills at Grade 1 across Orthographies

	Overall Fit Indexes					Comparative Fit Indexes		
Model and invariance level	**χ^2**	***df***	**CFI**	**RMSEA**	**SRMR**	**$\Delta\ \chi^2$**	**Δ *df***	**Δ CFI**
			Word recognition					
1 Baseline	53.740*	24	.992	.050	.020			
2 Factor loadings	58.852*	27	.991	.049	.024	5.112	3	.001
3 Phantom factor loadings	155.880*	37	.967	.081	.082	97.028*	10	.024
4 Regression coefficients	161.350*	42	.967	.077	.078	5.470	4	.000
			Phonological decoding					
1 Baseline	48.226*	24	.993	.045	.019			
2 Factor loadings	53.176*	27	.993	.044	.024	4.950	3	.000
3 Phantom factor loadings	68.721*	37	.991	.042	.036	15.545	10	.002
4 Regression coefficients	94.639*	41	.985	.052	.048	25.918*	4	.006
			Spelling					
1 Baseline	46.509*	24	.994	.044	.017			
2 Factor loadings	54.170*	27	.993	.045	.023	7.661	3	.001
3 Phantom factor loadings	180.981*	37	.961	.089	.065	126.811*	10	.032
4 Regression coefficients	191.654*	41	.959	.087	.068	10.673*	4	.002

Note. χ^2 = chi-square test statistic; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; Δ = difference between the comparison and nested model.

* $p < .001$.

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Table 7

Model Fit of the Hierarchical Latent Variable Regression Models Predicting Reading and Spelling Skills at Grade 2 across a) U.S./Australia and b) Scandinavia

Dependent variable	N	χ^2	*df*	*p*	CFI	RMSEA	SRMR
a)							
WR_G2	750	21.772	12	.040	.997	.033	.018
PD_G2	750	14.744	12	.256	.999	.017	.013
S_G2	750	28.186	12	.005	.995	.042	.015
b)							
WR_G2	230	18.906	12	.091	.989	.050	.025
PD_G2	230	18.292	12	.107	.989	.048	.031
S_G2	230	9.856	12	.629	1.000	.000	.018

Note. WR_G2 = Word recognition – Grade 2; PD_G2 = Phonological decoding – Grade 2; S_G2 = Spelling – Grade 2; χ^2 = chi-square test statistic; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual.

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Table 8

Incremental R^2 of the Hierarchical Latent Variable Regression Models Predicting Reading and Spelling Skills at Grade 2 across U.S./Australia ad Scandinavia.

	U.S./Australia			Scandinavia		
Steps	**WR_G2**	**PD_G2**	**S_G2**	**WR_G2**	**PD_G2**	**S_G2**
1 Autoregressor_G1	.741***	.719***	.716***	.661***	.561***	.621***
2 Vocabulary	.001	.003*	.000	.003	.002	.005
3 RAN_G1	.033***	.022***	.008***	.003	.037**	.000
4 PA_G1	.000	.004*	.004*	.001	.008[a]	.053†
3 PA_G1	.000	.006*	.005**	.001	.012[a]	.053†
4 RAN_G1	.033***	.019***	.006**	.003	.033**	.000
Total R^2	.78	.75	.73	.67	.61	.68

Note. WR_G2 = Word recognition – Grade 2; PD_G2 = Phonological decoding – Grade 2; S_G2 = Spelling – Grade 2; Autoregressor_G1 = the same reading and spelling variable measured at Grade 1; RAN_G1 = Rapid naming – Grade 1; PA_G1 = Phonological awareness – Grade 1;

[a] Negative regression weight;

[b] Vocabulary was only assessed in preschool.

† $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 9

Measurement and Structural Invariance Tests of the Hierarchical Latent Variable Regression Models Predicting Reading and Spelling Skills at Grade 2 across Orthographies

	Overall Fit Indexes					Comparative Fit Indexes		
Model and invariance level	χ^2	*df*	**CFI**	**RMSEA**	**SRMR**	$\Delta \chi^2$	Δ *df*	Δ **CFI**
Word recognition								
1 Baseline	40.678*	24	.996	.038	.020			
2 Factor loadings	51.433*	27	.993	.043	.027	10.755*	3	.003
3 Phantom factor loadings	82.820*	37	.988	.050	.052	31.387*	10	.006
4 Regression coefficient	83.974*	41	.988	.046	.052	1.154	4	.000
Phonological decoding								
1 Baseline	33.036*	24	.997	.028	.019			
2 Factor loadings	42.316*	27	.996	.034	.026	9.280*	3	.001
3 Phantom factor loadings	89.992*	37	.985	.054	.065	47.676*	10	.011
4 Regression coefficients	99.557*	41	.984	.054	.076	9.565*	4	.001
Spelling								
1 Baseline	38.043*	24	.996	.035	.015			
2 Factor loadings	48.586*	27	.994	.040	.026	10.543*	3	.002
3 Phantom factor loadings	97.422*	37	.983	.058	.063	48.836*	10	.011
4 Regression coefficients	119.438*	41	.978	.062	.061	22.016*	4	.005

Note. χ^2 = chi-square test statistic; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; Δ = difference between the comparison and nested model.

* $p < .001$.