

# Common Patterns of Prediction of Literacy Development in Different Alphabetic Orthographies

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## Abstract

Previous studies have shown that phoneme awareness, letter-sound knowledge, rapid automatized naming (RAN), and verbal memory span are reliable correlates of learning to read in English. However, the extent to which these different predictors have the same relative importance in different languages remains uncertain. In this article, we present the results from a 10-month longitudinal study that began just before or soon after the start of formal literacy instruction in four languages (English, Spanish, Slovak, and Czech). Longitudinal path analyses showed that phoneme awareness, letter-sound knowledge, and RAN (but not verbal memory span) measured at the onset of literacy instruction were reliable predictors, with similar relative importance, of later reading and spelling skills across the four languages. These data support the suggestion that in all alphabetic orthographies, phoneme awareness, letter-sound knowledge, and RAN may tap cognitive processes that are important for learning to read.

## Keywords

reading, educational psychology, literacy, cross-linguistic

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Psychologists now have a relatively advanced understanding of the proximal skills underlying children's ability to learn to read. It is well established that in the early stages of reading development, the ability to isolate phonemes in spoken words, knowledge of letter-sounds, and the speed of rapid automatized naming (RAN; the speed of naming lists of objects, colors, digits, or letters) are three independent longitudinal predictors of variation in children's later word-reading skills (e.g., Lervåg, Bråten, & Hulme, 2009; Muter, Hulme, Snowling, & Stevenson, 2004; Wolf & Bowers, 1999). Letter-sound knowledge and phonemic skills form the basis of the alphabetic principle (Byrne, 1998): the ability to map letters in printed words onto the speech sounds they represent. RAN, in contrast, seems to tap a separate mechanism, which is possibly related to the efficiency of an object-naming circuit involved in forming associations between printed words and their pronunciations (Lervåg & Hulme, 2009).

Although there is a growing consensus that phonemic skills, letter-sound knowledge, and RAN are powerful predictors of reading and spelling (i.e., literacy) development in English, controversy remains about their relative importance in other alphabetic orthographies. Share (2008) argued that studies of reading development have been led astray by their "Anglocentric" focus because English has an "outlier orthography" in terms of the inconsistency of its spelling-sound correspondences. In the study reported here, we assessed whether the longitudinal predictors of early literacy development showed an equivalent pattern in English and in three other,

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more consistent orthographies (Spanish, Czech, and Slovak). Our study is unique in assessing a range of critical predictors with large samples in a longitudinal design. All four language groups were first assessed in the very early stages of learning to read, with a reassessment 10 months later when the children had made considerable progress in literacy skills but when these skills were still far from fully automatized. Thus, our study focused on what could be called the foundation phase of literacy development, a phase that is critical because it seems that once initial reading skills are established, they show a very high degree of longitudinal stability (Lervåg et al., 2009).

Alphabetic orthographies vary greatly in the consistency of their spelling-sound correspondences. Languages such as Finnish have mainly consistent, one-letter-to-one-sound mappings, whereas English has many inconsistent letter-sound mappings and is generally considered the least consistent of any alphabetic orthography (e.g., Ziegler, Stone, & Jacobs, 1997). Basic literacy skills are learned more quickly in more consistent orthographies (e.g., Caravolas & Bruck, 1993; Landerl, Frith, & Wimmer, 1997; Seymour, Aro, & Erskine, 2003). It is much less clear, however, whether orthographic consistency affects the relative strength and stability of letter knowledge, phoneme awareness, and RAN as predictors of reading and spelling development (e.g., Caravolas, Volín, & Hulme, 2005; Georgiou, Torppa, Manolitsis, Lyytinen, & Parrila, 2012; Ziegler et al., 2010). We addressed these issues by assessing these predictors with directly comparable measures in groups with similar reading ability.

Studies in many different languages have measured letter knowledge early in development and found it to be an important longitudinal predictor of later literacy skills (e.g., Bruck, Genesee, & Caravolas, 1997; Kim & Petscher, 2011; Lervåg et al., 2009; Muter et al., 2004). However, evidence for the roles of RAN and phoneme awareness is much less consistent across languages. Although phoneme awareness is accepted as one of the strongest predictors of literacy development in English (e.g., Caravolas, Hulme, & Snowling, 2001; Muter et al., 2004; National Institute for Literacy, 2008; Wagner, Torgesen, & Rashotte, 1994), it has been argued that in relatively consistent orthographies, phoneme awareness has less relevance whereas RAN is a critical and dominant influence on literacy development (e.g., Wimmer, Mayringer, & Landerl, 2000).

However, studies comparing these predictors show many inconsistencies across languages. Three recent cross-sectional studies involving languages varying widely in consistency (including English, French, Portuguese, Dutch, Hungarian, Czech, and Finnish) found that phoneme awareness was a strong predictor of individual differences in reading skills across all these languages (Caravolas et al., 2005; Vaessen, Bertrand, Denes, & Blomert, 2010; Ziegler et al., 2010). The later two studies also found that RAN was an additional, albeit weaker, predictor. These results are at odds with the hypothesis that phoneme awareness is most predictive of reading development in English and RAN is most predictive in languages with consistent orthographies (e.g., de Jong & van der

Leij, 1999; Wesseling & Reitsma, 2000; Wimmer et al., 2000; Wimmer & Mayringer, 2002). However, these recent studies involved only concurrent measures obtained from groups in which reading skills were quite well developed.

There have been only two longitudinal cross-linguistic studies relevant to our hypothesis: Georgiou, Parilla, & Papadopoulos (2008), in which English and Greek were studied, and Georgiou et al. (2012), which focused on English, Greek, and Finnish. Georgiou et al. (2012) found, perplexingly, that neither phoneme awareness nor RAN predicted reading ability across the first 2 years of instruction in Finnish. However, the study of Georgiou et al. (2008), which started when children already had appreciable literacy skills, found that RAN but not phoneme awareness was a predictor of later reading fluency in English, but in Greek neither RAN nor phoneme awareness were predictors. This study therefore suggests that RAN is a less powerful predictor of literacy development in Greek (a language with a consistent orthography) than in English.

We also considered verbal short-term memory as another predictor of literacy development. Some English studies have shown verbal short-term memory to be another predictor that is separable from phonological awareness and other measures of language ability (e.g., Wagner & Torgesen, 1987). In cross-linguistic studies, verbal short-term memory has received less attention, though Vaessen et al. (2010) and Ziegler et al. (2010) found that it was a weak and highly inconsistent predictor of literacy development in the different orthographies they studied. We reassessed this issue in the current longitudinal study.

In summary, there are many inconsistent findings concerning the roles of RAN, phoneme awareness, letter knowledge, and verbal short-term memory as predictors of early literacy development in different alphabetic orthographies. Here, we aimed to clarify the picture by assessing the predictors of literacy development across a period of 10 months in the early stages of learning, in four languages that vary widely in orthographic consistency: English, Spanish, Czech, and Slovak.

## Method

It was critical to have an objective estimate of the consistency of the orthographies we were studying. These estimates were derived from children's printed word corpora (Kessler & Caravolas, 2011; Martínez & García, 2004; Masterson, Stuart, Dixon, & Lovejoy, 2003). We estimated orthographic consistency as the frequency with which a particular grapheme-phoneme mapping (for reading) or phoneme-grapheme mapping (for spelling) occurs divided by the total frequency of the grapheme or phoneme, respectively, no matter how it is pronounced or spelled. Such consistency values ranged from 0 to 1. For each word segment, estimated consistency was averaged across all word positions, independently of context. The estimates for reading and spelling consistency, respectively, were .72 and .62 in English, .90 and .92 in Czech, .90 and .92 in Slovak, and .96 and .90 in Spanish.

## Participants

A total of 735 children (188 English, 190 Spanish, 153 Czech, and 204 Slovak) participated in all tests at Time 1 (at the onset of literacy instruction), and 675 participated in all tests at Time 2 (approximately 10 months later). For some tests, there were small amounts of missing data, so the number of observations varied slightly across the individual measures. The main reason for missing data (< 4.5%) was that roughly 50 children in kindergarten moved before they started school.

Participant age, gender, and other demographic information are provided in Table 1. Children were recruited from large cities and surrounding areas in their respective countries, and all were monolingual speakers of their country's language. At Time 1 (middle of the school year), all children were attending kindergarten (reception year in England). The group discrepancies in age reflect differences in the age of school entry among countries. The English children, although younger, had started to receive formal literacy instruction 5 to 6 months before the study began. For the other groups, formal literacy instruction had not started. However, in their kindergarten classes, they were being taught some letter-sound knowledge and phonological awareness skills, and they were learning to recognize their own names and words on signs (see Appendix S1 and Table S1 in the Supplemental Material available online for more details). From first grade onward, all four groups received phonically based instruction.

## Procedure

All groups were initially assessed in February or March of their reception or kindergarten year (Time 1) and were retested

approximately 10 months later (Time 2; middle of Year 1 for English children and middle of Grade 1 for Spanish, Czech, and Slovak children). Parallel measures of all tests were created across the four languages, unless such measures already existed. All tests were administered individually (except for the picture-word matching, letter writing, and spelling tests) and in the same order over three testing sessions at each time point.

**Time 1 measures.** Five measures were taken at Time 1: general cognitive ability, letter knowledge, phoneme awareness, RAN for objects and for colors, and verbal memory span.

**General cognitive ability.** To assess general cognitive ability, we administered the Vocabulary and Block Design subtests of the third United Kingdom edition of the Wechsler Preschool and Primary Scale of Intelligence for Children (WPPSI-III<sup>UK</sup>; Wechsler, 2003) to the English Group and the Spanish version of the WPPSI-III (Wechsler, 2001) to the Spanish group. For the Czech and Slovak groups, we adapted the English version and created standardized scores based on extended kindergarten-aged samples. (See Table 1 for mean scores of all groups.)

**Letter knowledge.** In four separate trials, children were asked to say the names and sounds for each letter of their alphabet (upper and lower case). The number of letters correct was summed to give measures of letter-name and letter-sound knowledge.

**Phoneme awareness.** To measure phoneme awareness, we administered two different tasks: phoneme isolation and phoneme blending. Phoneme isolation was assessed using four blocks of eight nonword items (the task was based on one reported in Hulme, Caravolas, Málková, & Brigstocke, 2005, Study 1). In the first two blocks, children isolated and pronounced the initial phoneme of consonant-vowel-consonant

**Table 1.** Group Characteristics and Participants' General-Ability Scores for Each Group at Time 1 and Time 2

Group	N	Age (months)		Number of schools represented		Number of classrooms represented		Recruitment area	Mean WPPSI-III Block Design score	Mean WPPSI-III Vocabulary score
		M	Range	Time 1	Time 2	Time 1	Time 2			
English	188 (98 boys, 90 girls)	60.27 (SD = 3.67)	53–67	9	9	10	10	Northern England <sup>a</sup>	10.13 (SD = 3.15)	9.56 (SD = 2.67)
Spanish	190 (104 boys, 86 girls)	66.72 (SD = 3.66)	61–73	5	7	11	20	Granada, Andalusia	11.71 (SD = 3.42)	9.16 (SD = 3.43)
Czech	153 (76 boys, 77 girls)	71.86 (SD = 4.04)	64–85	20	44	47	53	Prague, Bohemia	10.35 (SD = 2.86)	10.24 (SD = 3.16)
Slovak	204 (110 boys, 94 girls)	71.59 (SD = 3.86)	62–81	12	22	—	23	Bratislava, Slovakia	10.22 (SD = 2.96)	9.89 (SD = 2.96)

Note: Time 1 was just after the start of formal literacy instruction for the English group and prior to the beginning of formal literacy instruction for the Spanish, Czech, and Slovak groups; Time 2 was 10 months later. Mean scaled scores on the third United Kingdom edition of the Wechsler Preschool and Primary Scale of Intelligence for Children (WPPSI-III<sup>UK</sup>; Wechsler, 2003) and the WPPSI-III in Spanish (Wechsler, 2001) were obtained at Time 1.

<sup>a</sup>English samples were recruited from urban centers in Cheshire, Lancashire, and Yorkshire.

(CVC) or consonant-consonant-vowel-consonant (CCVC) syllables, and on the last two blocks, they isolated and pronounced the final phoneme of CVC or consonant-vowel-consonant (CVCC) syllables. For the last eight items, the Spanish children isolated the final consonants of CCVC stimuli (as opposed to CVCC stimuli) because CVCC constructions are very atypical in Spanish. Testing was discontinued after four consecutive errors in a block.

Phoneme blending required children to blend aurally presented phonemic segments into words. Ten (11 in Czech and Slovak) mono- and bisyllabic items with increasingly complex syllable structures were administered in a fixed order without corrective feedback. The test was discontinued after six consecutive responses that showed no overlap with any of the sounds in the target word (for more details, see Appendix S2 in the Supplemental Material).

**RAN for objects and for colors.** Parallel versions of the RAN task for objects and RAN task for colors were created; across languages, the stimuli were identical and corresponded to names of comparable length, phonological complexity, familiarity, and frequency. Children sequentially named, as quickly as they could, five items that were repeated eight times each over five lines of a 21-cm × 29.7-cm piece of card. Two trials of each task were administered, with items arranged in a different quasirandom order. Prior to the first trial, children were asked to name each of the stimuli on a separate paper to ensure that they knew them. RAN scores were estimated from the average naming time for the 40 objects or colors across the two trials. Accuracy was estimated by averaging the errors on each trial. Error rates were very low across languages (0.39–1.98% for objects; 0.48–2.85% for colors).

**Verbal memory span.** To assess verbal memory span, we asked children to repeat, in order, lists of familiar monosyllabic words. The words were drawn without replacement from a pool of eight words. The lists varied in length from two to eight words, with four lists at each list length, and were spoken by the examiner at a rate of one word per second. The test was discontinued after three consecutive errors at a given list length. Each correctly repeated list was credited with 0.25 points.

**Time 1 and Time 2 measures.** Four skills were measured at both Time 1 and Time 2: reading aloud, picture-word matching, letter writing, and word spelling.

**One-minute reading test.** To assess reading skills, we asked children to read aloud a list of 140 high-frequency words as quickly as possible. The lists began with words consisting of single letters and grew to include more complex two- and three-syllable words (up to five syllables in Spanish). The distribution of words by syllable number varied across languages to reflect their distribution in each language. The number of words read correctly in 60 s was recorded and converted to the number of syllables read per minute (at Time 1, all the words attempted were monosyllables).

**Picture-word matching reading test.** This paper-and-pencil test required the child to mark the word (out of four presented)

that corresponded to an accompanying picture (see Table S2 in the Supplemental Material for examples). A list of 52 target words, which were cognates across all four languages, was used. All words except the first three (which were of very high frequency) were selected from medium-range frequencies between 10 and 500 occurrences per million. As far as possible, words contained the same number of syllables and retained a similar syllable structure across languages. Three distractor words accompanied each target; one with similar spelling, one with similar meaning, and one unrelated. The distractors were matched as closely as possible on frequency, grade appropriateness, and length. One demonstration item and two practice items were administered before children undertook the task for a duration of 3 min.

**Letter writing.** To assess letter-writing skills, we asked children to write the letters corresponding to isolated sounds pronounced by the administrator. Fifteen letters were selected in each language, of which five were the vowels (/a/, /e/, /i/, /o/, /u/), five were consonants with relatively consistent sound-letter mappings, and five were consonants with relatively inconsistent sound-letter mappings. Up to two points (for accuracy and orientation of the letter) were awarded for each correctly spelled phoneme.

**Word spelling.** We created parallel versions of a graded spelling-to-dictation test to assess children's word-spelling skills. At Time 1, children were asked to spell their name and 7 frequent, familiar words. At Time 2, the task was the same, but the list was extended to between 40 and 45 items. The words in each language contained subsets of items containing inconsistent mappings of different types. The syllabic structures were comparable across languages and included words of one to three syllables with and without consonant clusters.

## Results

Descriptive statistics and reliabilities for all variables at the two time points are shown for each group in Tables S3 and S4 in the Supplemental Material. At Time 1, the groups performed relatively similarly on key measures of early literacy, despite the fact that the English children had received more formal literacy instruction than had children in the other three groups. Although the English group tended to have somewhat better letter knowledge than the other groups (reflecting the emphasis placed on teaching letter knowledge in English reception classes), and the English and Spanish groups showed better spelling skills than the Czech and Slovak groups, the latter two groups were actually slightly better on the picture-word matching reading measure. Thus, overall literacy skills were similar, and all language groups showed substantial variability on key literacy measures at Time 1.

Before conducting the analyses, we standardized all variables within each language. We then computed composite scores for reading (1-min reading and picture-word matching tests), spelling (letter spelling and word spelling), phoneme awareness (phoneme isolation and phoneme blending), letter

knowledge (letter names and letter sounds), and RAN (for colors and for objects) by summing  $z$  scores. These summed composite variables were then restandardized for each language to ensure identical distributions ( $M = 0$ ,  $SD = 1$ ) for all variables. The correlations between the composite scores for each language are shown in Table S5 in the Supplemental Material.

Our principal interest was in the role of different cognitive skills—measured at Time 1 prior to (the Spanish, Czech, Slovak groups) or just after (the English group) the onset of formal literacy instruction—as predictors of variations in literacy skills measured at Time 2, 10 months later. Variations in Time 2 literacy skills were predicted from Time 1 measures of phoneme awareness, letter knowledge, RAN, verbal memory span, vocabulary, and nonverbal ability (assessed using the Block Design subtest of the WPPSI-III), as well as the autoregressive effects of reading skills and spelling skills. The analyses were conducted as a series of multigroup (multilanguage) structural equation models in Mplus (Version 6.1; Muthén & Muthén, 2010). In these models, we used robust (Huber-White) standard errors to allow for the effects of clustering of children within classrooms. The small amount of missing data was handled by full-information maximum-likelihood estimators (the default in Mplus).

The models for the prediction of reading and spelling are shown in Figure 1. Because vocabulary and nonverbal ability were not statistically reliable predictors in either model, they were dropped (although including them did not materially alter the pattern of predictive relationships reported). In these multigroup models, all unstandardized parameters (variances, path weights, and covariances between predictors) were constrained to be equal across languages.

The pattern of relationships was remarkably clear and nearly identical for reading and spelling. For reading, prior reading skills, phoneme awareness, letter knowledge, and RAN were all unique longitudinal predictors of the growth of reading skills in the transition from reception or kindergarten to the middle of Grade 1 or Year 1 in all four languages studied. Verbal memory span was not a reliable unique predictor. However, memory span had a lower reliability than RAN or phoneme awareness, and a more reliable measure might possibly have been a stronger predictor.

The pattern of predictive relationships for spelling was identical to that for reading (with prior spelling as the autoregressor substituted for prior reading). The fact that in both models all the parameters were constrained to be equal provides a stringent test of whether the relative importance of these measures as predictors of progress in learning to read and to spell was equivalent across the four languages studied. Both models provide truly excellent fits to the data—reading:  $\chi^2(63, N = 675) = 39.70$ ,  $p < .991$ , comparative fit index (CFI) = 1.00, Tucker-Lewis index (TLI) = 1.02, root mean square error of approximation (RMSEA) = 0.000, 90% confidence interval = [0.000, 0.000], standardized root mean squared residual (SRMR) = .041; spelling:  $\chi^2(63, N = 675) = 55.93$ ,  $p < .724$ , CFI = 1.00, TLI = 1.00, RMSEA = 0.000, 90% confidence interval = [0.000, 0.036],

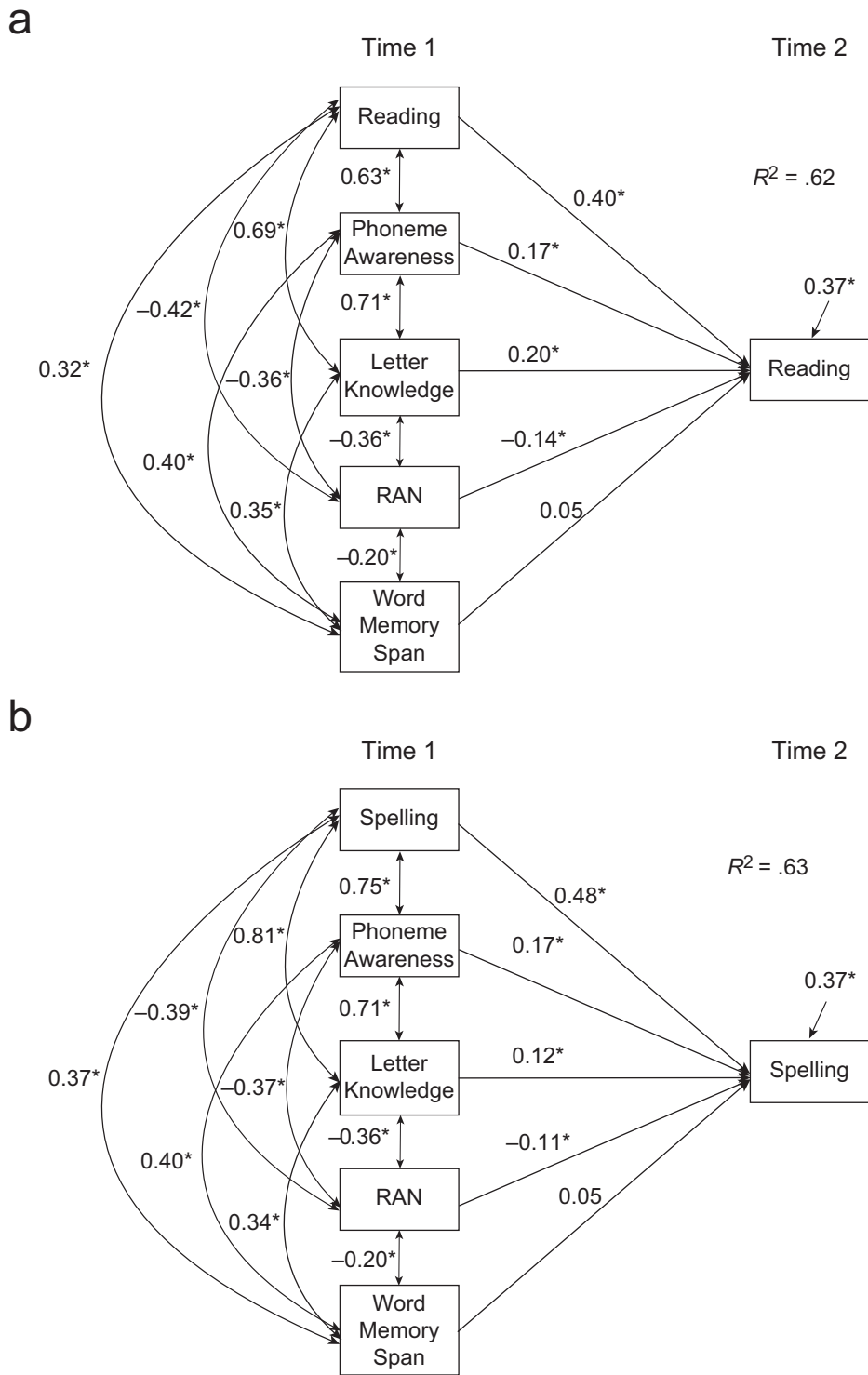
SRMR = .041 (there were no significant differences between these constrained models and equivalent models in which all parameters were freely estimated over languages). In addition, both models accounted for very high proportions of the variance in reading and spelling skills in all four languages—reading: overall  $R^2 = .62$ ,  $R^2$  for individual languages in the freely estimated model: .66 (English), .59 (Spanish), .70 (Czech), and .58 (Slovak); spelling:  $R^2 = .63$ ,  $R^2$  for individual languages in the freely estimated model: .62 (English), .68 (Spanish), .69 (Czech) and .57 (Slovak).

After the powerful autoregressive effects were accounted for, the other predictors overall accounted for an additional 9.5% (reading) and 4.5% (spelling) of the variance. It should be noted that all correlations among the Time 1 predictors were reliable in all languages. The excellent fits for these multigroup (multilanguage) models underline the fact that the intercorrelations among predictors and the longitudinal relationships among predictors and later reading and spelling scores did not differ significantly between languages. Equivalent models in which the autoregressors were omitted yielded similar results, with all predictors showing statistically reliable effects on the literacy outcomes that did not differ among languages. However, in such models, verbal memory span was a significant, though weak, predictor of both reading and spelling. These models (shown in Fig. S1 in the Supplemental Material) accounted for very high percentages of variance (55% for reading, 56% for spelling).

## Discussion

Our longitudinal study of the development of early literacy skills revealed a remarkably clear and consistent pattern across the four languages studied (English, Spanish, Czech, and Slovak). We found that three key measures (phoneme awareness, letter knowledge, and RAN) had the same relative importance as predictors of early literacy skills over a 10-month period in all four languages, but verbal short-term memory played no additional predictive role. The excellent fits of our multigroup models reflect the fact that the patterns of concurrent and longitudinal relationships among the measures did not differ significantly between languages. This, in turn, reflects the considerable efforts that were devoted to making our measures as similar and directly comparable across languages as possible.

With respect to the patterns of prediction, the dominant account of reading and spelling development in consistent orthographies proposes that although letter knowledge is an important predictor (e.g., Georgiou et al., 2012), phoneme awareness plays only a weak (e.g., Georgiou et al., 2008) or transient (e.g., de Jong & van der Leij, 1999) predictive role. Such claims, in turn, are typically explained in terms of phoneme awareness arising largely as a consequence of the rapid development of letter knowledge and reading skills in highly consistent orthographies (e.g., Share, 2008; Ziegler & Goswami, 2005). According to this argument, both reading



**Fig. 1.** Multigroup path models predicting the growth in (a) early reading skills and (b) early spelling skills in English, Spanish, Czech, and Slovak children from Time 1 (at the onset of literacy instruction) to Time 2 (10 months later). Each model included five predictors: the corresponding skill at Time 1, plus Time 1 measures of phoneme awareness, letter knowledge, rapid-automatized-naming (RAN) speed, and word memory span. Unstandardized path weights are shown, and asterisks indicate significant effects (\* $p < .01$ ).

accuracy and phoneme awareness become insensitive measures of individual differences in reading by the end of the first or second grade. RAN, in contrast, is argued to exert a strong

and persistent influence on reading fluency and on the quality of orthographic representations underlying spelling (e.g., Wimmer et al., 2000).

It is clear that the results from our large-scale longitudinal study conflict with this dominant account. Our results showed clearly that when phoneme awareness, letter knowledge, and RAN were assessed prior to formal reading instruction in three highly consistent orthographies (Spanish, Czech, and Slovak), each was an independent longitudinal predictor of later literacy skills. Furthermore, phoneme awareness appeared to be at least as strong a predictor of both reading and spelling development as RAN, even when reading was measured by speeded tests. Perhaps most strikingly, there was no evidence from our study of any reliable differences in the relative importance of these three measures as longitudinal predictors of literacy development in English compared with the languages that had other, more consistent orthographies.

The pattern of results from our longitudinal study aligns well with results from a number of recent concurrent studies of reading development in different European languages. A study by Ziegler et al. (2010) of second graders in five countries showed that phoneme awareness was the most important predictor of reading accuracy and speed in all languages, and RAN proved to be a weak and nonuniversal predictor of reading speed (letter knowledge was not assessed in this study). Similarly, a cross-sectional comparison of French, Dutch, and Hungarian first to fourth graders (Vaessen et al., 2010) showed that phoneme awareness, letter knowledge, and RAN were independent predictors of reading fluency in each grade across all three languages. However, neither of these large-scale cross-sectional studies included English participants, and it has often been claimed that English is thoroughly atypical of other orthographies in terms of its degree of spelling-sound inconsistency (Share, 2008). In addition, because all children already had well-established reading skills in these studies, it is hard to make claims about the likely direction of any causal influences (e.g., to claim that phoneme awareness is a cause rather than a consequence of differences in reading skill).

In our longitudinal study, we found the same pattern of relative weightings for all three predictors for both reading and spelling in all four languages studied, including English. Notably, phoneme awareness was at least as strong a predictor of later reading and spelling skills as RAN was. These patterns of longitudinal predictive relationships are consistent with (but certainly cannot prove) a causal theory in which the early development of reading and spelling skills in alphabetic orthographies depend on the cognitive skills tapped by phoneme awareness, letter knowledge, and RAN. In relation to such a causal theory, several studies have shown that training phonemic awareness in children is effective, particularly when coupled with phonically based reading instruction, in helping to improve children's word-reading skills (National Institute for Literacy, 2008). However, concluding that early phonemic skills may be one causal influence on the development of children's word-reading and spelling skills does not conflict with the idea that there may be reciprocal relationships with literacy skills, once they are developed, that serve to facilitate

the further development of phonemic skills (e.g., Hulme, Snowling, Caravolas, & Carroll, 2005; Perfetti, Beck, Bell, & Hughes, 1987).

In summary, we suggest that early progress in learning to read and spell in any language with an alphabetic orthography will depend on the child's ability to learn the sound-symbol mappings of the alphabet, the ability to segment and manipulate the speech segments (phonemes) that map onto the orthography, and the ability to fluently retrieve the pronunciations associated with symbols (letters and words). According to this testable model, letter-sound knowledge and phonemic skills form the basis of the alphabetic principle (Byrne, 1998), but RAN seems to tap a separable mechanism that is involved in forming associations between printed words and their pronunciations (Lervåg & Hulme, 2009). We emphasize, however, that phoneme awareness, letter knowledge, and RAN account for only modest amounts of variance in literacy skills after accounting for the powerful autoregressive effects of reading and spelling in our models. It is important to trace the earlier antecedents of these skills in studies of younger children before any knowledge of letter-sound relationships is acquired.

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### Supplemental Material

Additional supporting information may be found at <http://pss.sagepub.com/content/by/supplemental-data>

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