Cognitive Development of Fluent Word Reading Does Not Qualitatively Differ Between Transparent and Opaque Orthographies

Anniek Vaessen
Maastricht University

Daisy Bertrand
Aix-Marseille Université and Centre National de la Recherche Scientifique

Dénes Tóth and Valéria Csépe
Hungarian Academy of Sciences

Luís Faïsca and Alexandra Reis
Universidade do Algarve

Leo Blomert
Maastricht University

Although the transparency of a writing system is hypothesized to systematically influence the cognitive skills associated with reading development, results of cross-language investigations are inconsistent and usually do not address this issue in a developmental context. We therefore investigated the cognitive dynamics of reading fluency of different word types in Grades 1–4 in three orthographies differing in degree of transparency (Hungarian, Dutch, and Portuguese). The overall results showed that the relative strength of the contributions of phonological awareness and rapid naming to word reading fluency shifted as a function of reading expertise: The contribution of phonological awareness remained significant in all grades but decreased as a function of grade, whereas the contribution of rapid naming increased. Orthographic depth systematically modulated the strength of the cognitive contributions to reading, but not the overall developmental pattern. Together, these results indicate that the cognitive development of reading skill is fairly universal (at least for alphabetic scripts) and that differences in orthographic depth will not recruit different cognitive processes but will mainly be expressed in rate of reading development.

Keywords: reading development, orthographic depth, phonological awareness, rapid naming, cross-language comparison

At initial stages of learning to read an alphabetic script, children typically decode words by mapping each letter onto its corresponding sound speech. This phonological decoding process initially costs much time and effort. However, to achieve the high level of automatization that is the key characteristic of skilled reading, complete words and morphemes must be linked directly to their phonological or semantic counterparts (Perfetti, 1985). Therefore, most models of reading development describe a developmental shift from slow phonological decoding to automatic recognition of whole-word forms (e.g., Ehri, 1995, 2005; Frith, 1985; Marsh, Friedman, Welsh, & Desberg, 1981; Share, 1995, 1999). Some of these models have suggested that this shift occurs in a stagelike manner, in the sense that children move through a series of stages dominated by one strategy (Frith, 1985; Marsh et al., 1981). The phase theory of Ehri (1995, 2005) also suggests that children proceed through a number of phases during the development of fluent reading skills: a pre-alphabetic phase in which words are recognized on the basis of visual cues; a partial alphabetic phase, in which children know some but not all letter–speech sound correspondences and may recognize words partially by phonetic cues and partially by contextual guessing; a full alphabetic phase, when children’s knowledge of the alphabetic principle is complete and they are able to decipher new words, and a consolidated alphabetic phase, in which full connections are formed between morphographic units (e.g., words, morphemes, onsets, rhymes) and their phonological and semantic counterparts. However, in contrast to traditional stage models of reading, this theory assumes that the shift from one phase to another is rather transitional and
that boundaries between phases are less sharp. The self-teaching hypothesis of Share (1995, 1999, 2008) also argues for a more transitional, item-based, instead of stage-based, view, in the sense that the ability to recognize a word by sight depends more on the familiarity of a word than on the dominant strategy assumed typical for a given developmental reading stage. Every word is unfamiliar at one point in reading development and hence has to be deciphered by phonological decoding. This phonological decoding of words lies at the basis of forming connections between orthographic (word-specific) patterns and phonological codes (Ehri, 2005; Share, 1995). Because children are exposed more to words that have a high frequency of occurrence, orthographic representations will be established more quickly for high-frequency than for low-frequency words. Share (2008) therefore recommended investigating reading development in “the context of an unfamiliar-to-familiar/novice-to-expert framework” (p. 592).

A recent study of Vaessen and Blomert (2010) demonstrated that the shift from phonological decoding to automatic word recognition is accompanied by a concomitant gradual shift in the relative importance of the cognitive skills underlying reading. Phonological awareness was related to word reading fluency until the sixth grade, but its contribution to reading fluency was much stronger in beginning phases of reading development, when children rely heavily on phonological decoding strategies. In contrast, the contribution of rapid automatized naming (hereinafter referred to as rapid naming) was modest in beginning readers but gradually increased as a function of reading experience. In line with the item-based view on reading development proposed by Share (1999, 2008), the shift in the relative importance of phonological awareness and rapid naming occurred earlier for high-frequency than for low-frequency words; rapid naming was the strongest contributor to high-frequency word reading fluency from the third grade on, but its contribution to low-frequency word reading fluency only dominated phonological awareness in Grade 5. As might be expected, phonological awareness remained the dominant contributor to pseudoword reading fluency, although rapid naming also contributed substantially.

Several other studies in transparent orthographies have reported a declining influence of phonological awareness and a strong influence of rapid naming on reading fluency (e.g., de Jong & van der Leij, 1999, 2002; Landerl & Wimmer, 2008; Lervåg, Bråten, & Hulme, 2009; Nikolopoulos, Goulandris, Hulme, & Snowling, 2006). In contrast, English-language studies usually report a stronger and longer lasting influence of phonological awareness (e.g., Swanson, Trainin, Necoechea, & Hammill, 2003; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Wagner, Torgesen, & Rashotte, 1994) and only a modest influence of rapid naming on reading (Parrila, Kirby, & McQuarrie, 2004; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007; Wagner et al., 1994). This discrepancy between transparent and opaque orthographies might indicate that the cognitive dynamics of reading vary as a function of the orthographic consistency of a language. However, it should be noted that reading performance in transparent orthographies is typically based on fluency measures, whereas most English-language studies have focused on reading accuracy. Because phonological awareness is generally measured with accuracy measures in all types of orthographies, the influence of phonological awareness on reading fluency in transparent orthographies might thus be attenuated. Similarly, the influence of (speeded) rapid naming in opaque orthographies might be underestimated as a result of the use of reading accuracy measures (Georgiou, Parrila, Kirby, & Stephenson, 2008; Share, 2008; Vaessen & Blomert, 2010). To illustrate the effect of this measurement-parameter incompatibility, Vaessen and Blomert (2010) showed a stronger and longer lasting influence of phonological awareness on reading fluency when a speeded measure of phonological awareness was included. Similarly, English-language studies including speeded reading measures have usually found strong contributions of rapid naming (e.g., Bowers, 1993; Cirino, Israeli, Morris, & Morris, 2005; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004), indicating that differences between transparent and opaque orthographies might be less pronounced than is often assumed.

Nevertheless, orthographic consistency might influence the cognitive dynamics of reading development. For instance, the orthographic depth hypothesis (Katz & Frost, 1992) holds that the consistent, one-to-one relationship between letters and speech sounds in transparent orthographies strongly encourages the use of phonological decoding processes. In contrast, opaque orthographies support the recognition of words by their visual orthographic structure, because grapheme–phoneme decoding often might lead to erroneous results. A weak version of the orthographic depth hypothesis (Frost, 2005) proposes relative, rather than qualitative, differences between transparent and opaque orthographies, but both versions of the hypothesis assume a stronger involvement of phonological decoding strategies in transparent than in opaque orthographies. An alternative interpretation (psycholinguistic grain size theory; Ziegler & Goswami, 2005) emphasized that children in all alphabetic orthographies use phonological decoding strategies but that children learning to read in more opaque orthographies are required to develop more flexible decoding strategies not only at the grapheme–phoneme level but also at the level of larger units such as syllables, onset, rhymes, and/or morphemes. Although this interpretation has many features in common with the orthographic depth hypothesis, its predictions regarding the role of phonological processing in transparent and opaque orthographies differ, as it assumes equal or even stronger involvement of phonological processing in opaque as compared with transparent orthographies (Georgiou, Parrila, & Papadopoulos, 2008; Ziegler & Goswami, 2005).

Empirical investigations of the impact of orthographic consistency on the cognitive predictors of reading show rather contrasting results. Some studies (Georgiou, Parrila, Kirby, & Stephenson, 2008; Mann & Wimmer, 2002) reported phonological awareness as the strongest predictor of reading accuracy and fluency in English and rapid naming as the stronger predictor of reading accuracy and fluency in transparent orthographies (e.g., Greek and German). Others found strong influences of phonological awareness on reading performance in both transparent (respectively, Czech and Dutch) and English (Caravolas, Volin, & Hulme, 2005; Patel, Snowling, & de Jong, 2004) orthographies.

It should be noted that the abovementioned cross-linguistic studies compared English with one other, more transparent, orthography. However, in a recent review, Share (2008) argued that the English orthography has an outlier position in terms of its extreme ambiguous letter–speech sound correspondences. Nevertheless, results from non-Anglophone studies are usually interpreted in the light of theories based on Anglophone research, although “the outcomes of non-Anglophone investigations are likely to offer a better approximation to the global norm” (Share, 2008, p. 604). Therefore, a recent cross-
language investigation of Ziegler et al. (2010) included five languages (Finnish, Hungarian, Dutch, Portuguese, and French) lying on a continuum of orthographic consistency, to systematically investigate the impact of orthographic consistency on the cognitive skills underlying reading. Orthographic consistency was expressed in a script entropy measure for each language (Borgwaldt, Hellwig, & De Groot, 2005; see also the Method section of the current article). The advantage of using word onset entropy measures is that the orthographic consistency of languages with varying orthographic structures can be meaningfully compared because all of them have word onsets (Ziegler et al., 2010). Ziegler et al. showed that phonological awareness was an important predictor of reading accuracy and speed in all orthographies, although the strength of the contribution of phonological awareness to reading performance systematically varied with the degree of entropy; that is, the role of phonological awareness was relatively stronger in more opaque orthographies.

To summarize, the results of Ziegler et al. (2010), as well as the results of Georgiou, Parrila, Kirby, and Stephenson (2008) and Mann and Wimmer (2002), therefore indicated that orthographic consistency does have an impact on the strength of the contributions of phonological awareness. However, none of these studies specifically addressed the question of how orthographic consistency influences the time course of the cognitive development of reading. The results of Vaessen and Blomert (2010) indicated a shift in the relative importance of the cognitive skills underlying reading fluency as a function of both reading experience and word type, but this study was restricted to Dutch readers. Therefore, the purpose of the present study was to investigate how orthographic consistency modulates the developmental course of the cognitive skills underlying reading fluency.

Besides measures of phonological awareness and rapid naming, we included additional measures for two cognitive skills that are thought to play a role in reading acquisition and skilled reading: letter–speech sound processing and verbal working memory. Although verbal working memory is strongly tied to phonological processes (Baddeley, 1995), and phonological awareness problems and verbal working memory problems seem to stem from the same underlying phonological deficit (e.g., Tijms, 2004), others have reported that verbal working memory contributed uniquely to word reading even when controlling for phonological awareness levels (Georgiou, Das, & Hayward, 2008; McCallum et al., 2006), and therefore we included a measure of verbal working memory.

Kindergarten letter–speech sound knowledge is reported to be strongly related to early reading performance (Puolakanaho et al., 2007; Scarborough, 1990; Share, Jorm, Maclean, & Matthews, 1984; Wagner et al., 1994; Wimmer & Hummer, 1990). However, because children are supposed to know which letter belongs to which speech sound after a relatively short period of reading instruction even in opaque orthographies (Hardy, Smythe, Stennet, & Wilson, 1972; Seymour, Aro, & Erskine, 2003; Wentink & Verhoeven, 2003), only a few studies have focused on the relationship between letter–speech sound processing and reading after the initial phases of reading acquisition. One of these studies (Leppanen, Niemi, Aunola, & Nurmi, 2006) showed that letter–speech sound knowledge and reading were strongly correlated at least until Grade 4. One recent cross-language investigation has indicated that letter–speech sound knowledge might have a stronger relationship with reading fluency in English than in a transparent orthography like Greek (Manolitsis, Georgiou, Stephenson, & Parrila, 2009). Moreover, recent brain research has shown that automation of letter–speech sound correspondences takes years to develop even in normal readers and even though children typically know perfectly which letter belongs to which speech sound after the first grade (Froyen, Bonte, van Atteveldt, & Blomert, 2009; Froyen, van Atteveldt, Bonte, & Blomert, 2008). Thus, including measures of efficiency of the processing of letter–speech sound correspondences might shed more light on the role of grapheme–phoneme integration in fluent reading development and the potentially modulating influence of orthographic consistency on this relationship.

**The Present Study**

The present study investigates the impact of orthographic consistency on the relative importance of four cognitive skills (phonological awareness, rapid naming, letter–speech sound processing, and verbal working memory) for word reading fluency in a developmental context. The large unselected school sample (N = 2,244) consisted of first through fourth graders from three different European countries with languages varying in orthographic consistency (Hungarian, Dutch, and Portuguese). The degree of orthographic consistency was based on word onset entropy (see Method section).

The reading task included three different word types (high frequency, low frequency, and pseudowords) because it was previously shown that the relative importance of the cognitive contributors to reading fluency was influenced by both reading experience and word familiarity (Vaessen & Blomert, 2010). Moreover, all cognitive tasks (except verbal working memory tasks) measured speed as well as accuracy, thereby avoiding speed–accuracy confounds in their relation with reading fluency. The task designs used in the different languages were the same, as they are adaptations of the same test battery (Blomert & Vaessen, 2009; Csépe, Tóth, Vaessen, & Blomert, 2010; Reis, Fáisca, Vaessen, & Blomert, 2010), but test items were adapted to the specifics of each language. Creating completely parallel tasks by simply translating a “common test” into different languages would have been impossible for most cognitive skills because of the large differences in orthographic and phonological structure between the languages. This would have led to insensitive tests likely to be subject to ceiling effects (Seymour et al., 2003).

**Method**

**Participants**

The sample consisted of 674 Hungarian, 954 Dutch, and 616 Portuguese primary schoolchildren from Grade 1 to Grade 4. The sample size, mean age, and average number of months of formal reading instruction per grade are presented in Table 1. All first graders were tested at the end of the school year. In all countries, a small group of second graders was tested in September or October (Hungary, n = 15; Netherlands, n = 20; Portugal, n = 44), whereas the rest of the second graders were tested in the middle of or at the end of the school year. As reading performance of the beginning second graders resembled that of the first graders, they were included in the first-grade sample.

The results presented in Table 1 show that, at least in the first two grades, average number of months of formal reading instruction is comparable. Furthermore, it is noticeable that Hungarian...
children enter primary school when they are seven years old, whereas Dutch and Portuguese children enter school when they turn six years old. However, correlations between age and reading level were low ($r = .01$ to $.04$), suggesting that the influence of age at school onset on reading performance was negligible once amount of reading instruction was taken into account.

For a portion of the sample (Hungary, $n = 607$; Netherlands, $n = 462$; Portugal, $n = 242$), data were available on educational levels of the mother and father (Level 1 = primary school or less; Level 2 = secondary school or vocational education; Level 3 = college or university). In the Hungarian sample, 4% of fathers and 7% of mothers had a Level 1 education; 63% of fathers and 57% of mothers had a Level 2 education; and 33% of fathers and 36% of mothers had a Level 3 education. In the Dutch sample, only 2% of fathers and 1% of mothers had a Level 1 education, 54% of fathers and 61% of mothers had a Level 2 education, and 44% of fathers and 38% of mothers had a Level 3 education. In the Portuguese sample, these proportions were 14% of fathers and 9% of mothers with a Level 1 education, 73% of fathers and 72% of mothers with a Level 2 education, and 13% of fathers and 19% of mothers with a Level 3 education. Correlations between educational level and reading fluency level were rather low: $r = .10$–.20 in the Hungarian sample, $r = .07$–.12 in the Dutch sample, and $r = .12$–.20 in the Portuguese sample.

In all three countries, formal reading instruction started at school entrance. No formal instruction on letter–speech sound relations or phonological training was provided in kindergarten. In the Netherlands, all official reading instruction methods are phonics based, and in Hungary all official reading instruction methods are at least partly phonics based. In Portugal, teaching methods can be more variable. From a large part of the Portuguese sample ($n = 570$), individual information on teaching method was available: 67% of these children learned to read with a (partly) phonics-based method, 27% received syllabic-based training, and 7% received whole-word–based training. In a previous study with Portuguese students, Mendonça et al. (2008) found no significant influence of teaching method on reading performance.

### Procedure

The samples were all part of national standardization studies of a reading test battery. In the Dutch sample, 17 schools in five different regions of the country participated. In the Portuguese sample, 31 schools were included, all from the Algarve region. In the Hungarian sample, 10 schools participated, all from the Budapest region; schools in this region were selected in such a way that neighborhoods of both low and high socioeconomic status were represented. First, the schools were approached for participation. When the schools were willing to participate, parents were asked for permission by letter. All children who received parental permission to participate were tested, regardless of their reading and spelling level.

Tasks were individually administered at the schools by a trained project coworker outside the classroom. All tasks were administered in either one or two sessions. The first and the second test session always fell within one week.

### Measure of Orthographic Consistency

The degree of orthographic consistency was estimated by using script entropy computations for the initial letter–speech sound mapping in each language (Borgwaldt et al., 2005; Treiman, Berch, Tincoff, & Weatherston, 1993). Script entropy values were adopted from Borgwaldt et al. (see also Ziegler et al., 2010) and were defined as follows:

$$H = \sum p_i \log_2 \left( \frac{1}{p_i} \right),$$ (1)

where $p_i$ is the probability of the first pronunciation of a given letter, $p_2$ is the probability of the second pronunciation of the letter (if a second pronunciation exists), and so forth for all $n$ possible pronunciations of that letter. If a letter always corresponds to one phoneme, its entropy value is zero. Therefore, the higher the entropy value, the larger is the number of pronunciations of one letter and the more inconsistent are the letter–speech sound correspondences. The entropy values for the Hungarian, Dutch, and Portuguese language were 0.17, 0.23, and 0.42, respectively. Because onset entropy was used as a general measure of orthographic consistency in the current study, it is important to know to what extent this measure is comparable to other measures of orthographic consistency, such as rhyme consistency. A study of Perry and Ziegler (2002) has shown that onset entropy and rhyme entropy values of German and English were comparable. Moreover, Ziegler et al. (2010) showed that the ranking order of languages with many monosyllabic words (German, English, French, and Dutch) remains the same regardless of whether the onset or the rhyme is used. Finally, Borgwaldt et al. (2005) showed that the onset entropy ranking order of the included languages is in line with the descriptions of the languages’ orthography and phonology. Onset entropy thus seems to be a reliable measure of the orthographic consistency of a language.

### Tasks

The tasks used for this study were all part of a computerized cognitive reading test (Dyslexia Differential Diagnosis Maastricht; Blomert & Vaessen, 2009) and the Portuguese (Reis et al., 2010)
and Hungarian (Csépe et al., 2010) versions of this test. The task designs were very similar, but items were adapted to the specific characteristics of each language.

**Word reading.** The word reading task contained three different subtasks: high-frequency words, low-frequency words, and pseudowords. For each subtask, participants were instructed to accurately read as many words as possible in half a minute. A total of 15 words per screen were presented (with a maximum of 75 words for each subtask). Words and pseudowords increased in length and syllabic structure. In the Netherlands and Hungary, the first screen of 15 items contained monomorphemic words without consonant clusters, the second screen contained monomorphemic words with consonant clusters, the third screen featured two-syllabic words without consonant clusters, the fourth screen showed two-syllabic words with consonant clusters, and the last screen contained three- or four-syllabic words. In Portugal, the task design was the same, except that, in the first two screens, two-syllabic words were used (in Portuguese, most words have at least two syllables). The task resulted in a fluency score (correct words per half minute) for each subtask. Test–retest reliabilities were .91 in the Hungarian sample and .95 in the Dutch sample (reported in the test manual). For the Portuguese sample, test–retest reliabilities were not available at the time of the study.

**Phonological awareness.** Pseudowords were presented auditorily (over headphones). The child was instructed to delete a speech sound (the beginning consonant, the end consonant, or a consonant within a consonant cluster) and to provide the remaining pseudoword. In all three countries, the task contained three levels that varied in difficulty: The first level contained CVC words (where C = consonant and V = vowel) from which the first C had to be deleted, the second level contained CVCC words or CVCVC words from which the first or the last consonant had to be deleted, and the third level contained CCVCC words from which the consonant within the cluster had to be deleted. The administrator pressed a button as soon as the participant gave an answer to indicate response time. Response time was calculated as time between stimulus offset and the button press. Accuracy score was calculated as percentage of correct items. Internal consistency indices of the accuracy scores were .94 for the Portuguese sample and .87 for Dutch and Hungarian sample. Internal consistency of speed scores was .96 for the Portuguese sample, .93 for the Dutch sample, and .95 for the Hungarian sample.

**Rapid naming.** The child was instructed to name visually presented letters, digits, or objects as fast as possible. Sheets with 15 items (five letters, digits, or objects repeated three times) were presented on the screen. Each set of 15 items was presented two times, with a different order of items. The letter and digit names were monosyllabic in each country, the object names were either mono- or bisyllabic (with the exception of one item in Portuguese, which contained three syllables). Response time was calculated as the mean reaction time of the two presentations. The naming tasks had a reliability of .82 for the Portuguese sample, .80 for the Dutch sample, and .86 for the Hungarian sample.

**Letter–speech sound association tasks.** Two tasks were used to measure accuracy and automation of letter–speech sound processing: a letter–speech sound identification task and a letter–speech sound discrimination task. In the letter–speech sound identification task, a phoneme was presented over the headphones, and at the same time four letter combinations were presented on the screen (e.g., /b/ and ‘b,’ ‘d,’ ‘t,’ or ‘p’). The child was instructed to choose which letter combination belonged to the phoneme by pressing the corresponding button. In the letter–speech sound discrimination task, a visual letter combination and an auditory presented speech sound were presented at the same time, and the child was instructed to judge whether the letter and the speech sound were the same or different (e.g., /b/ and ‘a’). Accuracy (percentage correct) and response time (s/item) were measured. For each country, the letter–speech sound combinations that were specific for their language were used. The accuracy scores of the letter–speech sound identification and the letter–speech sound discrimination task, respectively, had an internal consistency of .69 and .84 for the Portuguese sample, .70 and .80 for the Dutch sample, and .76 and .89 for the Hungarian sample. The speed scores on the letter–speech sound identification task and the letter–speech sound discrimination task, respectively, had an internal consistency of .88 and .93 for the Portuguese sample, .90 and .95 for the Dutch sample, and .92 and .97 for the Hungarian sample.

**Verbal working memory.** We used two tasks of verbal working memory: a phoneme span task and a syllable span task. In both tasks, a sequence of phonemes/syllables was aurally presented, and the child was instructed to repeat this sequence in the same order. The phoneme span task contained only consonants. The syllable span task contained monosyllabic syllables with a CVC or CCV structure. The syllables or the combination of syllables did not form existing words. The sequences ranged from two to six items. Accuracy score was calculated as total number of correctly repeated items within each sequence. Reliability coefficients for the phoneme span task were .73 for the Portuguese sample, .63 for the Dutch sample, , .53 for the Hungarian sample, and coefficients for the syllable span task were .75 for the Portuguese sample, .71 for the Dutch sample, and .68 for the Hungarian sample.

**Baseline response time.** A row of four empty squares was presented on the screen. Each stimulus consisted of an animation figure that appeared in one of the four squares. The participant was instructed to respond as fast as possible by pressing the corresponding button. Mean response time was measured over 20 items. This task was the same in all countries. The task had an internal consistency of .94 for the Portuguese sample, .93 for the Dutch sample, and .95 for the Hungarian sample.

**Data Preparation**

Because reading fluency was treated as a dependent variable, participants with missing values on these variables were not included in the sample. In addition, participants with more than two missing values were excluded from analyses. For the other participants, missing values were imputed with a version of expectation maximization, an imputation method described by Schneider (2001) and implemented in MatLab (Schneider, 2008). All variables had less than 3% missing values. Random simulations of the imputation method showed that it could accurately predict actual values (mean correlation = .70; mean root mean square relative imputation error = .07) and did not distort the distribution of the variables.

Because the letter–speech sound tasks required a motor response, and response time measures were based on this motor response, we used the baseline response time task to control for effects of individual differences in motor response time. We first...
regressed the baseline response time on the letter–speech sound identification and discrimination response times. Subsequently, we computed the residuals, which were used as corrected response time scores for the letter–speech sound tasks.

For the regression analyses, we used standardized T scores (calculated separately for each country) instead of raw scores. Use of standardized scores has several advantages: First, intrinsically differences between countries in difficulty level of tasks due to differences in task construction are leveled out, equalizing results over countries. Second, these standardized T scores are normalized, thus reducing effects of outliers or non-normally distributed data. Third, the standardization method is based on months of formal reading instruction, so all analyses are automatically controlled for mediating effects of amount of reading instruction.

Results

Descriptive Statistics

Because this study includes many cognitive variables (manifest as well as latent), we provided an overview of the names and labels of the tasks and the label of the cognitive variable used in the analysis (Table 2). Tables 3 and 4 show the means and standard deviations for the reading and cognitive measures for each grade and country. Direct statistical comparison of raw scores is not useful, as items of the tasks are adapted to the specific characteristics of each language. Nevertheless, it is worth noticing that Portuguese readers performed relatively poor on all reading tasks.

Table 2

<table>
<thead>
<tr>
<th>Task</th>
<th>Variable name (manifest or latent)</th>
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<tr>
<td>High-frequency word reading fluency</td>
<td>Phonological awareness accuracy</td>
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<tr>
<td>Low-frequency word reading fluency</td>
<td>Phonological awareness reaction time</td>
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<tr>
<td>Pseudoword reading fluency</td>
<td>Rapid naming</td>
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<tr>
<td>High-frequency word reading accuracy</td>
<td>Letter–speech sound accuracy</td>
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<tr>
<td>Low-frequency word reading accuracy</td>
<td>Letter–speech sound reaction time</td>
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<tr>
<td>Pseudoword reading accuracy</td>
<td>Rapid automatized naming</td>
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<td>Phoneme deletion accuracy</td>
<td>Rapid automatized naming</td>
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<td>Phoneme deletion speed</td>
<td>Rapid automatized naming</td>
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<td>Rapid automatized naming letters</td>
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<td>Rapid automatized naming digits</td>
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<td>Rapid automatized naming objects</td>
<td>Rapid automatized naming</td>
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<tr>
<td>Letter–speech sound identification accuracy</td>
<td>Letter–speech sound identification accuracy</td>
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<td>Letter–speech sound discrimination accuracy</td>
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<td>Letter–speech sound identification speed</td>
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<td>Letter–speech sound discrimination speed</td>
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<td>Phoneme span</td>
<td>Phoneme span</td>
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<td>Syllable span</td>
<td>Syllable span</td>
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<tr>
<td>Baseline response time task</td>
<td>Baseline response time task</td>
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Note. Latent variables are shown in italics.

Table 5 represents the correlations between the reading and cognitive tasks for each country. The overall correlational pattern was remarkably similar between countries, although the relationship between phoneme deletion accuracy and reading fluency was strongest in Portuguese and weakest in Hungarian (0.58–0.66 for the Portuguese sample; 0.46–0.52 for the Dutch sample, and 0.38–0.41 for the Hungarian sample), as was the relationship between accuracy on the letter–speech sound tasks and reading fluency (0.42–0.48 for the Portuguese sample, 0.32–0.39 for the Dutch sample, and 0.25–0.30 for the Hungarian sample).

Creating Latent Variables

To reduce the number of cognitive predictor variables, we created latent variables by conducting an exploratory factor analysis (principal components with oblimin rotation) on the cognitive variables that showed significant correlations with reading performance (phoneme deletion accuracy; phoneme deletion response time; rapid naming letters, digits, and objects; phoneme span; syllable span; letter–speech sound identification accuracy; letter–speech sound discrimination accuracy; letter–speech sound identification speed). We initially extracted six factors (using Jolliffe’s criterion, which allows eigenvalues of .70 and higher; Jolliffe, 1972, 1986): a Rapid Naming factor, a Letter–Speech Sound Accuracy factor, a Verbal Working Memory factor, a Letter–Speech Sound Speed factor, and a Phonological Awareness factor. However, phoneme deletion accuracy loaded on more than one factor (Phonological Awareness and Verbal Working Memory), and loadings on the Phonological Awareness factor were relatively low (.51). More important, it might be theoretically interesting to separate effects of phonological processing speed and phonological processing accuracy. Furthermore, letter–speech sound identification reaction time was the only task that loaded on the Letter–Speech Sound Speed factor. Therefore, we decided to use the standardized T scores on the phoneme deletion accuracy, phoneme deletion response time, and letter–speech sound reaction time tasks in further analyses. We conducted a new exploratory factor analysis on the three rapid naming tasks, the two letter–speech sound accuracy tasks, phoneme span, and syllable span. Three factors were extracted, referred to as Rapid Naming, Letter–Speech Sound Accuracy, and Verbal Working Memory (eigenvalues for these factors were 2.58, 1.37 and 0.94, respectively; explained variance = 70.0%). The factor loadings and correlation matrix are presented in Table 6.

The Effect of Grade and Entropy on the Cognitive Contributions to Reading Fluency

We conducted linear mixed-effects analyses (LME procedure of R; Bates, 2008). The predictor variables could be categorized into two types of variables: (a) intraindividual variables (cognitive variables: Rapid Naming (latent), Letter–Speech Sound Accuracy (latent), Verbal Working Memory (latent), phonological awareness accuracy, phonological awareness response time, and letter–speech sound response time) and (b) interchildren variables (with entropy and grade as quantitative variables; no other interchildren variables were included). Therefore, we conducted three sets of multilevel regression analyses (with two levels: cognitive variables at the first level and grade and entropy at the second level) to
investigate the modulating effect of entropy and grade on the
cognitive predictor variables of reading fluency of high-frequency
words, low-frequency words, and pseudowords.

The initial models included all possible relationships (see Figure 1
for an example). Nonsignificant relationships were excluded from
the model (in order of least significant values first), and analyses
were repeated until only significant relationships were left in the
model. The results of the final models for reading fluency of
high-frequency words, low-frequency words, and pseudowords are
presented in Table 7.

Grade effects. Grade modulated the relationship between
phonological awareness accuracy and high-frequency, low-
frequency, and pseudoword reading fluency (the strength of the
contribution of phonological awareness accuracy decreased with
grade; high-frequency reading fluency: unstandardized $\beta = -0.07$,
$\text{SE} = 0.01$; low-frequency reading fluency: unstandardized $\beta =
-0.11$, $\text{SE} = 0.02$; pseudoword reading fluency: unstandardized $\beta =
-0.04$, $\text{SE} = 0.02$). The contribution of Letter–Speech Sound
Accuracy to high-frequency and pseudoword reading fluency also
decreased as a function of grade (high-frequency reading fluency:
unstandardized $\beta = -0.49$, $\text{SE} = 0.12$; pseudoword reading
fluency: unstandardized $\beta = -0.45$, $\text{SE} = 0.01$). In contrast, the
relationship between Rapid Naming and reading fluency of all word
types increased as a function of grade (high-frequency reading fluency:
unstandardized $\beta = 0.76$, $\text{SE} = 0.0001$; low-frequency reading flu-
ency: unstandardized $\beta = 0.55$, $\text{SE} = 0.001$; pseudoword reading
fluency: unstandardized $\beta = 0.38$, $\text{SE} = 0.05$). The influence of
phonological awareness response time on reading fluency was
equally strong in all grades (i.e., there was no interaction with
grade). The relationships between Verbal Working Memory and
reading fluency, and letter–speech sound speed and reading flu-
ency were modest and did not change as a function of grade.

Entropy effects. Entropy modulated the effect of phonologi-
cal awareness accuracy and phonological awareness response time
on high-frequency, low-frequency, and pseudoword fluency, but in
different directions: Whereas phonological awareness accuracy
was more important in opaque orthographies (high-frequency
reading fluency: unstandardized $\beta = 0.77$, $\text{SE} = 0.0001$; low-
frequency reading fluency: unstandardized $\beta = 0.88$, $\text{SE} = 0.0001$;
pseudoword reading fluency: unstandardized $\beta = 0.79$, $\text{SE} = 0.0001$),
phonological awareness response time was more important in
transparent orthographies (high-frequency reading fluency: un-
standardized $\beta = -0.69$, $\text{SE} = 0.0001$; low-frequency reading fluency:
unstandardized $\beta = -0.73$, $\text{SE} = 0.0001$; pseudoword reading
fluency: unstandardized $\beta = -0.69$, $\text{SE} = 0.0001$). Entropy had a small effect on
the strength of the contribution of letter–speech sound response time
to high-frequency word reading fluency (unstandardized $\beta = 0.34$, $\text{SE} =
0.05$) and on the strength of the contribution of Letter–Speech Sound
Accuracy to pseudoword reading fluency (unstandardized $\beta = 0.34$, $\text{SE} =
0.05$). Entropy did not influence the strength of the contribution of
Rapid Naming or Verbal Working Memory.

There was no three-way interaction between grade, entropy and
the cognitive variables, indicating that the influence of grade on
the strength of the cognitive contributors does not differ between
languages with varying orthographic consistency.

Cognitive Contributions per Grade

As we were specifically interested in the influence of entropy on
the contributions of cognitive variables at different levels of read-

Table 3
Reading Performance (Raw Scores)

<table>
<thead>
<tr>
<th>Task/Country</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
</tr>
</tbody>
</table>
We conducted hierarchical regression analyses with phonological awareness accuracy, phonological awareness response time, Rapid Naming (latent), Letter–Speech Sound Accuracy (latent), letter–speech sound response time, and Verbal Working Memory (latent), and entropy value in the first step (all variables were centered) and interaction terms between entropy and cognitive variables in the second step, because this method provides standardized beta coefficients, which are necessary to compare the strength of the modulating influence of entropy on the cognitive contributions to reading speed. Nonsignificant predictors were excluded from the model (in order of least significant first), until all remaining relationships were significant. The results are presented in Table 8 and visualized in Figures 2, 3, and 4 to illustrate the developmental trend.

The results showed that the contributions of phonological awareness accuracy, phonological awareness response time, and Rapid Naming to reading fluency were substantial in all grades and for all word types, except for the contribution of phonological awareness accuracy to high-frequency fluency in Grade 4. The involvement of Letter–Speech Sound Accuracy was strong in beginning readers (βs = .26 to .29, ps < .0001) but decreased in
Grades 2, 3, and 4 (β = .07, p < .05, and β = .16, p < .0001, respectively). Rapid Naming became increasingly involved in word reading fluency and was the most important contributor to reading fluency of all word types in Grades 3 and 4 (βs = .29 to .46, ps < .0001). The contribution of phonological awareness response time was rather stable in Grades 2 to 4 (βs = .18 to .29, ps < .0001). In Grade 1, contributions were weaker (βs = .10 to .13, ps < .1). The contributions of letter–speech sound response time and Verbal Working Memory were not significant or were very weak (βs = .07 to .10, ps < .05).

The main effect of entropy was not significant in any of the models (which was expected, because standardized scores for reading was calculated for each country separately). However, entropy did influence the strength of the contributions of phonological awareness response time and phonological awareness accuracy in some of the grades. In Grade 1, entropy effects were strongest (phonological awareness × entropy: βs = .11 to .12, ps < .01; phonological awareness × entropy: βs = −.10 to −.12, ps < .01). In Grade 2, only the contributions of phonological awareness accuracy and phonological awareness response time to
high-frequency fluency, and not to low-frequency or pseudoword fluency, were significantly modulated by entropy (phonological awareness accuracy × entropy: $\beta = .08, p < .05$; phonological awareness response time × entropy: $\beta = -.06, p < .05$). In Grade 3, by contrast, entropy only modulated the contributions of phonological awareness accuracy and phonological awareness response time to low-frequency and pseudoword reading fluency, and not to high-frequency word reading fluency (phonological awareness × entropy: $\beta = -.11$ to $-.12, ps < .01$).

The contribution of letter–speech sound accuracy was only modulated by entropy in Grade 3 ($\beta$s = $-.08$ to $-.09, p < .05$), which might suggest that in beginning readers letter–speech sound accuracy contributions are equally strong across all countries but remains important over a longer period of time in languages with an opaque orthography.

Discussion
The present study investigated the developmental relationship between cognitive skills and reading fluency of different word types and the modulating influence of orthographic consistency on this relationship. The results showed that phonological awareness accuracy, phonological awareness speed, rapid naming, and letter–speech sound association accuracy all substantially contributed to reading fluency, whereas the contributions of letter–speech sound

Figure 1. Example of initial linear mixed effect model. PA-A = phonological awareness accuracy; PA-RT = phonological awareness reaction time; RAN = rapid naming; LSS-A = letter–speech sound accuracy; LSS-RT = letter–speech sound reaction time; VWM = verbal working memory. See text for additional explanation of the model.
speed and verbal working memory were modest or nonsignificant. More important, the contributions of phonological awareness accuracy, rapid naming and letter–speech sound accuracy were modulated by grade; the contributions of phonological awareness accuracy and letter–speech sound accuracy declined with more reading experience, whereas rapid naming contributions to reading fluency of all word types increased in all three orthographies. The effects of grade on the cognitive contributions were most pronounced for high-frequency words and less pronounced for pseudowords (in line with the results of Vaessen & Blomert, 2010).

This grade effect on the cognitive contributions to reading fluency was not modulated by entropy (i.e., there was no three-way interaction between grade, entropy, and cognitive skills), indicating that the cognitive development of reading fluency follows a similar pattern across orthographies varying in consistency. Furthermore, entropy did not influence the contribution of rapid naming to reading fluency in any of the grades tested, indicating that the strength of the relationship between rapid naming and reading is equally strong in opaque and transparent orthographies.

The gradually increasing relationship between rapid naming and reading fluency possibly reflects an increasing role of efficient matching of visual/orthographic and phonological information in fluent reading (Berninger, Abbott, Billingsley, & Nagy, 2001; Bowers & Ishaik, 2003; Vaessen, Gerretsen, & Blomert, 2009) that occurs in all (alphabetic) orthographies, independent of the orthographic consistency.

The degree of entropy did, however, modulate the strength of the contributions of phonological awareness accuracy and phonological awareness speed to high-frequency fluency in Grades 1 and 2 and to low-frequency and pseudoword fluency in Grades 1 and 3; phonological awareness accuracy contributed more strongly in opaque orthographies, whereas phonological awareness speed seemed to be more important in transparent orthographies. Moreover, the contribution of letter–speech sound accuracy to reading fluency was equally strong in the different orthographies in first and second grades but was stronger in opaque than in transparent orthographies in the third grade, implying that letter–speech sound association skills probably remain important for reading for a longer period in opaque orthographies than in transparent orthographies.

Table 7
Linear Mixed Effect Analyses: Unstandardized Beta Coefficients

<table>
<thead>
<tr>
<th>Task</th>
<th>Model 1 Y: High-frequency fluency</th>
<th>Model 2 Y: Low-frequency fluency</th>
<th>Model 3 Y: Pseudoword fluency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>30.27****</td>
<td>26.43****</td>
<td>24.45****</td>
</tr>
<tr>
<td>X1; Phonological awareness accuracy</td>
<td>0.17****</td>
<td>0.20****</td>
<td>0.23****</td>
</tr>
<tr>
<td>X2; Phonological awareness reaction time</td>
<td>0.16**</td>
<td>0.21**</td>
<td>0.21**</td>
</tr>
<tr>
<td>X3; Rapid automatized naming</td>
<td>3.63***</td>
<td>3.12**</td>
<td>3.09***</td>
</tr>
<tr>
<td>X4; Letter–speech sound accuracy</td>
<td>1.25***</td>
<td>1.50***</td>
<td>1.16***</td>
</tr>
<tr>
<td>X5; Letter–speech sound reaction time</td>
<td>0.07**</td>
<td>0.07**</td>
<td>0.07**</td>
</tr>
<tr>
<td>X6; Verbal working memory</td>
<td>0.47*</td>
<td>0.49**</td>
<td>0.40*</td>
</tr>
</tbody>
</table>

Level 2
1. Entropy
   - Phonological Awareness Accuracy × Entropy 0.77****
   - Phonological Awareness Reaction Time × Entropy −0.69***
   - Letter–Speech Sound Accuracy × Entropy ns
   - Letter–Speech Sound Reaction Time × Entropy 0.34*

2. Grade
   - Phonological Awareness Accuracy × Grade −0.07***
   - Rapid Automated Naming × Grade 0.76***
   - Letter–Speech Sound Accuracy × Grade −0.49**
   - Entropy −23.18*
   - Grade 3.66***

One-level model
−2 log-likelihood 7,678.7
Akaiake’s information criterion 15,375.3
Parameter 9

Complete two-level model
−2 log-likelihood 7,641.4
Akaiake’s information criterion 15,330.9
Parameter 24

Final model
−2 log-likelihood 7,653.1
Akaiake’s information criterion 15,340.3
Parameter 17

Note. Level 1 = individuals; Level 2 = entropy and grade. AIC = Akaiake’s information criterion.
*p ≤ .05. **p ≤ .01. ***p ≤ .001. ****p ≤ .0001.
The Interplay Between Phonological Accuracy and Phonological Speed

It is worth noting that the effect of orthographic consistency on phonological awareness speed was opposite the effect of orthographic consistency on phonological awareness accuracy; that is, phonological awareness speed was more important for reading in transparent orthographies, whereas phonological awareness accuracy was more important in opaque orthographies. There might be several explanations for this discrepancy in the effect of phonological awareness speed and phonological awareness accuracy on reading. First, it is possible that performance on the phonological awareness task reached ceiling levels faster in transparent than in opaque orthographies (for similar argumentation, see Caravolas, Hulme, & Snowling, 2001; Patel et al., 2004), thereby reducing the statistical power of phonological awareness accuracy favoring phonological awareness speed as the best discriminating variable. However, the performance on the phoneme deletion task in the present study did not reach ceiling in any of the languages, not even in Grade 4. Moreover, if ceiling effects were the reason for the stronger effect of phonological awareness task in Grade 1, this effect should have been most obvious in grades in which the phoneme deletion task in the present study did not reach ceiling. However, the performance on the phoneme deletion task in the present study did not reach ceiling in any of the languages, not even in Grade 4. Moreover, if ceiling effects were the reason for the stronger effect of phonological awareness task in Grade 1, this effect should have been most obvious in grades in which the phoneme deletion task in the present study did not reach ceiling. However, the performance on the phoneme deletion task in the present study did not reach ceiling in any of the languages, not even in Grade 4. Moreover, if ceiling effects were the reason for the stronger effect of phonological awareness task in Grade 1, this effect should have been most obvious in grades in which the phoneme deletion task in the present study did not reach ceiling.
opposite; the effect of orthographic consistency was largest in Grade 1.

An alternative explanation could be that phonological awareness speed cannot be reliably tested if phonological awareness accuracy is too low. Because many Portuguese first graders showed low performance on phonological awareness accuracy, the effect of phonological awareness speed on reading could be reduced in these children, and this could explain the negative effect of entropy value in Grade 1.

A final possible explanation for the stronger involvement of phonological awareness speed in transparent orthographies might be that phonological awareness speed accrues importance when certain levels of reading expertise are reached. That is, it is possible that skills such as efficiency of phonological decoding and fast retrieval of phonological information (which might be captured by speed on phonological awareness tasks) mainly assume importance when reading speed becomes a more salient characteristic of reading skill. In opaque orthographies, this phase of reading development might be reached at a later point in time than in transparent orthographies, explaining why the contribution of phonological awareness speed on reading was weaker in Portuguese participants mainly in the first grades.

Implications for Universal Models of Fluent Reading Development

The fact that we found a similar pattern of results in all three orthographies, that is, a strong influence of phonological awareness in beginning readers and a gradual shift in the relative importance of phonological awareness and rapid naming on reading fluency as a function of reading experience, indicates that cognitive contributions to reading development are relatively independent of orthographic depth. These results do not support claims that readers in transparent orthographies use cognitively different reading strategies than do readers in opaque orthographies (as predicted by strong versions of the orthographic depth hypothesis; Katz & Frost, 1992). Moreover, a weak version of the orthographic depth hypothesis (i.e., readers in transparent orthographies rely relatively more heavily on phonological decoding strategies; Frost, 2005) was not supported by the current results either, as phonological awareness and letter–speech sound processing contributed equally strongly or even more strongly in opaque orthographies as compared with transparent orthographies (which is in line with previous reports; Georgiou, Parrila, Kirby, & Stephenson, 2008; Mann & Wimmer, 2002; Ziegler et al., 2010).

Rather, the current data suggest that fluent reading recruits the same cognitive processes in different orthographies but that the time course of the cognitive developmental pattern is influenced...
by orthographic features, such as transparency. That is, in opaque orthographies, it is more difficult to grasp the basic principle of the alphabetic structure of an orthography because letter–speech sound correspondences are ambiguous, and children learning to read in an opaque orthography probably have to develop more elaborate, complex phonological decoding strategies (as suggested by Ziegler & Goswami, 2005). Consequently, it might take longer to form stable connections between orthographic (word-specific) patterns and phonological codes (i.e., moving to a consolidated alphabetic phase, Ehri, 1995, 2005), fluent reading develops at a slower rate in opaque orthographies (e.g., Frith, Wimmer, & Landerl, 1998; Goswami, Gombert, & De Barrera, 1998; Goswami, Ziegler, & Richardson, 2005; Landerl, Wimmer, & Frith, 1997; Seymour et al., 2003), and phonological processing and decoding skills are involved in reading for a longer period of time. In other words, “phonemic awareness is likely to be equally important in consistent and inconsistent orthographies but at different phases in development” (Share, 2008, p. 598).

Generalization to the English Orthography

As noted before, English has an outlier position regarding its orthographic consistency, and therefore “universal” models of reading development might not be directly applicable to English (Share, 2008). However, Share also assumes that the beginning and the end state of reading are universal for all alphabetic orthographies: Phonological decoding is important for the initial acquisition of literacy skills in all (alphabetic) orthographies, whereas the quintessence of skilled reading is to automatically and effortlessly recognize words by sight. If the hypothesis that this shift is reflected in a concomitant shift in the relative importance of phonological awareness and rapid naming to word reading fluency (see also Vaessen & Blomert, 2010) is correct, it seems reasonable to assume that this shift might eventually also occur in English readers, although phonological awareness might be important for a longer period of time when learning to read in English than is the case when learning to read in other orthographies (Torgesen et al., 1997; Wagner et al., 1994). In line with this assumption, some English-language studies including a wide age range also demonstrated a shift in the relative importance of phonological awareness and/or rapid naming for word reading (Badian, 2001; Kirby, Parrila, & Pfeiffer, 2003).

Potential Limitations of This Study

Some limitations of the current study are worth mentioning. First, the present study focused on only one aspect of an orthography: orthographic consistency defined in terms of word onsets. Obviously, the structure of an orthography is defined by more than only this type of orthographic consistency, and other linguistic aspects, such as syllabic complexity (Seymour et al., 2003), might also have had an impact on rate of reading development. However, the results of the current study do not indicate a strong influence of syllabic complexity on reading development, as children learning to read in Portuguese, which has a simple syllabic structure, showed a slower rate of reading development than did children learning to read in Dutch, which has a complex syllabic structure. Nevertheless, it remains possible, in principle, that other linguistic characteristics, such as syllabic stress patterns (Duncan, Cole, Seymour, & Magnan, 2006) or semantic ambiguity (van Orden & Kloos, 2005) also influenced reading development in the three orthographies tested in this study.

Another limitation of the present study (and other cross-language investigations) is that systematic nonlinguistic differences exist between countries, such as instructional methods (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001; Ziegler & Goswami, 2006), school support systems (Blomert, 2009; Ise et al., in press), and economic status of a country and parental education, which possibly affect the rate of reading development. For instance, the parental educational level of the Portuguese sample was lower than that of the Dutch sample, which might have led to their poorer reading performance. However, the Hungarian children also showed a lower parental educational level, but their reading levels were comparable to those of the Dutch children, showing that parental education does not, by itself, lead to lower reading performance. Moreover, parental educational level did not correlate strongly with reading performance within one country (correlations ranged from .07 and .20), suggesting that this factor also might not have had a large impact on between-country differences in reading performance. Nonetheless, other structural cross-country differences might have an influence on reading development.

A final factor that might influence the rate of reading development is the age at which formal reading instruction starts. In Hungary, children enter school when they are seven years old, whereas Portuguese and Dutch children are typically six years old. However, correlations between age and standardized reading scores were not significant, suggesting that age does not affect reading performance once the amount of formal reading education is taken into account. Moreover, a large-scale European study that included 13 different orthographies showed that the age of school entrance did not affect reading performance (Seymour et al., 2003).

In closing, it is worth mentioning that despite these linguistic and nonlinguistic differences among the three countries (which might have contributed to differences in rate of reading development), the results regarding the developmental course of the cognitive skills associated with reading fluency were remarkably similar, supporting a fairly universal cognitive basis of fluent word reading development in alphabetic orthographies.

Conclusion

The results of the present study indicate that cognitive development of fluent word reading (in alphabetic scripts) follows a similar pattern in orthographies varying in consistency of their letter–speech sound mappings. In all three included orthographies, the weight of the contributions of phonological awareness, letter–speech sound processing, and rapid naming shifted as a function of reading expertise and word type and frequency, and orthographic consistency did not modulate this general effect. However, the contributions of phonological awareness and letter–speech sound processing to reading fluency were important for a longer period of time in opaque orthographies, suggesting that orthographic consistency does influence the rate at which the reading system develops. Because of the ambiguous letter–speech sound correspondences characteristic of opaque orthographies, children learning such languages probably have to develop more elaborate decoding strategies, and
consequently phonological skills remain important for a longer period of time. Nevertheless, the results strongly indicate that the same cognitive components underlie the development of fluent reading skills in opaque and transparent orthographies.

References