The role of orthographic and phonological processing in dyslexia and reading

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Chapter 2 Predicting word reading fluency in Dutch children in a longitudinal study: The role of phonological and orthographic processing*

Abstract

The present study investigated the role of orthographic processing in gaining Dutch reading fluency and spelling ability in the period from Grade 2 to 4 in a sample of 129 children, controlling for the influence of phoneme awareness, rapid serial naming, and initial levels of vocabulary. Orthographic processing, defined as word-specific orthographic knowledge and fast identification of larger orthographic units, was expected to be important in the fluency phase, when readers need to read polysyllabic words. By using multilevel modeling with an autoregressive structure, the results revealed that in predicting (polysyllabic) word and pseudoword reading fluency orthographic processing was an important predictor. This was in addition to phoneme awareness and the increasing influence of rapid serial naming. In predicting spelling ability the use of word-specific orthographic knowledge was an important predictor, in addition to the increasing role of phoneme awareness. Therefore, all components are needed to increase precise and redundant orthographic and phonemic connections in order to develop automatic and efficient visual word recognition and efficient spelling ability.

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2.1 Introduction

This study aims to investigate the role of orthographic processing in the acquisition of word reading fluency. This was motivated by two observations. First, although the role of orthographic processing is acknowledged within reading research (e.g., Badian, 2001; Barker, Torgesen, & Wagner, 1992; Bowey & Muller, 2005; Burt; 2006; Cunningham, Perry, & Stanovich, 2001; Hagiliassis, Pratt, & Johnston, 2006; Olson, Forsberg, Wise, & Rack, 1994; Share 1995; Sprenger-Charolles, Siegel, Béchennec, & Serniclaes, 2003; Wood, 2009), its contribution to the development of reading fluency is not thoroughly investigated in a relative transparent language like Dutch, the language under study. None of the Dutch longitudinal prediction studies has addressed this question during the years of reading acquisition (Grade 1 - 4) (e.g., Aarnoutse, van Leeuwe, & Verhoeven, 2005; Bast & Reitsma, 1998; de Jong & van der Leij, 1999; Verhagen, Aarnoutse, & van Leeuwe, 2008; Verhoeven & van Leeuwe, 2009).

The second observation is that findings of previous studies suggest that orthographic processing is important in predicting reading fluency after the years of reading acquisition, in adolescents and adults (Bekebrede, van der Leij, Plakas, Share, & Morfidi, 2010; Morfidi, van der Leij, de Jong, Scheltinga, & Bekebrede, 2007). In addition, it has been established that there are individual differences among older dyslexics in orthographic processing. Dyslexics in the age range of adolescents and adults all have phonological problems but combine them with relatively large individual orthographic differences (in Dutch: Bekebrede, van der Leij, & Share, 2009; Bekebrede et al., 2010; van der Leij & Morfidi, 2006; see for a Swedish example: Miller-Guron & Lundberg, 2000). In fact, substantial subgroups of dyslexics have word-specific orthographic knowledge in the normal range which is far better than expected based on their overall reading skill. These two observations led us to the question whether the foundations of these differences may emerge at an earlier stage. That is, whether there are early signs of the impact of the role of orthographic processing on gaining reading fluency, especially in the period when the development of reading fluency is at its peak (the period from Grade 2 to 4).

2.1.1 The role of orthographic processing in word identification

To become a fluent reader automaticity in decoding must be reached, which implies fast, effortless, autonomous, and not consciously aware processing of words independent of familiarity. Automaticity enables the reader to shift attention to higher-order tasks (Logan, 1997). To develop automatic and efficient visual word recognition processes, Perfetti (1992) has argued that the precision and redundancy of orthographic and phonemic connections at the sublexical and lexical level have to be increased in order to be used in a flexible and rapid way. This process, which will be called orthographic processing throughout this chapter, implies “crystallized” orthographic ability (Share, 2008b, p.43), i.e., connections at the lexical level (word-specific knowledge), and at the sublexical level of single letters, letter clusters, and syllables (Berninger et al., 1992).

It has been suggested that using word-specific knowledge is less important in a relative transparent orthography (Ziegler & Goswami, 2005), because fast efficient phonological recoding is all the reader needs to identify the word. However, experience with words may establish orthographic knowledge ranging from lexical to sublexical knowledge relatively early to be used to recognize not only the specific words (Reitsma, 1983), but also other words with equal parts, e.g., their orthographic neighbours (e.g., Andrews, 1997; Marinus & de Jong, 2010). There is an “interactive convergence of orthographic and phonological representations when reading” (Booth, Perfetti, & MacWhinney, 1999, p.17). It may be assumed that the role of orthographic processing may increase when the reader has to read words of two or more syllables. As is tentatively suggested in a recent Dutch study, knowledge of larger orthographic units may be necessary to overcome both the consistency problem (orthographic units may have different pronunciations) and the granularity problem (grain size and complexity of orthographic units may vary) (Verhoeven & van Leeuwe, 2009; see also Ziegler & Goswami, 2005). The consistency and granularity problem both exist in Dutch. For example, the pronunciation of <u>en</u> is different in the first and second syllable of *dennen* (firs), and the VC-cluster <u>op</u> is connected to one syllable in *stop*, but splits up in two in *open*. The use of (sub)lexical orthographic knowledge gains influence as an independent source of information when words with a complex orthographic structure have to be recognized, which is the case from third grade onwards when polysyllabic Dutch words, which contain many inconsistencies, have to be learned (Verhoeven & van Leeuwe, 2009). This belongs to the idea of a continuous process from print to sound conversion to automatic whole word recognition (Share, 1999; 2008a), in which larger orthographic units – sublexical orthographic knowledge – are important (Wesseling & Reitsma, 2000).

2.1.2 The role of orthographic processing in spelling ability

Orthographic processing is also very relevant for spelling ability. In order to spell a word, the speech sounds have to be transposed into corresponding letters, that is mapping phonology to orthography. All different kinds of phonological units are vital in spelling: single phonemes, onsets, rimes, speech-sound clusters, and whole words (e.g., Ziegler, Stone, & Jacobs, 1997). These phonological units have to be matched to graphemes, grapheme clusters, and words. Besides knowledge about the phoneme-grapheme correspondences (Treiman & Bourassa, 2000), the quality of the lexical representation in the mental lexicon is important. Both phonological and orthographic information is needed to form this representation (Perfetti, 1992; Perfetti & Hart, 2002). As in most alphabetic languages, in Dutch the phoneme-grapheme correspondences needed for spelling are less regular than the grapheme-phoneme correspondences needed for reading. Due to these differences in irregularities there are often more ways to spell a word than to read a word. Therefore, spelling is more difficult to acquire than reading (Bosman & van Orden, 1997).

2.1.3 The need to control for phoneme awareness and rapid serial naming as independent predictors

The goal of the present study is to shed light on the role of orthographic processing in predicting reading fluency and spelling ability. In order to investigate the unique contribution of orthographic processing, other predictors have to be controlled for. Two phonological processing variables that are not part of the process of word identification but have strong correlations to the process of reading acquisition, phoneme awareness and rapid serial naming, are used to control for their independent contribution to reading fluency and spelling ability (de Jong & van der Leij, 1999; Vaessen & Blomert, 2010).

There is abundant evidence that phoneme awareness is one of the strongest predictors of reading acquisition, irrespective of language (e.g., Bowey, 2005; Cardoso-Martins & Pennington, 2004; Holopainen, Ahonen, & Lyytinen, 2004; Ziegler & Goswami, 2005). However, the period during which phoneme awareness affects typical reading development appears to be different across languages with differences in orthographic depth. Especially in relative transparent languages phoneme awareness is one of the strongest predictors of early reading, but it is only a longitudinal predictor during a short period of time in the early stages (de Jong & van der Leij, 1999; Landerl & Wimmer, 2008; Leppänen, Aunola, Niemi, & Nurmi, 2008; Lervåg, Bråten, & Hulme, 2009; Verhagen et al., 2008). As a concurrent predictor phoneme awareness has a strong influence until Grade 4. However, the influence declines as a function of word frequency (Vaessen & Blomert, 2010). However, in the perspective of the discussion about the importance of phoneme awareness in predicting reading fluency, sensitivity to individual differences in the period when the development of reading fluency is at its fastest, is important (Caravolas, Volín, & Hulme, 2005; de Jong & van der Leij, 2003), next to the distinction between longitudinal and concurrent predictors (Lervåg et al., 2009; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). With respect to spelling acquisition phoneme awareness is a key element (e.g., Bosman & van Orden, 1997; Frith, 1985; Treiman & Bourassa, 2000). In order to spell a word correct, it is essential to segment the spoken word into separate phonemes. Phoneme awareness is an important predictor of spelling ability in both relative transparent orthographies, such as German and Czech, as in a deep orthography as English (Caravolas et al., 2005; Cardoso-Martins & Pennington, 2004; Moll, Fussenegger, Willburger, & Landerl, 2009; Wimmer & Mayringer, 2002).

In contrast to phoneme awareness, which essentially is a subskill within the auditory modality, rapid serial naming involves intermodal processing, i.e., the fluency of naming of colors, pictures, or symbols (letters or digits). The naming of symbols implies lexical access and retrieval of well-known information. It requires the mapping of a visual symbol to a speech sound, a syllable with a meaning. This mapping, as in all mappings with larger units than the phoneme, involves suprasegmental phonology, in contrast to segmental phonology as used in phoneme awareness. Furthermore, the relationship between word reading fluency and alphanumeric naming grows stronger during development (van den Bos, Zijlstra, & lutje Spelberg, 2002).

Although both phoneme awareness and rapid serial naming are strong predictors at the start of reading acquisition, it has been suggested that the role of phoneme awareness diminishes after the early grades, whereas the role of rapid serial naming is increased (Kirby, Parrila, & Pfeiffer, 2003), because laborious phonological recoding processes are gradually replaced by fluency of word reading. Especially in relative transparent languages rapid serial naming is the most influential predictor of reading (e.g., de Jong & van der Leij, 1999; 2003; Georgiou, Parrila, & Papadopoulos, 2008; Holopainen et al., 2001; Moll et al., 2009; Vaessen & Blomert, 2010; Vaessen, Gerretsen, & Blomert, 2009; Wimmer & Mayringer, 2002; Wimmer, Mayringer, & Landerl, 2000). Whereas rapid serial naming is important in predicting reading fluency, the role in spelling is less clear. In prediction studies the role of phoneme awareness is more influential, rapid serial naming may be additive in explaining spelling ability (Cardoso-Martins & Pennington, 2004; Compton, DeFries, & Olson, 2001; Moll et al., 2009; Savage, Pillay, & Melidona, 2008). However, there is also evidence that rapid serial naming has not an additive role in predicting spelling (Nikolopoulos, Goulandris, Hulme, & Snowling, 2006).

In addition to phoneme awareness and rapid serial naming, the semantic aspect could be of importance in predicting reading fluency. However, with regard to letter knowledge it can be assumed that letter knowledge is already acquired in Grade 1 (Aarnoutse et al., 2005). Furthermore, the meaning component is especially important for reading comprehension, less for word reading fluency and spelling, and not at all for pseudoword reading fluency (e.g., Frost, Madsbjerg, Niedersøe, Olofsson, & Sørensen, 2005; Wood, 2009). The focus in the present study was not on letter knowledge, nor on semantic knowledge. However, vocabulary was included in this study to serve as a cognitive control variable to control for possible semantic effects (Wood).

2.2 The present study

To investigate the role of orthographic processing in a relative transparent orthography, the present study examined the predictors of fluency of Dutch (polysyllabic) word and pseudoword reading, and spelling ability in Grade 2, 3, and 4 in a longitudinal design, which controlled for the influence of phoneme awareness and rapid serial naming. Both orthography to phonology mapping (reading), and phonology to orthography mapping (spelling) was included. To ensure a broad vision on reading development, the unfamiliar to familiar framework (Share, 2008a) was included by using both words and pseudowords. The focus was on reading fluency because in a relative transparent language like Dutch, high levels of accuracy are obtained fairly early (Seymour, Aro, & Erskine, 2003; Verhoeven & van Leeuwe, 2009).

As described in the introduction, our primary interest was the development of reading and spelling in Grade 2 to 4 when children show an increased fluency in word reading and a large progress in spelling skills. Our main hypothesis was that orthographic processing at the sublexical and lexical level explains additional variance above phoneme awareness and rapid serial naming. With regard to polysyllabic word reading fluency, it was expected that the role of phoneme awareness with its emphasis on segmental phonology (Goswami, 2000) would diminish over the grades (e.g., de Jong & van der Leij, 1999; Wimmer & Mayringer, 2002). In addition, it was expected that the role of rapid serial naming would become more important in predicting word reading fluency (e.g., Moll et al., 2009). Because it has been suggested that the relationship between alphanumerical rapid serial naming and word reading fluency becomes stronger during development (van den Bos et al., 2002), indicating the increasing influence of speed of lexical access and retrieval of over-learned intermodal connections. At the same time, orthographic processing would gain influence (e.g., Reitsma, 1983; Share, 1995), stressing the increasing use of large orthographic units at the lexical and sublexical level (Perfetti, 1992). Furthermore, it was expected that vocabulary plays a role in predicting word reading fluency at this age, because the semantic aspect affects the acquisition of word reading fluency (de Jong & van der Leij, 2002; Wood, 2009).

In addition, pseudoword reading fluency is incorporated as a dependent variable. This will shed light on the issue whether or not the predictors are independent of familiarity at the lexical level. It was hypothesized that the role of phoneme awareness, in contrast to the predictions of word reading fluency, remained stronger, because non-existing words were involved. In identifying pseudowords there can be no direct word identification, so phonological processes at the phoneme level remain important. It was also expected that rapid serial naming was an important predictor of pseudoword reading fluency, because in typical reading development, progress in fluency tends to become increasingly independent of familiarity (van den Broeck, Geudens, & van den Bos, 2010) and the increasing influence of speed of access and retrieval also applies to sublexical units. With regard to orthographic processing it may be argued that word-specific (lexical) orthographic knowledge does not predict pseudoword reading fluency, because whole word identification is impossible in reading pseudowords. However, representations from other known words may facilitate identification of sublexical parts of the pseudowords, using familiar larger orthographic units, which is also seen in the neighbourhood effect (that is, pseudowords with more neighbours were read faster (Andrews, 1997; Marinus & de Jong, 2010)). Furthermore, in contrast to word reading fluency, the role of vocabulary is absent, because it involves non existing words.

In predicting spelling ability it was expected that phoneme awareness was important across Grade 2 to 4, because segmental phonology is of importance in spelling acquisition (Goswami, 2000; Treiman & Bourassa, 2000). In contrast to fluency of (pseudo)word reading, the influence of rapid serial naming would be less important, because the speed of lexical access and retrieval of phonological labels of well-known symbols from memory is of minor importance in the relatively slow and elaborate process of spelling. Moreover, rapid serial naming involves suprasegmental phonology and in spelling it was expected that segmental phonology was more crucial, therefore phoneme awareness was expected to play a critical role (e.g., Savage et al., 2008). In addition, it was expected that orthographic processing predicts spelling ability, because lexical representations are necessary in the process of mapping of phonology to orthography (Bekebrede et al., 2009; Cardoso-Martins & Pennington, 2004; Perfetti, 1992).

2.2.1 Considerations of how to operationalize the theoretical concepts

To investigate the predictors of (pseudo) word reading fluency and spelling in second to fourth grade, the issue of sensitivity and equivalence of measures had to be resolved to correctly operationalize the theoretical concepts. Because this was a longitudinal study, the content and format of the measures used in the three years should, as much as possible, be the same for all grades to enable comparison across grades. The measures needed to be easy enough to avoid floor effects at second grade and difficult enough to avoid ceiling effects at the later grades. Designing the study, six decisions were made.

Firstly, in order to operationalize orthographic processing we wanted to include both the lexical and the sublexical level and speed of processing. In addition to a three-choice task measuring processing of word-specific orthographic knowledge that has showed differentiating value amongst good and poor readers in earlier studies (Horsley, 2005), another measure was designed which required flexible and rapid processing of orthographic representations at the sublexical and lexical level (Booth et al., 1999). This orthographic processing task existed of words and pseudowords with one and two syllables and involved a brief presentation (200 ms) on a computer screen that stresses the need for fast processing and use of larger orthographic units (Yap & van der Leij, 1993a) in both words and pseudowords.

Secondly, in the operationalization of phoneme awareness we incorporated two different phoneme awareness tasks. First a deletion task, a commonly used task which has proven its value as a good representative of a phonological task that distinguishes between good and poor readers (e.g., Hagiliassis, et al., 2006; Messbauer & de Jong, 2003). Second, a task that involves the manipulation of phonemes, a word reversal task, which was successfully used in a sample of young adolescents and adults (Bekebrede et al., 2009; 2010).

Third, to specify rapid serial naming, only the digit card was used in all grades. Using digits is a solid condition for the speed of cross-modal matching. We did not use letters for a possible confounding effect, because in reading letters there is more ambiguity, i.e., naming the sound or the letter. Besides, letters are involved in word reading fluency, even though levels of letter knowledge are mastered at this age. Moreover, previous studies showed that rapid serial naming of digits is a good predictor of reading and differentiates between reading levels (e.g., Caravolas et al., 2005; de Jong & van der Leij, 2003; Denckla & Rudel, 1974; Morfidi et al., 2007; van den Bos et al., 2002; Wimmer et al., 2000).

Fourth, passive vocabulary in Grade 2 was measured because vocabulary predicts word reading fluency at a younger age (e.g., de Jong & van der Leij, 2002). Fifth, to specify word and pseudoword reading fluency, the same standardized timed reading aloud tasks were used in all the grades, measuring how many polysyllabic words or pseudowords are read in one or two minutes. We chose for polysyllabic words, because the need for orthographic processing, using larger orthographic units, is stressed in reading polysyllabic words (Verhoeven & van Leeuwe, 2009). These tasks are commonly used to measure reading fluency in Dutch in first to sixth grade (van den Bos, lutje Spelberg, Scheepstra, & de Vries, 1994; Verhoeven & van Leeuwe, 2009).

Lastly, because of the fast increasing mastery of spelling categories ranging from simple one-syllabic words to complex polysyllabic words in Grade 2 to 4, it is difficult to use exactly the same spelling task covering second to fourth grade. Therefore, dictation tasks from the Dutch pupil monitoring system were used to measure spelling ability, which adapt spelling categories to grade level. In this monitoring system the scores of each dictation task are transformed into 'scale scores' to compare the scores over grades.

2.3 Method

2.3.1 Participants

Participants were 129 children (60 boys, 69 girls) from six different schools for regular education in the Netherlands across different regions in the Netherlands (urban/rural population). The children were tested in Grade 2, 3, and 4. The mean age in Grade 2 was 7 years and 10 months (*SD* = 6 months, range 6;11 – 9;3). Based on a norm referenced reading task (three minutes test, see below), our sample was quite similar distributed compared to the national norms in Grade 2 (25% top reading level, our study 30.8%; 50% average readers, our study 44.6%; 15% poor readers, our study 13.1%; and 10% very poor readers, our study 11.5%). Hence, our sample was a representative sample of the Grade 2 population. Eight children repeated a class (five in Grade 2 and three in Grade 3). These children remained in the sample in the grade they were supposed to be, to preserve the reading distribution. All children learned to read with a phonics based - letter and word level - program called ‘Veilig Leren Lezen’ [Learning to Read Safely] (Mommers, Verhoeven, van der Linden, Stegeman, & Warnaar, 1990), which is the most commonly used reading program in the Netherlands.

2.3.2 Phoneme awareness

Word reversal. A computerized word reversal task (Bekebrede et al., 2009) was used to measure phoneme awareness. The children heard two pseudowords using headphones (e.g., *ket – tek*). They had to indicate on the computer keyboard whether the second word was the reverse of the first. The word reversal task consisted of 6 examples and 30 items in Grade 2 and 40 items in Grade 3 and 4, all monosyllabic pseudowords with one or two consonants at the beginning or at the end of the word. The internal consistency (Cronbach’s α) was found to be .72, .81, and .82 for Grade 2, 3, and 4, respectively.

Sound deletion. Secondly, a sound deletion task was used to measure phoneme awareness (see also de Jong & van der Leij, 2003; Messbauer & de Jong, 2003). The experimenter auditively presented 27 pseudowords to the participant. First the children had to repeat the pseudoword, subsequently they were required to delete a given sound from the word (e.g., what is /*grar*/ without /*g*/) and sound out what was left. The first nine items consisted of one syllable, the following nine items consisted of two syllables, and the last nine items consisted of two syllable words where the sound that had to be deleted occurred twice. The internal consistency (Cronbach's α) was found to be .88, .82, and .84 for Grade 2, 3, and 4, respectively.

2.3.3 Rapid serial naming

Rapid serial naming. Rapid naming of digits (Denckla & Rudel, 1974) was used. A card with 50 digits (*1, 3, 5, 6, 8*) was presented to the children. They were asked to name the digits as quickly and accurately as possible. The time to name the digits was recorded. Test-retest reliability was found to be .79.

2.3.4 Orthographic processing

Orthographic choice. The orthographic choice task with three choices of Horsley (2005) was used to measure word-specific orthographic knowledge. The children saw 70 items on printed pages, each item consisted of three words. These words were homophones, e.g., *tijd-teid-tijt* [time]. The participants were required to choose the correctly spelled word (*tijd*). The accuracy score was the number of correctly chosen words in 10 minutes. Internal consistency (Cronbach's α) was found to be .98, .91, and .87 for Grade 2, 3, and 4, respectively.

Flashed word and pseudoword production. This task (Bekebrede et al., 2009) required flexible and rapid processing of orthographic representations at the sublexical and lexical level to be used to identify familiar and unfamiliar words. Silent reading and spelling of words and pseudowords was needed to perform the task. A word or pseudoword was flashed on a computer screen for 200 ms and was then masked. The participant was asked to type the flashed (pseudo)word. There were three examples followed by three blocks of ten words. The first block consisted of 10

CCVC words, the second block consisted of 10 CVCC words, and the last block contained 20 CVCV and CVCCVC words. In Grade 2 the last block consisted of only 12 words. In each block half the words were pseudowords. In Grade 4 seventy-five participants performed this test. The internal consistency (Cronbach's α) was found to be .96, .95 and .92 for Grade 2, 3 and 4, respectively.

2.3.5 Reading and spelling measures in Dutch

Word reading fluency. The Drie Minuten Test (DMT) [Three Minute Test] (Verhoeven, 1995) consists of three word cards of increasing difficulty. The third card was administered in all grades. It consists of 120 words with multiple syllables. The child has to read aloud as many words as possible in one minute. The test score was the number of words read correctly in one minute on the third word card. Reliabilities were reported to be over .86 (Moelands, Kamphuis, & Verhoeven, 2003).

Pseudoword reading fluency. The Klepel (van den Bos et al., 1994) is a single pseudoword reading task, which requires phonological recoding. It consists of 116 pseudowords of increasing difficulty. The child is required to read aloud as many words as possible in two minutes. Parallel test reliabilities were reported to be over .89 (van den Bos et al., 1994).

Spelling ability. Scores from the schools were obtained for spelling ability. Spelling ability was measured with a spelling dictation test from the Dutch pupil monitoring system (from the Dutch National Institute for Measurement in Education, Cito). Different dictation tests were used for each grade (M4, M5, and M6; van den Bosch, Gillijns, Krom, & Moelands, 1997). All the spelling tests consist of mono- and polysyllabic words with orthographic patterns of various complexities. Scores were reported into 'scale-scores' to compare over grades. Reliability (accuracy of measurement (MAcc)) was reported to be above .86 (Moelands & Kamphuis, 2001).

2.3.6 Vocabulary

Receptive vocabulary. Receptive vocabulary (Verhoeven, 1993) scores in Grade 2 were obtained from the schools from the Dutch pupil monitoring system (Cito). The test consisted of 50 items of four pictures. The teacher named a word and the children had to mark the correct picture which belonged to the word. This task was used for practical reasons. Reliability is reported by the author to be over .90.

2.3.7 Procedure

All students from the six schools were tested in January – February in three consecutive years. The tasks were administered in two sessions. One individual session included all the paper and pencil tests and the other session the computerized tasks. Dependent on how many computers were available, one to ten children were tested at the same time. For practical reasons, all children received the same fixed order of the tests: word reversal and flashed (pseudo)word production. In a separate session the paper and pencil tests were administered in the following order: three minutes test (Card 3), sound deletion, Klepel, and rapid naming digits. The orthographic choice task was administered in class. The scores of the vocabulary task and spelling task were retrieved from the school (Dutch pupil monitoring system). These tasks were administered by the classroom teacher.

2.3.8 Analyses

To investigate the predictors of (pseudo)word reading fluency and spelling ability we used multilevel (or mixed) modeling. This statistical technique has a number of advantages over repeated measures ANOVA, with its restrictive assumptions, or structural equation modeling, that requires a much larger ratio of sample size over the number of variables in the analysis. First, multilevel modeling has the advantage that it is possible to take different patterns of missingness into account while still making use of all available data. Second, it is possible to consider various longitudinal (autoregressive) structures in addition to compound symmetry. Third, it is possible to simultaneously investigate the effect of fixed predictors (e.g., sex) and a number of time-varying predictors (e.g., repeatedly administered reading related tasks). Fourth, it is possible to simultaneously investigate the effects on reading fluency and the effects on changes in reading fluency.

To investigate change in reading fluency and predictors of change, we conducted a four-step multilevel analysis (procedure Mixed from the Statistical Package for the Social Sciences version 15.0) in which the measurement occasions were treated as nested within pupils. For each of the three dependent variables (word reading fluency, pseudoword reading fluency, and spelling ability), we first fitted a model with a random intercept, representing mean baseline scores at Time 1, and two fixed regressions representing deviations from baseline at Time 2 and Time 3. With this so-called “fixed occasion” model (Snijders & Bosker, 1999) we used likelihood-ratio tests to investigate which longitudinal covariance structure provided the best fit: compound symmetry, autoregressive structure or unstructured. In the second step, we added predictor variables with fixed effects. After stepwise removal of insignificant effects, only predictors with significant effects were retained in Model 2. In the third step, we added interaction effects between predictor variables and time to investigate predictors of change. Only the significant effects were retained in Model 3. In the fourth and final step, we checked for random effects, to investigate whether the effects varied among children. Again, we only retained random effects that improved model fit significantly.

2.4 Results

When a principal component analysis with oblique transformation (because of possible correlations between the factors) was performed on all measures (except the dependent (pseudo)word reading fluency and spelling ability), a four factor solution was extracted that explained 75% of the variance (see Table 2.1 for the factor loadings). The first factor with an eigenvalue of 7.99 consisted of the orthographic processing tasks (i.e., orthographic choice and flashed (pseudo)word production) of the three years (factor loadings between .64 - .91). The second factor with an eigenvalue of 1.71 consisted of rapid serial naming of digits of all years (factor loadings between .67 - .88). The third factor with an eigenvalue of 1.27 consisted of both phoneme awareness tasks (i.e., word reversal and sound deletion) of all years (factor loadings between .51 - .87). The last factor existed of only Grade 2 vocabulary (eigenvalue 1.04, factor loading .98).

Table 2.1
Principal component loadings on all independent variables

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Word reversal G4			.51	
Deletion G4			.82	
Orthographic choice G4	.86			
Flashed production[1] G4	.92			
Rapid serial naming G4		.67		
Word reversal G3			.70	
Deletion G3			.87	
Orthographic choice G3	.88			
Flashed production[1] G3	.86			
Rapid serial naming G3		.88		
Word reversal G2			.56	
Deletion G2			.83	
Orthographic choice G2	.80			
Flashed production[1] G2	.64			
Rapid serial naming G2		.82		
Vocabulary G2				.98

Note. Accounted for 75% of the variance.
G4 = Grade 4; G3 = Grade 3; G2 = Grade 2.
[1]Flashed production = Flashed (pseudo)word production.

2.4.1 Word reading fluency

Parameter estimates for the word reading fluency model are given in Table 2.2. The longitudinal covariance structure was best described by a first-order autoregressive structure with an autocorrelation of .84 - .91, where the variance over time was the same, but the covariance depended on the time interval (Hox, 2002). In Model 1 significant effects for Time 2 (20.69) and Time 3 (32.64) indicated significant improvement in word reading fluency. In Model 2, orthographic choice, flashed (pseudo) word production, rapid serial naming, phoneme awareness (both deletion and word reversal), and Grade 2 vocabulary contributed significantly to the explanation of word reading fluency.

Model 3 showed that the effect of rapid serial naming changed over time. The effect was significantly larger on Time 2 (Grade 3) and Time 3 (Grade 4) than in Time 1 (Grade 2). The effect of the other predictors remained the same throughout the grades. As an aside we note that when only orthographic choice was added to the model, there was an interaction with time: the effect for Time 3 was larger than for Time 1. However, when other predictors were entered this interaction effect disappeared. The model fit including this interaction effect of orthographic choice did not improve significantly ($\chi^2 = 1.44$, $df = 2$, $p > .05$).

In the final model (Model 4 in Table 2.2) a random effect of orthographic choice was added. It improved the model fit significantly ($\chi^2 = 10.25$, $df = 1$, $p = 0.0014$), indicating that the effect of orthographic choice on word reading fluency varied across children. After inclusion of interaction effects in Model 3 and random effects in Model 4, the fixed effect of word reversal on word reading fluency was no longer significant. When the predictors were added (Model 2) in comparison with the model with only the three measurement occasions of word reading fluency (Model 1), 80% of the variance between the children was explained. In addition, 2% was explained by including interaction effects between Time and rapid serial naming, and an additional 11% (93%) was explained by including a random effect of orthographic choice.

Table 2.2
Parameter estimates (regression coefficients and standard errors) for multilevel models of word reading fluency

	Model 1		Model 2		Model 3		Model 4	
Intercept	37.38**	(1.71)	-14.21	(9.64)	-20.59*	(9.42)	-17.94†	(9.12)
T2	20.69**	(.74)	-2.31	(1.57)	11.88*	(5.17)	12.55*	(5.13)
T3	32.64**	(1.02)	-1.83	(2.09)	30.07**	(7.39)	29.03**	(7.05)
Vocabulary			.66**	(.20)	.63**	(.19)	.60**	(.18)
Deletion			.31**	(.12)	.24*	(.11)	.22*	(.11)
Word reversal			.30**	(.11)	.20	(.11)	-.16	(.11)
RAN			-.58**	(.11)	-.26††	(.14)	-.26*	(.13)
Ortho choice[1]			.51**	(.07)	.49**	(.07)	.47**	(.07)
Flashed (pseudo) word production			.74**	(.09)	.85**	(.09)	.85**	(.08)
Interaction Time2*ran					-.48**	(.17)	-.47**	(.17)
Interaction Time3*ran					-1.20**	(.27)	-1.08**	(.26)
Between pupil variance	372.82**	(42.46)	101.14**	(10.25)	93.10**	(9.16)	50.48**	(9.86)
Autoregression coefficient	.91**	(.01)	.59**	(.06)	.57**	(.06)	.24	(.15)
Random Ortho choice[1]							.02*	(.006)
-2log likelihood (*df*)	2920.80 (5)		2359.13 (11)		2338.90 (13)		2328.65 (14)	
AIC[2]	2930.80		2381.13		2364.90		2356.65	
Explained variance within pupils			.72		.75		.86	
Explained variance between pupils			.80		.82		.93	

Note. [1]Ortho = Orthographic; [2]AIC=Akaike's Information Criterion.
Model 1: predicted by time; Model 2: predicted by time and main effects; Model 3: predicted by time, main effects, and interaction effects; Model 4: predicted by time, main effects, interaction effects, and random effect.
* $p < .05$, ** $p < .01$, † $p = .051$, †† $p = .057$.

2.4.2 Pseudoword reading fluency

Parameter estimates for the pseudoword reading fluency model are given in Table 2.3. The longitudinal covariance structure was best described by a heterogeneous first-order autoregressive structure where the variances for the three times were different, but the covariances depended on the time interval (Hox, 2002). The variances appeared to be larger further in time (i.e., at a later age). There was an autocorrelation of .84-.89.

In Model 1, significant effects of Time 2 (12.20) and Time 3 (20.68) indicated growth in pseudoword reading fluency. In Model 2, orthographic choice, flashed (pseudo)word production, rapid serial naming, and phoneme awareness (both deletion and word reversal) contributed significantly to the prediction of pseudoword reading fluency. Grade 2 vocabulary had no single effect on predicting pseudoword reading fluency, not even a contribution when no other predictors were entered. Therefore, this predictor was not added in the final model.

Model 3 showed that the effect of rapid serial naming changed over time. The effect was significantly larger in Time 2 (Grade 3) and Time 3 (Grade 4) than in Time 1 (Grade 2). The effect of orthographic choice of Time 3 being larger than in Time 1 just missed significance. The effect of the other predictors remained the same throughout the grades. In the final model (Model 4 in Table 2.3) a random effect of orthographic choice was added. It improved the model fit significantly ($\chi^2 = 8.02$, $df = 1$, $p = 0.005$) indicating that the effect of orthographic choice on pseudoword reading fluency varied across children. After inclusion of the interaction effects, the interaction effect for orthographic choice Time 3 just missed significance ($p = .055$). However, it improved the fit of the final model, therefore this interaction effect did appear in the third and fourth model ($\chi^2 = 6.18$, $df = 2$, $p = 0.046$).

When the predictors were added (Model 2) in comparison with the model with only the three measurement occasions of pseudoword reading fluency (Model 1), 70% of the variance between the children was explained. By including interaction effects between Time and rapid serial naming and orthographic choice 4% was added, and an additional 19% (in total 93%) was explained by including a random effect of orthographic choice.

Table 2.3
Parameter estimates (regression coefficients and standard errors) for multilevel models of pseudoword reading fluency

	Model 1		Model 2		Model 3		Model 4	
Intercept	36.38**	(1.44)	22.43**	(4.66)	15.77**	(4.97)	16.52**	(4.84)
T2	12.20**	(.75)	-5.20*	(1.54)	15.06*	(6.09)	15.55*	(6.18)
T3	20.68**	(1.04)	-5.88*	(2.16)	-.73	(13.45)	.13	(11.76)
Deletion			.47**	(.11)	.40**	(.11)	.38**	(.10)
Word reversal			.30**	(.11)	.24*	(.11)	.24*	(.11)
RAN			-.59**	(.11)	-.34**	(.12)	-.33**	(.12)
Ortho choice[1]			.32**	(.06)	.30**	(.07)	.27**	(.07)
Flashed (pseudo)word production			.47**	(.08)	.59**	(.08)	.57**	(.08)
Interaction Time2*ran					-.65**	(.16)	-.63**	(.16)
Interaction Time3*ran					-.77*	(.30)	-.71**	(.27)
Interaction Time2*ortho					-.05	(.06)	-.05	(.06)
Interaction Time3*ortho					.27	(.15)	.26†	(.13)
Variance T1	268.24**	(33.20)	85.66**	(11.56)	82.20**	(10.93)	45.19**	(8.61)
Variance T2	335.98**	(41.83)	122.05**	(17.10)	105.90**	(14.78)	42.21**	(13.55)
Variance T3	357.39**	(44.10)	154.96**	(24.73)	131.98**	(20.63)	43.24**	(16.43)
Autoregression coefficient	.89**	(.02)	.67**	(.05)	.65**	(.05)	.24	(.17)
Random Ortho choice[1]							.03**	(.007)
-2log likelihood (*df*)	2931.161 (7)		2379.707 (12)		2354.822 (16)		2343.278 (17)	
AIC[2]	2945.161		2403.707		2354.822		2377.278	
Explained var.[3] within pupils			.62		.67		.86	
Explained var.[3] between pupils			.70		.74		.93	

Note. [1]Ortho = Orthographic; [2]AIC=Akaike's Information Criterion; [3]var. =variance.
Model 1: predicted by time; Model 2: predicted by time and main effects; Model 3: predicted by time, main effects, and interaction effects; Model 4: predicted by time, main effects, interaction effects, and random effect.
* $p < .05$, ** $p < .01$, † $p = .055$.

2.4.3 Spelling ability

Parameter estimates for the spelling ability model are given in Table 2.4. The longitudinal covariance structure of spelling ability, just as for pseudoword reading fluency, was best described by a heterogeneous first-order autoregressive structure with an autocorrelation of .61-.72. The variances appeared to be larger further in time (i.e., at a later age).

In Model 1, significant effects for Time 2 (7.54) and Time 3 (18.38) showed improvement in spelling ability. In Model 2, orthographic choice, rapid serial naming, phoneme awareness (both deletion and word reversal), and word reading fluency contributed significantly to the explanation of spelling ability. Both flashed (pseudo)word production and Grade 2 vocabulary had no single effect on predicting spelling ability. Grade 2 vocabulary did not even predict spelling ability with no other predictors entered. Therefore these predictors were not added to the final model.

Model 3 showed that the effect of sound deletion changed over time. The effect was significantly larger in Time 3 (Grade 4) than in Time 1 (Grade 2). The effect of the other predictors remained the same throughout the grades. In the final model (Model 4 in Table 2.4) a random effect of sound deletion was added. It improved the model fit significantly ($\chi^2 = 6.43$, $df = 1$, $p = 0.011$), indicating that the effect of sound deletion on spelling ability varied across children. It should be noted that rapid serial naming had a suppression effect in predicting spelling ability (see Discussion).

When the predictors were added (Model 2) in comparison with the model with only the three measurement occasions of spelling ability (Model 1), 73% of the variance between the children was explained. By including interaction effects between Time and sound deletion 2% was added, and an additional 12% was explained by including a random effect of sound deletion, making the total variance explained by the final model (Model 4) 87%.

Table 2.4
Parameter estimates (regression coefficients and standard errors) for multilevel models of spelling ability

	Model 1		Model 2		Model 3		Model 4	
Intercept	119.06**	(.70)	94.39**	(2.74)	95.58**	(2.89)	95.66**	(2.79)
T2	7.54**	(.52)	.44	(.87)	-.18	(2.01)	.38	(1.96)
T3	18.38**	(.79)	7.70**	(1.13)	-4.23	(2.88)	-3.27	(2.70)
Deletion			.34**	(.06)	.21*	(.09)	.22*	(.09)
Word reversal			.15*	(.06)	.13*	(.06)	.13*	(.06)
RAN			.13†	(.07)	.15*	(.07)	.15*	(.06)
Orthographic choice			.21**	(.04)	.23**	(.04)	.22**	(.04)
Word reading fluency (DMT3)			.12**	(.03)	.12**	(.02)	.11**	(.02)
Interaction Time2*deletion					.05	(.11)	.04	(.11)
Interaction Time3*deletion					.62**	(.14)	.59**	(.14)
Variance T1	62.17**	(7.55)	32.54**	(4.09)	32.30**	(4.05)	25.90**	(3.84)
Variance T2	51.86**	(6.62)	19.10**	(2.46)	18.80**	(2.40)	11.86**	(2.69)
Variance T3	88.30**	(11.25)	40.80**	(5.43)	34.63**	(4.51)	26.38**	(4.25)
Autoregression coefficient	.71**	(.04)	.25**	(.07)	.23**	(.07)	-.05	(.12)
Random Deletion							.02**	(.006)
-2log likelihood (df)	2458.628 (7)		2309.565 (12)		2289.366 (14)		2279.928 (15)	
AIC[1]	2472.628		2333.565		2317.366		2309.928	
Explained variance within pupils			.54		.58		.68	
Explained variance between pupils			.73		.75		.87	

Note. [1]AIC=Akaike's Information Criterion.
Model 1: predicted by time; Model 2: predicted by time and main effects; Model 3: predicted by time, main effects, and interaction effects; Model 4: predicted by time, main effects, interaction effects, and random effect.
* $p < .05$, ** $p < .01$, † $p = .056$.

2.5 Discussion

To confirm the correct operationalization of the theoretical concepts, the principal component analysis demonstrated that both word-specific orthographic knowledge and fast identification of larger orthographic units in a brief exposure task with words and pseudowords loaded on the same factor and was a stable orthographic processing factor over the three years.

The same was true for the phoneme awareness factor (sound deletion and word reversal). However, it should be noted that in all grades sound deletion had a higher factor loading. Rapid serial naming over the three years and vocabulary were two additional separate factors.

Orthographic processing, as measured with word-specific orthographic knowledge and fast identification of larger orthographic units, is an important predictor of Dutch polysyllabic word reading fluency, in addition to phoneme awareness, rapid serial naming, and initial level of vocabulary. Furthermore, from the high autocorrelations it appeared that reading ability in Grade 2 is strongly related to later reading skills. The results showed that, contrary to the predictions based on the results of other studies, the role of phoneme awareness did not diminish over grades. The effect over the years remained the same. In accordance with the predictions, the role of rapid serial naming became stronger during the years. Moreover, there was individual variability in word-specific orthographic knowledge, meaning that there are substantial differences between children.

Orthographic processing is also an important predictor of pseudoword reading fluency, in addition to phoneme awareness and rapid serial naming. As expected, vocabulary had no influence in predicting pseudoword reading fluency. Again, high autocorrelations indicated that pseudoword reading ability in Grade 2 is strongly related to later pseudoword reading skills. Furthermore, comparable to word reading fluency, the role of rapid serial naming became stronger over the years. Phoneme awareness was also important, but the effect remained the same over the years. There was a trend to significance that the influence of word-specific orthographic knowledge on pseudoword reading fluency became stronger, which gives some support to the view that word-specific orthographic knowledge may be used to identify unfamiliar words (see also the neighbourhood effect, e.g., Andrews, 1997; Marinus & de Jong, 2010). As in word reading fluency, there was individual variability in word-specific orthographic knowledge between the children.

To predict spelling ability, only word-specific orthographic knowledge played a significant role, whereas fast identification of larger orthographic units had no additive role. Apparently, fast (sub)lexical orthographic processing, measured with a brief exposure task, is not crucial for spelling ability. However, word reading fluency was essential. As predicted, phoneme awareness contributed to the prediction and rapid serial naming did not. The effect of phoneme awareness (sound deletion) became stronger during the years, and there was individual variability in sound deletion between the children.

The central issue in the present study was the role of orthographic processing. When controlled for phoneme awareness, rapid serial naming and initial level of vocabulary, orthographic processing predicted word and pseudoword reading fluency. This suggests that orthographic processing is especially important in the phase when the precise and redundant connections between orthographic and phonemic representations of polysyllabic words are learned and automatized (Booth et al., 1999; Verhoeven & van Leeuwe, 2009). Moreover, the individual variability in word-specific orthographic knowledge that was found among older dyslexics (Bekebrede et al., 2009; 2010) seemed already to be present in younger persons across the entire reading ability range, adding to the prediction of word and pseudoword reading fluency.

With regard to the individual variability, an additional exploratory analysis was carried out to investigate whether poor young readers would also show larger individual variability in orthographic processing than in phonological processing. This was found in young adolescents and adults (the phonological-core variable-orthographic differences model; van der Leij & Morfidi, 2006; Bekebrede et al., 2009). Confirming the model, poor readers defined as the lowest 25% in Grade 4 on word reading fluency with better orthographic processing in Grade 4 – with equal orthographic processing compared to average readers in Grade 4 –, performed the same on phoneme awareness, rapid serial naming, and reading comprehension (in Grade 4 as well as in Grade 2 and 3) as the poor readers with worse orthographic processing. However, they were better on polysyllabic word reading in Grade 4 and showed a trend to do better on spelling. Important to note, that it did not matter for these results if orthographic processing was seen as a composite of word-specific orthographic knowledge and fast identification of larger orthographic units, or was seen as solely word-specific knowledge. The compensatory mechanism of gathering orthographic knowledge already seems to be present at this age and is starting to give an advantage, as was the case in young adolescents. Therefore, due to the variability in word-specific orthographic knowledge, there are children who, at least from Grade 4 upwards, could escape from the constraints of phonological recoding and exchange more serial processing (fast grapheme to phoneme conversion) for parallel processing using larger orthographic units.

The present study also showed that, in accordance with other studies, rapid serial naming was essential to predict reading fluency and it became more important during the years (e.g., de Jong & van der Leij, 2003; Kirby et al., 2003; Landerl & Wimmer, 2008; Vaessen & Blomert, 2010; Wimmer & Mayringer, 2002). When children understand the basic phonological principles in combination with reading experience, the relationship between the lexical access and retrieval of names of well known symbols (e.g., digits) and reading fluency grows stronger (van den Bos et al., 2002; van den Broeck et al., 2010). However, it is important to note that the additional role of orthographic processing in predicting word reading fluency supports the view that the retrieval of orthographic knowledge is different from the retrieval of symbol knowledge, in accordance with Moll et al. (2009).

Most longitudinal studies in a relative transparent orthography have indicated that phoneme awareness is only a strong predictor in the early phases of reading acquisition. In later grades it has not an additional effect on top of earlier reading skills (Kirby et al., 2003; Landerl & Wimmer, 2008), although it remained an important concurrent predictor (Lervåg et al., 2009). In the present study phoneme awareness remained important in predicting both word and pseudoword reading fluency, similar to the findings of Cardoso-Martins and Pennington (2004) and Roman, Kirby, Parrila, Wade-Woolley, and Deacon (2009). The differences between the studies may be that phoneme awareness tasks are not sensitive enough to have a large predictive role when administered very early in the reading acquisition process (i.e., kindergarten). In this phase it is about initial phoneme awareness: awareness of sounds without mapping them to graphemes. During reading development letter knowledge and reading skills influence phoneme awareness (Snowling, 2000). Therefore, when phoneme awareness is administered in the fluency period with tasks of appropriate difficulty, it might be more sensitive to predict reading fluency. In this phase it is about more advanced phoneme awareness, the tasks that are administrated are more complex. For example, whereas blending and rhyming – initial phoneme awareness – do not differentiate children, sound deletion does (Bosse, Tainturier, & Valdois, 2007; de Jong & van der Leij, 2003; Hulme et al., 2002; Wesseling & Reitsma, 2000). Moreover, the present study used polysyllabic words as a dependent variable. It may be argued that phoneme processing at the segmental level is important in reading polysyllabic words, which are more complex to identify than mono-syllabic words.

The role of initial level of vocabulary differed in the prediction of word and pseudowords reading fluency, in agreement with the predictions. When familiar (existing) words are used, vocabulary has an influence, whereas vocabulary does not play a role in the prediction of non-familiar (non-existing) words (de Jong & van der Leij, 2002; Wood, 2009).

The present study also addressed the prediction of spelling ability. In this phase of spelling acquisition phoneme awareness has an increasing influence on spelling proficiency (Treiman & Bourassa, 2000). Besides, there existed individual variability in phoneme awareness. The spelling ability was dependent of the individual performance of phoneme awareness. Both word-specific orthographic knowledge and reading polysyllabic words had an additive value in predicting spelling ability. Reading polysyllabic words stresses the need to process larger orthographic units, such as morphemes. It is well-known that morpheme knowledge is important in spelling ability (Treiman & Bourassa, 2000). The contribution of word-specific orthographic knowledge supports the view that lexical representations are important for accurate spelling (Perfetti, 1992). However, fast identification of larger orthographic units, measured with a brief exposure task, did not contribute significantly to the prediction of spelling ability. Apparently, rapid identification of orthographic units does not play a role in spelling, which is dictated by the relatively slow and elaborate process of phonology to orthography mapping.

With regard to the present study, there are three methodological issues that needed to be discussed. Firstly, although the principal component analysis demonstrated that both phoneme awareness measures loaded on a single factor with higher loadings for sound deletion, representing a relatively stable phoneme awareness factor over the three years, sound deletion added a significant contribution to the final model of predicting word reading fluency, but the other measure of phoneme awareness, word reversal, did not. In contrast, in predicting pseudoword reading fluency and spelling ability sound deletion and word reversal contributed both to the prediction. There is a possibility that sound deletion is a better measure for segmental phonology than word reversal. Moreover, in pseudoword reading fluency and spelling ability the role of phoneme awareness is more stressed (Treiman & Bourassa, 2000) whereby both measures had a contribution.

Secondly, the principal component analysis also indicated that the brief exposure task and the orthographic choice task loaded on a single factor, representing a relatively stable orthographic processing factor over the three years. Although it has been suggested in an earlier section that the absence of a contribution of the brief exposure task to the prediction of spelling may be related to the relatively slow spelling mechanisms, it should be noted that for practical reasons not all children performed this brief exposure orthographic processing task in the last year (Grade 4). Therefore the additional gaining or predictive value may have been restricted. However, *t*-tests showed no systematic relationship between missingness among average readers on this brief exposure task in Grade 4 and this brief exposure task a year earlier (Grade 3) ($t(70.6) = -0.9$, $p = .39$). Thirdly, in predicting spelling ability, rapid serial naming had a negative effect. It seems that rapid serial naming suppressed the relation between word reading fluency and spelling. Apparently, there is irrelevant variance on rapid serial naming, which is not related to spelling ability. Both rapid serial naming and word reading fluency involve speed, which is not common for spelling ability. It could be that this relation affects the predictive power of rapid serial naming to spelling ability, and therefore a negative effect arose and the influence of word reading fluency was enhanced. When rapid serial naming was excluded from the prediction, the effect of reading fluency was smaller (although still significant), suggesting that in predicting spelling ability speed is not crucial in Grade 2 to 4.

In sum, the most important contribution of the present study to the available evidence is that orthographic processing, operationalized as word-specific orthographic knowledge and fast identification of larger orthographic units, is an important predictor for word and pseudoword reading fluency and spelling ability in a relatively transparent language, in addition to phoneme awareness and rapid serial naming (and vocabulary in the case of word reading fluency). Orthographic processing is a stable and distinct factor from phoneme awareness and rapid serial naming over the three years. Therefore, orthographic processing should be incorporated in future longitudinal research in investigating gaining fluency.