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Predicting early spelling difficulties in children with specific language impairment: A clinical perspective

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ABSTRACT

This study focused on the precursors of spelling difficulties in first grade for children with specific language impairment (SLI). A sample of 58 second-year kindergartners in the Netherlands was followed until the end of first grade. Linguistic, phonological, orthographic, letter knowledge, memory, and nonverbal-reasoning skills were considered as precursors, as was spelling level at an earlier point in time. Spelling difficulties at the end of first grade were most accurately identified by letter knowledge at the beginning of first grade and word spelling at the middle of first grade. It is concluded that spelling development in children with SLI can be seen as an autocatalytic process in which, without intervention, poor spellers generally remain poor spellers, and good spellers remain good spellers. A focus on early spelling intervention is thus emphasized.

1. Introduction

Children with specific language impairment (SLI) have a failure in their language development, despite at least average non-verbal intelligence, adequate hearing and vision, no known neurological, physical, emotional or social problems, and adequate opportunity to acquire language skills (McArthur & Bishop, 2001). The failures can be receptive and/or expressive, and arise in different areas of communication; phonology, morphology, syntax, semantics, and/or pragmatics (Botting & Conti-Ramsden, 2004). As a consequence of their language delay (Bishop, 1992; Leonard, 1998), children with SLI are at risk for the development of spelling difficulties (e.g., Nauclér, 2004). A large number of children and adults with SLI indeed exhibit spelling problems that are persistent and remain stable over time (e.g., Snowling, Bishop, & Stothard, 2000; van Weerdenburg, Verhoeven, Bosman, & van Balkom, 2011). To alleviate or even prevent the development of spelling problems, early identification and intervention may provide a solution. Research on the precursors of spelling difficulties is necessary to make early identification possible.

Previous research with typically developing children indicates that letter knowledge, phonological awareness, working memory, and rapid naming are precursors of early spelling. This is shown in Table 1. Letter knowledge is one of the most important precursors of the development of spelling knowledge (Caravolas, Hulme, & Snowling, 2001; Furnes & Samuelsson, 2010; Lervåg & Hulme, 2010; Muter, Hulme, Snowling, & Taylor, 1998; Ouellette & Sénéchal, 2008), because it is frequently found in various studies. This is not surprising, because spelling in an alphabetical language requires the knowledge of all graphemes (i.e., letters or letter clusters) that represent the phonemes of the language.

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Table 1
Overview of the kindergarten precursors of spelling in typically developing children.

Study	Task/precursors	Factor	R^2
Bradley and Bryant (1983)	Sound categorization	Phonological awareness	.06–.08
Stage and Wagner (1992)	Sound categorization	Phonological awareness	
	Letter span	Working memory	
Muter et al. (1998)	IQ	Intelligence	.14–.18
	Phoneme identification + phoneme deletion	Phonological awareness	.16–.36
	Letter naming	Letter knowledge	.19–.30
Caravolas et al. (2001)	Phoneme isolation	Phonological awareness	
	Letter-name and letter-sound knowledge	Letter knowledge	
	Phonological spelling	Spelling	
	Word reading	Reading	
Ouellette and Sénéchal (2008)	Letter-name and letter-sound knowledge	Letter knowledge	.37–.44
	Isolating and comparing phonemic segments, elision, blending words	Phonological awareness	.36–.41
	Visual recognition of legal characters, visual recognition of permissible sequences within words	Orthographic awareness	.08–.19
	Comprehension of grammatical morphemes	Morphology	.11–.18
Furnes and Samuelsson (2010)	Syllable and phoneme blending, word elision, syllable and phoneme elision, sound matching, rhyme and final phoneme matching, phoneme identity training test	Phonological awareness	
	Receptive letter knowledge	Letter knowledge	
	Rapid naming of objects and colours	Rapid naming	
Lervåg and Hulme (2010)	Rapid naming of objects and colours	Rapid naming	
	Phoneme isolation, phoneme deletion	Phonological awareness	
	Letter naming	Letter knowledge	
	Verbal short-term memory	Working memory	

Phonological awareness is a second major precursor of spelling of typically developing children, because it is frequently found in different studies (Bradley & Bryant, 1983; Caravolas et al., 2001; Furnes & Samuelsson, 2010; Lervåg & Hulme, 2010; Muter et al., 1998; Ouellette & Sénéchal, 2008; Stage & Wagner, 1992). Phonological awareness is a broadly defined concept and the reviewed studies (see Table 1) reveal that a large number of different tasks have been used to measure phonological awareness. We define phonological awareness as the ability to segment words into their phonemes, because this phoneme segmentation is a prerequisite for spelling (Bosman, 2004). To be able to spell, one has to divide a word into its phonemes and have to connect each phoneme to its corresponding graphemes, before the words can be written down.

Working memory is a third precursor of spelling of typically developing children (Lervåg & Hulme, 2010; Stage & Wagner, 1992). Working memory is considered to include both temporary storage and processing of information. The relatively heavy demand that spelling tasks put on working memory processes might be an explanation for the predictive value of working memory (Lervåg & Hulme, 2010). To be able to spell, one has to keep track of the coupling of phonemes to graphemes in the right order. If this process does not proceed properly, spelling may be hampered.

A fourth precursor of spelling of typically developing children is rapid naming (Furnes & Samuelsson, 2010; Lervåg & Hulme, 2010). Rapid naming involves the retrieval of lexical phonological representations from long-term memory (Ramus & Szenkovits, 2008). To spell a word, lexical phonological information has to be retrieved from memory.

Not all precursors of spelling of typically developing children predict spelling of children with SLI. Vandewalle, Boets, Ghesquière, and Zink (2010) investigated the precursors of spelling of children with SLI at the end of first grade. Letter knowledge, phonological awareness (rhyme production, end rhyme identity, first sound identity task, and end sound identity task), and verbal short-term memory in kindergarten did not predict spelling performance very well at the end of first grade. Rapid, automatized naming in kindergarten, however, was strongly correlated with spelling in first grade. This shows that what is predictive for typically developing children, may not be the case for children with SLI. It is, therefore, warranted to investigate the precursors of early spelling of children with SLI.

Although letter knowledge, phonological awareness, working memory, and rapid naming predicted spelling of typically developing children, the predictive value of these skills is generally limited to the first year of formal spelling instruction. Caravolas et al. (2001) found that during the first one and a half year of education, spelling was predicted by letter knowledge and phonological awareness, whereas letter knowledge and phonological awareness had no predictive value for spelling skills when children were in second grade. Lervåg and Hulme (2010) reported similar results: rapid naming, phonological awareness, letter knowledge, and short-term memory predicted early spelling skills, but only early spelling skills predicted further growth in spelling skills.

Because the precursors of spelling in children with SLI are not yet clear, we used a large battery of possible precursors for spelling difficulties to investigate this issue. Because children with SLI generally have poor linguistic, phonological, and memory skills, we also took into account orthographic skills. Orthographic awareness is the ability to visually recognize legal symbols and patterns within printed words (Mather & Goldstein, 2001). By measuring phonological skills in kindergarten, we made sure that these skills were not yet influenced by spelling abilities. The skills that are precursors of spelling according to previous studies, most often only partially predict spelling, and the predictive value is limited to a short period of time.

Because the precursors of spelling of children with SLI are still unclear, in our study, we used a longitudinal design with a large number of precursors. We followed children from the second year of kindergarten until the end of first grade. We took into account linguistic, phonological, orthographic, letter knowledge, memory skills, and nonverbal reasoning, but also spelling level at an earlier point in time.

We chose these precursors, because children with SLI are known to have problems with linguistic skills, like for example articulation, and with phonological skills, like phoneme identification (Bishop, 1997). Vandewalle et al. (2010) showed that children with SLI could also have problems with letter knowledge. Children with SLI may differ from typically developing children with respect to memory skills, like verbal sequential memory (van Weerdenburg, Verhoeven, & van Balkom, 2006) and nonverbal-cognitive abilities (Ellis Weismer, Evans, & Hesketh, 1999). Children with SLI have lower scores on these precursor skills than typically developing children. We took into account spelling level, because Lervåg and Hulme (2010) showed that spelling was best predicted by spelling level at an earlier point in time. Orthographic knowledge acquired during kindergarten is a new variable that has not been tested before in this group. However, previous research showed that orthographic knowledge predicted spelling of typically developing children (Ouellette & Sénéchal, 2008). Therefore, this variable was also included as precursor in this study.

The aim of the present study was twofold. The first goal was to assess the discriminatory power of each of the before mentioned tests, that is, to what extent can each test reliably distinguish between good and poor spellers with SLI. The second goal was to assess which of the precursors, a set of related tests, best predicts spelling difficulties in children with SLI.

2. Method

2.1. Participants

This study was conducted with children who attended special-education schools for children with SLI in the Netherlands. Three different schools with second-year kindergartners were invited to participate in order to obtain a sufficient number of children.[1] Deaf and hearing-impaired children were excluded from the study. Because of illness or absence, 20 children were excluded.[2] The final sample consisted of 58 kindergartners (21 girls, 37 boys) between the ages of 64 and 90 months ($M = 75.5$, $SD = 6.0$). The over representation of boys is typical for children with SLI (Robinson, 1991). All participating children spoke Dutch. Most children had Dutch as their native language. However, there were some children with a mother tongue different than Dutch; six children spoke Turkisch at home, one child spoke Moroccan at home, one child spoke Arabic at home, and five children spoke both Dutch and another language at home.

2.2. Materials

This section covers the different tests that were used to measure linguistic, phonological, orthographic, letter knowledge, and memory skills, and nonverbal reasoning and spelling skills.

2.2.1. Linguistic skills

Linguistic skills were assessed on three different aspects. The first one was *Linearity of spoken language awareness*, measured by the subtest 'Laatste en eerste woord horen' [Hearing the last and first word] from Taal voor Kleuters [Language for infants] (van Kuyk, 1996). The child was presented with four drawings and had to point to the one that corresponded with the first or last word spoken by the experimenter. The score equaled the number of correct responses. The lowest possible score was 0 and the highest possible score was 8.

The second one was *Articulation skills*, measured by the 'Utrechts Articulatie Onderzoek, verkorte vorm 5;0–6;0 jarigen' [Utrecht's articulation research, short version for children of 5;0–6;0 years old] (Peddemors-Boon, van der Meulen, & de Vries, 1977). The child received a booklet and had to name the image on each page. Examples of items were *'fles' [bottle]* in which the phoneme cluster /*fl*/ had to be pronounced correctly and *'heks' [witch]* in which the phoneme cluster /*ks*/ had to be pronounced correctly. Each of the 44 items contained a consonant or a combination of consonants that had to be pronounced correctly. Each consonant or combination of consonants appears in pairs across successive items. The reliability of this test was .87 (Peddemors-Boon et al., 1977). The score equaled the number of correctly pronounced consonants or combinations of consonants. The lowest possible score was 0 and the highest possible score was 44.

The third one was *Rapid naming* by means of the subtests color naming, number naming, and picture naming of the test 'Serieel Benoemen en Woorden Lezen' [Serial Naming and Word Reading] (van den Bos, 2004). The child had to name colors, numbers, and pictures as quickly and as accurately as possible. The card with colors contained squares in the colors black, yellow, red, green, and blue. The card with numbers contained the numbers 2, 4, 8, 5, and 9. The card with pictures contained pictures of a tree, duck, chair, pair of scissors, and a bicycle. Each card consisted of five rows with ten items each. The five

[1] No differences exist between the test scores of children from the different schools, except for the tests: *awareness of written language*, *phoneme spelling*, and *word spelling*. Children of school A had lower scores on *awareness of written language* than children of school B and C ($p < .01$). Children of school B scored lower on *word spelling* than children of school A and C, respectively ($p < .01$).

[2] The scores of the group of children that dropped out of the study did not differ significantly from the scores of the remaining group on the tasks that were administered at kindergarten, but they were significantly younger ($M = 71.5$) than the group that participated in the study ($M = 75.6$) ($p < .01$).

different items on each card were all repeated ten times in a random order. The reliability of this test for children at the age of 7 is .80 for the naming of colors, .84 for the naming of numbers, and .78 for the naming of pictures (van den Bos, 2004). The experimenter recorded the time it took the child to name the colors, numbers, and pictures. A limited number of naming errors are accepted, children with more than 15 errors on color naming, 20 errors on number naming, or 4 errors on picture naming, were removed from the analysis of the particular task (more than 3 *SD* above the mean).

2.2.2. Phonological skills

Phonological skills were assessed on two different aspects: *Sound awareness and rhyming skills*, measured by the subtest 'Klank en rijm' [Sound and rhyme] from Taal voor Kleuters [Language for infants] (van Kuyk, 1996). The experimenter named the four drawings for each item and gave the instruction. On the sound-awareness items, the child had to point to the drawing with a particular first sound, or the two drawings with a similar first sound. On the rhyme items, the child had to point to the drawing that rhymed with a particular word, the drawing that did not rhyme, or the drawings that rhymed with each other. The score equaled the number of correct items. The test consisted of four sound-awareness items and four rhyme items; the lowest possible score was 0 and the highest possible score was 8.

Auditory synthesis was measured by two tests. The first one was *Auditory synthesis I*, measured by the subtest 'Auditieve synthese' [Auditory synthesis] from Taal voor Kleuters [Language for infants] (van Kuyk, 1996). The child had to point to the drawing corresponding to the word that was named in isolated sounds. For instance, the instruction of the experimenter was: 'Point at the */s/-/o/-/k/ [sock]*'. The child had to choose the correct drawing out of four drawings. The score equaled the number of correctly synthesized items. The lowest possible score was 0 and the highest possible score was 8.

The second test was *Auditory synthesis II*, a modification on *Auditory synthesis I*. The child had to point to the drawing corresponding to the word that was sounded out by the experimenter such that each phoneme was pronounced extendedly and smoothly turned into the next. For instance, the instruction of the experimenter was: 'Point at the *ssssooookkk [sock]*'. The items were the same as in *Auditory synthesis I*. The score equaled the number of correct items. The lowest possible score was 0 and the highest possible score was 8.

2.2.3. Orthographic skills

Orthographic skills were assessed on three different aspects. The first one was the *Awareness of written language*, which was measured by the subtest 'Schriftoriëntatie' [Awareness of written language] from Taal voor Kleuters [Language for infants] (van Kuyk, 1996). The task contained eight items. One item in which the child had to choose the letter out of a number, letter, word, and sentence; two items that consisted of a sentence in which the child had to underscore a particular part of the sentence; one item that consisted of a word, in which the child had to underline the grapheme in the middle; three items that consisted of four drawings, in which the child had to choose the drawings that were related to written language (for instance, choosing drawings containing words, like a news paper, a book or a letter); and one item that consisted of twelve graphemes in which the child had to underline all graphemes that were the same as the first grapheme. The score equaled the number of correct items. The lowest possible score was 0 and the highest possible score was 8.

The second one was *Letter-symbol distinction*, measured by a computer task. A stimulus appeared on the computer screen, after which the child had to decide whether the stimulus contained only real letters or had letters and a symbol. The child responded by pushing a green or red key on a box. If the stimulus contained only real letters, the children had to push the green button. If there was a symbol that was not a letter in the string, the children had to push the red button. The score equaled the number of correct items. The lowest possible score was 0 and the highest possible score was 60.

In this task, 60 stimuli were used: 30 letter strings and 30 strings with both letters and a symbol. Each string contained between two and four signs. The letters in a particular string were all vowels or consonants. Because of the large amount of stimuli, the stimuli were distributed over two lists. Prior to the test items, there were five practice items for each list. These items were used to provide the children feedback on their responses. When a child did not understand the instruction, it was repeated, until the child understood the instruction. Half of the children started with the first list and the other half with the second list. Appendix A presents the stimuli used in the letter-symbol distinction task.

The stimuli were presented in lowercase letters using 40 point, Arial Black font. Each trial started with a fixation point in the center of the screen (a plus-sign, 18 point, Arial bold) that was presented for 1000 ms prior to the presentation of the stimulus. The stimuli then appeared and remained on the screen until the child responded by pushing the green or red button. The keys on the button box were arranged so that the green key appeared on the right for right-handed children and the left for left-handed children. The software program E-prime controlled for stimulus presentation, stimulus randomization, response latency registration, and data recording.

The third assessment of orthographic knowledge was *Wordiness judgement*. It was measured by a task in which each item contained three stimuli; a pseudoword, a nonword, and a string of letters with a symbol each containing two to four characters. Pseudowords were non-existing words that consist of an orthographically legal letter string, for example *'nit'* or '*biek*'. The pseudowords were matched with existing words in their bigram frequencies. Nonwords consisted of orthographically illegal letter strings, for example *'hvk'* or '*oaau*'. Pseudowords are pronounceable and nonwords are not. An example of a string of letters with a symbol is '*%oe*' or *'hj#*'. The children had to point to the stimulus that looked most like a real word.

The stimuli were presented on paper in lowercase using 40 point, Arial Black font. Each item was presented on a separate piece of paper. There were fifteen different item orders. However, the order of the stimuli (pseudoword, nonword, string of

letters with a symbol) within each item remained the same in each of the different item orders. Prior to the task, there were four practice items. These items were used to provide feedback to the children. Appendix B presents the stimuli used in this task. The score was computed by multiplying the number of times the child pointed to a pseudoword by 3, multiplying the number of nonwords by 2, and the number of strings of letters with a symbol by 1. We have chosen for this scoring system because pseudowords are strings that have a legal ordering of letters, but do not have meaning. Nonwords are strings with illegal ordering of letters and no meaning. Letter strings contain symbols and additional illegal elements. The lowest possible score was 30 and the highest possible score was 90.

2.2.4. Letter knowledge

Letter knowledge was assessed with both *Letter reading* and *Phoneme spelling*. The first one, *Letter reading*, was measured with a computer task. A letter appeared on the computer screen, after which the child had to provide the letter sound. Responses were recorded by a voice key. The stimuli were presented in lowercase letters of Arial Black font, point size 72. The 'a' and the 'aa' were also presented in lowercase letters of Berlin Sans FB Demi font like '**ɑ**' and '**ɑɑ**', point size 72, because the way in which these graphemes were presented to the child depends on the educational method. This task contained 36 stimuli: consonants, vowels, and digraphs. After 18 stimuli there was a pause and the child was able to decide when he or she was ready to start with the second block of stimuli. There were two different lists with the same stimuli, but in different order. List 1 started with Block 1 followed by Block 2; the second list started with Block 2 followed by Block 1. Half of the children started with List 1 and the other half started with List 2. Prior to the task proper, children were presented with five practice items. These practice items were digits, because all graphemes were included in the real task, so we could not include graphemes as practice items. Appendix C presents the graphemes used in the letter-reading tasks. The score equaled the number of correctly named graphemes. Because all 36 graphemes appeared twice, the lowest possible score was 0 and the highest possible score was 72. Sometimes a child made a noise that set off the voice key inadvertently and, caused the grapheme to disappear from the screen before the child was able to name the grapheme. To make sure that all children were able to name each grapheme, all graphemes were presented twice.

The letter was located at a fixed point in the center of the screen using 72 point, Arial Black font. Each trial started with a fixation point in the center of the screen (a plus-sign, 46 point, Arial) that was presented for 750 ms prior to the presentation of the stimulus. After the fixation point, there was a delay of 150 ms before the letter was presented at a fixed point in the middle of the screen. The stimuli then appeared and remained on the screen until the child named the letter. Naming times were registered with a voice key. The voice key was a microphone that registered the time between the appearance of the stimulus on the screen and the first noise that was made. The experimenter evaluated and recorded correctness of the response by pushing a key on the button box, which initiated the next item. The software program E-prime controlled stimulus presentation, stimulus randomization, response latency registration, and data recording.

The second letter-knowledge task was *Phoneme spelling*, which required the child to write each grapheme that corresponds to the phoneme named by the experimenter. The experimenter named the isolated phoneme and mentioned a word that contained the target phoneme. Children did not have to segment the word, because the experimenter also named the target phoneme isolated from the word. They just had to write down isolated graphemes. Appendix D presents the graphemes used in this test. In the test for Letter reading, we used 36 graphemes because the '**a**' and the '**aa**' were also presented as '**ɑ**' and '**ɑɑ**'. In school books, both graphic representations of the same phoneme are used. Therefore, each representation was presented in the test for Letter reading. Consequently, for Phoneme spelling, we only had 34 graphemes, because the '**a**' and the '**aa**' were only presented once. The score equaled the number of correctly written graphemes. The lowest possible score was 0 and the highest possible score was 34.

2.2.5. Memory skills

Memory skills were assessed on three different aspects. The first one was an indication of *Long-term memory* measured by the '12-woordentest' [12-words test], an adaptation of Braams and Partners of the '15-woordentest' [15-words test] developed by Kalverboer and Deelman (1964). Three single words were removed from the original test; the remaining twelve consisted of six pairs, words related by category (for instance, tulip and rose). The child had to remember words that were named by the experimenter. Appendix E presents the words used in this test. The task started with the experimenter naming all twelve words. The child was asked to repeat all the words he or she remembered. After the first trial, the second trial started with the experimenter naming all twelve words once more and again the child was asked to repeat the words he or she remembered. The same procedure was repeated in a third, fourth, and fifth trial. After 20 min, the recall trial was presented. Without the experimenter repeating the words, the child was asked to name all the words he or she still remembered from the first five trials. The score equaled the number of words the child named in the recall session, with the lowest possible score being 0 and the highest possible score 12.

The second assessment of memory skills was *Short-term memory*, which was measured by the subtest 'Digit recall' from the Dutch version of the Wechsler Intelligence Scale for Children-III (Wechsler, 2005), which required the child to repeat a string of digits spoken by the experimenter. For example, the experimenter named the string '4 6 9′, after which the child had to repeat this string by saying '4 6 9′. The first two strings contained three digits, the following two strings contained four digits to a maximum of nine digits. The test was terminated when a child failed on two consecutive items with the same number of digits. The score was the number of correctly named strings. The lowest possible score was 0 and the highest possible score was 18.

The third assessment of memory skills was *Working memory* measured by the subtest 'Backward digit recall' of the Dutch version of the Wechsler Intelligence Scale for Children-III (Wechsler, 2005). The procedure for 'backward digit recall' was almost the same as for 'digit recall'. But, in contrast to 'digit recall', the child had to repeat the string backwards. For instance, the experimenter named the string '8 3 5′, after which the child had to say '5 3 8′. The construction of the strings was the same, but the maximum string length was eight digits. Prior to the 'backward digit recall', there were two practice items. The lowest possible score was 0 and the highest possible score was 16. The reliability of 'digit recall' and 'backward digit recall' was .79 for children at the age of six years and six months old (Wechsler, 2005).

2.2.6. Nonverbal reasoning

Nonverbal reasoning was assessed by *Nonverbal-deductive reasoning* measured by the 'RAVEN's Standard Progressive Matrices' (Raven, 2003). The test contains 60 items in five sets. Each item included a figure with a missing piece. The child had to choose the correct piece out of six or eight possible pieces. Appendix F presents an example of the RAVEN (Raven, Raven, & Court, 1998). The score equaled the number of correctly identified pieces. The lowest possible score was 0 and the highest possible score was 60.

2.2.7. Spelling skills

Spelling skills were measured by the 'Schaal Vorderingen in Spellingvaardigheid 1 Dictee 2′ [Scale Progression in Spelling Abilities 1 Dictation 2] (van den Bosch, Gillijns, Krom, & Moelands, 1991). The child had to write monosyllabic words that had consistent phoneme-to-graphemes relations. The monosyllable words had a 'vc' (vowel-consonant), 'cvc', 'ccv', 'ccvc', or 'cvcc' structure. The score equaled the number of correctly spelled words. For each word, the number of correctly written graphemes was computed and divided by the number of graphemes within that word. Because the test contained 22 items, the lowest possible score was 0 and the highest possible score was 22.

2.3. Procedure

Letters were sent to the school administration of special-education schools for children with SLI, inviting them to participate in the study. Reply forms were attached with the letter. A few weeks later, the schools were also contacted by phone.

The first author administered the tests individually with the help of research assistants. All individual test sessions took place in a separate quiet room in the school. Three tests, nonverbal-deductive reasoning, letter and word spelling were administered group wise. Table 2 presents the time table for each test that was administered.

Table 2
Overview of the different tests at each moment of measurement.

	Kindergarten	Grade 1		
	February 2008	October 2008	January 2009	May 2009
Linguistic skills				
Linearity of spoken language awareness	x			
Articulation		x		
Rapid naming			x	
Phonological skills				
Sound awareness and rhyming	x			
Auditory synthesis I	x			
Auditory synthesis II	x			
Orthographic skills				
Awareness of written language	x			
Letter-symbol distinction	x			
Wordiness judgement	x			
Letter knowledge				
Letter reading	x			
Phoneme spelling		x		
Memory skills				
Long-term memory		x		
Short-term memory		x		
Working memory		x		
Nonverbal reasoning				
Nonverbal-deductive reasoning			x	
Spelling				
Word spelling			x	x

2.4. Data analysis

To investigate the discriminatory power of all variables, we first calculated percentages of valid and false positive and negative outcomes. Secondly, we computed the sensitivity and specificity indexes. Thirdly, we performed an ANOVA analysis. Finally, a logistic regression analysis was performed to examine which combination of precursors discriminated best between poor and typical spellers.

We defined the 25% children that had the lowest scores on the precursors to be at risk for spelling difficulties. The 25% lowest scoring children on spelling were indicated as poor spellers. We chose the 25% lowest scoring children as scoring below standard, because this criterion is also used in Dutch standardized tests.

Before the letter-symbol distinction and letter-reading data were analyzed, the following responses were removed from the data set: naming errors, errors due to voice-key failure, extremely short responses (less than 250 ms), and extremely long responses (more than 3 *SD* above the participants' mean). For the analyses of the rapid naming, letter-symbol distinction, and letter-reading tests, reaction times were assessed so that shorter times indicated better performance.

3. Results

3.1. Descriptive statistics

Mean and standard deviation values on the different tests are shown in Table 3.

3.2. Predicting early spelling difficulties

The percentages of valid and false positive and negative outcomes were calculated, the sensitivity and specificity indexes were computed, ANOVA analyses were performed, and a logistic regression analysis was performed to examine the prediction of spelling difficulties.

3.2.1. Percentages of valid and false positive and negative outcomes

Valid positive rate refers to the number of children who were predicted to have spelling difficulties that turned out to actually have spelling difficulties. False positive rate refers to the number of children who were predicted to have spelling

Table 3
Overview of the mean and standard deviation values on the precursor tests.

	N	Highest possible score	25th percentile	*M*	*SD*
Linguistic skills					
Linearity of spoken language awareness	51	8	4	5.8	2.1
Articulation	58	44	34	36.4	7.1
Rapid naming colors	53		170.0	184.6	21.0
Rapid naming numbers	55		132.0	146.0	28.7
Rapid naming pictures	56		45.6	55.3	23.7
Phonological skills					
Sound awareness and rhyming	51	8	2	4.3	2.0
Auditory synthesis I	51	8	4	5.7	1.9
Auditory synthesis II	25	8	6	7.0	1.4
Orthographic skills					
Awareness of written language	51	8	3	5.0	2.1
Letter-symbol distinction – score	52	60	45	49.8	8.4
Letter-symbol distinction – reaction time	51		3647.2	1879.3	636.8
Wordiness judgement	54	90	63	69.7	8.3
Memory skills					
Long-term memory	58	12	0	3.0	2.5
Short-term memory	58	18	3	4.5	1.2
Working memory	58	16	0	1.1	1.2
Nonverbal reasoning					
Nonverbal-deductive reasoning	58	60	14	20.7	8.2
Letter reading					
Score	52	72	12	22.9	13.7
Reaction time	47		1424.3	1409.2	421.4
Phoneme spelling					
Phoneme spelling	58	34	12	16.6	6.5
Word spelling					
Middle of first grade	58	22	5.8	12.7	6.6
End of first grade	58	22	14.5	16.8	5.3

Table 4
Overview of the percentages valid and false positives and negatives.

Precursor	Valid positive	False positive	Valid negative	False negative	Sensitivity	Specificity
Linguistic skills						
Linearity of spoken language awareness	13.7	13.7	66.7	5.9	.70	.83
Articulation	6.9	19.0	56.9	17.2	.29	.75
Rapid naming colors	11.3	15.1	60.4	13.2	.46	.80
Rapid naming numbers	5.5	18.2	58.2	18.2	.23	.76
Rapid naming pictures	10.7	14.3	62.5	12.5	.46	.81
Phonological skills						
Sound awareness and rhyming	11.8	19.6	60.8	7.8	.60	.76
Auditory synthesis I	9.8	15.7	61.7	9.8	.50	.80
Auditory synthesis II	12.0	20.0	48.0	20.0	.38	.71
Orthographic skills						
Awareness of written language	3.9	23.5	56.9	15.7	.20	.71
Letter-symbol distinction – score	7.7	19.2	55.8	17.3	.31	.74
Letter-symbol distinction – reaction time	8.5	14.9	61.7	14.9	.36	.81
Wordiness judgement	12.7	12.7	63.6	10.9	.54	.83
Memory skills						
Long-term memory	10.3	22.4	53.4	13.8	.43	.70
Short-term memory	5.2	10.3	65.5	19.0	.21	.86
Working memory	22.4	25.9	50.0	1.7	.93	.66
Nonverbal reasoning						
Nonverbal-deductive reasoning	8.6	20.7	55.2	15.5	.36	.73
Letter reading						
Score	11.5	13.5	61.5	13.5	.46	.82
Reaction time	8.3	16.7	60.4	14.6	.15	.78
Phoneme spelling						
Phoneme spelling	19.0	6.9	69.0	5.2	.79	.91
Word spelling						
Middle of first grade	18.5	7.4	74.1	0.0	1.00	.91

difficulties that turned out to be typical spellers. Valid negative rate refers to the number of children who were predicted to become a typical speller and turned out to be typical spellers. False negative rate refers to the number of children that were predicted to become a typical speller, but turned out to have spelling difficulties. The percentages of valid and false positive and negative rates were computed for all precursors. These percentages are shown in Table 4. Phoneme spelling at the beginning of first grade and word spelling at the middle of first grade had the highest valid positive and negative rates, compared to the false positive and negative rates. This means that phoneme spelling at the beginning of first grade and word spelling at the middle of first grade best discriminated between children with and without spelling difficulties at the end of first grade.

3.2.2. Sensitivity and specificity indexes

The sensitivity index refers to the accuracy of a precursor to correctly identify children with spelling difficulties. The sensitivity index was computed for each precursor, by dividing the number of valid positives by the sum of the number of valid positives and false negatives. The specificity of a precursor refers to correctly identify children who do *not* have spelling difficulties. The specificity index was computed for each precursor by dividing the number of valid negatives by the sum of the valid negatives and false positives. The results are shown in Table 4. These results confirm the fact that phoneme spelling at the beginning of first grade and word spelling at the middle of first grade were the precursors that best identified children with spelling difficulties and children without spelling difficulties.

3.2.3. ANOVA analysis

All precursors were transformed into standardized *z*-scores, and thereafter, sum scores were computed for linguistic, phonological, orthographic, letter knowledge, memory, and nonverbal-reasoning skills. Word spelling at the middle of first grade was removed from these analyses for two reasons. The first reason was because of its strong correlation with letter knowledge. The second reason was because otherwise there would be circularity, because word spelling would predict word spelling. The 25% best and 25% poorest spellers at the end of first grade were selected. ANOVA analyses indicated that poor spellers at the end of first grade already had low scores on the precursor variables in kindergarten and vice versa. This is true for all precursors: linguistic skills, $F(1,31) = 21.19$, $p < .001$; phonological skills, $F(1,26) = 17.03$, $p < .001$; orthographic skills, $F(1,30) = 8.31$, $p < .01$; memory skills, $F(1,31) = 19.60$, $p < .001$; nonverbal-reasoning skills, $F(1,31) = 4.22$, $p < .05$; and letter knowledge skills, $F(1,31) = 40.94$, $p < .001$.

3.2.4. Logistic regression analysis

All sum scores were submitted into a stepwise logistic regression analysis to examine which combination of precursors discriminated best between children with spelling difficulties and children with a typical spelling development. The results showed that based on a model with only spelling level at the end of first grade, 50% of the children were classified into the correct category. However, when letter knowledge was included into the model, 85.7% of the children were classified correctly. Only letter knowledge had a unique discriminative value, B = −3.47, SE = 1.31, $p < .01$.

4. Discussion

This study was designed to investigate the main precursors of spelling difficulties for first grade children with SLI. A large number of precursors were used to predict spelling skill, namely, linguistic, phonological, orthographic, letter knowledge, memory skills, and nonverbal reasoning. Apart from these precursors, spelling level at an earlier point in time was taken into account as a precursor of spelling difficulties.

Calculation of the valid positive, valid negative, false positive, and false negative rates, showed that phoneme spelling at the beginning of first grade and word spelling at the middle of first grade best discriminated between typical spellers and poor spellers. The sensitivity index showed that on the basis of word spelling at the middle of first grade, children with spelling difficulties at the end of first grade could be identified 100% correctly. The sensitivity index showed that both phoneme spelling at the beginning of first grade and word spelling at the end of first grade were rather accurate precursors to correctly identify children who do *not* have spelling difficulties (91% accuracy). The results of the logistic regression analysis showed that only letter knowledge has unique discriminative value.

To summarize, kindergarten precursors do have some discriminative value for the prediction of spelling difficulties. However, the only precursor that really has a unique discriminative value, is letter knowledge. Spelling difficulties can be best predicted by spelling level at an earlier point in time. We take these outcomes as a signature of autocatalytic processes regarding the acquisition of spelling. Without intervention, poor spellers at the middle of first grade generally remain poor spellers at the end of first grade, and good spellers at the middle of first grade remain good spellers at the end of first grade. These results are in line with Caravolas et al. (2001) and Lervåg and Hulme (2010), they also concluded that spelling was best predicted by spelling at an earlier point in time.

4.1. Implications for future research

The results of the present study indicated that the predictive value of kindergarten precursors, like among others, letter knowledge, phonological awareness, working memory, and rapid naming is negligible compared to the predictive value of spelling skill itself. Consequently, it is important that future research will focus on the development of spelling skills itself instead of focusing on precursors that have scarcely any predictive value.

Appendix A. Letter-symbol distinction

Practice items

btg	**znt**
wzk	**pkl**
aei	**ioa**
#gh	**^ht**
nm?	**tr=**

Test items

mvn	**m!n**
lzp	**l#p**
fnh	**fn?**
bgm	**?gm**
dbk	**d^k**
oea	**oe}**
lv	**^eu**
ooee	**oo∼**
blt	**b+t**
dws	**d(s**
vts	**v∼s**
hjr	**hj#**
oeee	**@ee**
rwz	**rw***
knz	**kn?**
hvk	**h\k**
aoe	**=ae**
oaau	**oaa-**

euu	**Su**
oij	**<ij**
ioe	**%oe**
ieoo	**ie%**
oau	**>au**
oou	***ou**
wz	**)z**
pnw	**pn>**
iui	**/ui**
uuu	**uu=**
uuei	**{ei**
brt	**+rt**

Appendix B. Wordiness judgement

Practice items

zek	→	☼
♡	**cccc**	**hon**
dddd	**rim**	€
♫	**re**	**xx**

Test items

Pseudowords	Nonwords	String with symbols
nem	**mvn**	**m!n**
roo	**hjr**	**hj#**
vot	**vts**	**v~s**
lop	**lzp**	**l#p**
duk	**dbk**	**d^k**
mas	**oea**	**oe}**
nit	**knz**	**kn?**
kal	**blt**	**b+t**
huk	**hvk**	**h\k**
zil	**aoe**	**=ae**
zeun	**oaau**	**oaa-**
sak	**euu**	**Su**
fij	**oij**	**<ij**
woe	**ioe**	**%oe**
muid	**ieoo**	**ie%**
hauk	**oau**	**>au**
aag	**oou**	***ou**
vour	**wz**	**)z**
wui	**pnw**	**pn>**
beg	**iui**	**/ui**
haap	**uuu**	**uu=**
len	**uuei**	**{ei**
mar	**brt**	**+rt**
weig	**bgm**	**gm?**
jaf	**fnh**	**fn?**
tief	**dws**	**d(s**
foo	**oeee**	**@ee**
beem	**ooee**	**oo~**
luus	**rwz**	**rw***
biek	**lv**	**^eu**

Appendix C. Letter reading

Practice items

1 2 3 4 5

Test items

a b d e f g h i j k l m n o p r s t u v w z
eu ou ui oe au ei ij ie
oo ee uu aa
'a' 'aa'

Appendix D. Phoneme spelling

Test items

b d f g h j k l m n p r s t v w z
a e i o u
aa ee oo uu
eu ui oe ie au ou ei ij

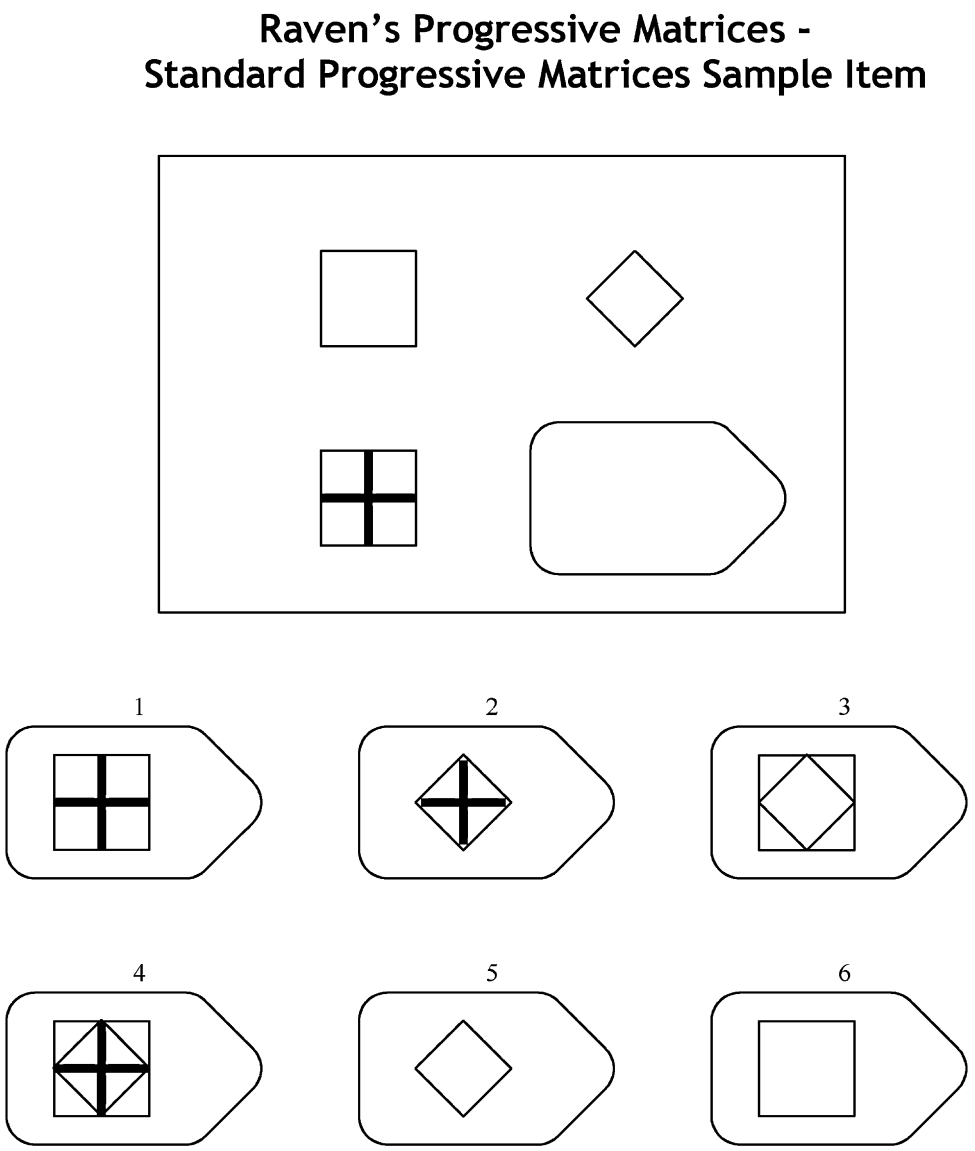
Write down the …	of …	
i	ik	[I]
k	kaas	[cheese]
m	mus	[sparrow]
aa	aap	[monkey]
n	nek	[neck]
r	rook	[vapor]
oo	oom	[uncle]
s	sok	[sock]
o	om	[around]
v	vis	[fish]
p	pak	[package]
e	en	[and]
t	teen	[toe]
ee	een	[one]
eu	reus	[giant]
b	boos	[angry]
ui	uil	[owl]
g	gaap	[yawn]
oe	koe	[cow]
d	doek	[cloth]
a	appel	[apple]
f	fiets	[bicycle]
l	lamp	[lamp]
h	huis	[house]
u	hut	[shed]
j	jas	[coat]
uu	muur	[wall]
z	zaag	[saw]
ie	knie	[knee]
w	wolf	[wolf]
au	auto	[car]
ou	hout	[wood]
ij	ijs	[ice]
ei	geit	[goat]

Appendix E. Long-term memory

Test items

peer *[pear]*,
koe *[cow]*,
bril *[glasses]*,
tulp *[tulip]*,
duim *[thumb]*,
stoel *[chair]*,
kers *[cherry]*,
leeuw *[lion]*,
hoed *[hat]*,
roos *[rose]*,
neus *[nose]*,
bed *[bed]*.

Appendix F. Nonverbal reasoning



Simulated item similar to those in the *Raven's Progressive Matrices – Standard Progressive Matrices*.

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