Predicting Progress in Early Literacy Skills

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Abstract

This study focused on predicting progress in letter reading, word reading, letter spelling, and word spelling in first grade for children with language and communication problems. A sample of 78 second-year kindergartners was followed until the end of first grade. With respect to predictors, linguistic, phonological, and orthographic skills were considered, but also reading and spelling level at an earlier point in time. To account for all possible kind of processes, three linear and one nonlinear regression models were used to accomplish the analyses. The best predictor of *level of* and *progress in* letter reading, word reading, letter spelling, and word spelling in first grade is the same skill at an earlier point in time. Although the pattern of progress in letter reading between kindergarten and first grade, letter spelling, and word spelling appears to be continuous, the pattern of progress in letter reading and word reading between the middle and the end of first grade is discontinuous. The results also indicate a Matthew effect for word reading only.

Reading and spelling are fundamental and important skills in society and education. Education is based on the ability to read and spell, so failure in these areas will have large consequences for learning. For decades, researchers have looked into predictors of reading and spelling, to make early identification of problems in these areas possible. The majority of prediction studies on reading and spelling followed children from kindergarten into first or second grade. The general pattern of this research resulted in a coherent set of predictors for reading, namely, letter knowledge, phonological awareness, and rapid naming. This is shown in Table 1. It presents an overview of studies that have investigated the main predictors of early reading in normally developing children. Although research on predicting spelling ability is much rarer (Nauclér, 2004), the general pattern of predictors of early spelling is similar to that of reading. Table 2 presents an overview of studies that have investigated the main predictors of early spelling in normally developing children, and the main predictors are again letter knowledge, phonological awareness, and working memory. The fact that letter knowledge is one of the best predictors of reading and spelling performance is not surprising. After all, reading and spelling in an alphabetical language requires the knowledge of all graphemes (i.e., letters or letter clusters) that represent the phonemes of the language.

Less obvious is the role of phonological awareness for the prediction of literacy skills. Phonological awareness refers to the ability to recognize, discriminate, and manipulate the sounds of the language (e.g., Anthony & Francis, 2005). Phonological awareness is a broadly defined concept and the reviewed studies reveal that a large number of different tasks has been used to measure phonological

awareness. Adams (1990) identified five levels of phonemic awareness in which tasks can be classified. At the most basic level, the child only has to have ear for the sounds of words. This level includes performing rhyming tasks. For example, the child might be asked to tell which of the three words does not rhyme: '*hat', 'cat', 'dog'*. At the second level, the child has to be able to compare and contrast the sounds of words in rhyming and alliteration tasks. For example, the child might be asked to tell which of three words begins with a different sound: '*dog'*, '*sun'*, and '*doll'*. At the third level, the child is familiar with the notion that words can be divided into phonemes, and knows how the phonemes sound in isolation. Examples of tasks are blending phonemes or syllable-splitting. For phoneme blending, the child has to listen to the sounds and put them together to form a word. For example, the instructor might say '*/c/-/a/-/t/'* and the child has to say '*cat'*. At the fourth level, the child has to be able to segment phonemes. For this task, the child has to say which sounds it hears in a particular word. For example, the instructor might say '*dog'*, and the child has to respond with '*/d/-/o/-/g/'*. At the final level, the child has to be able to manipulate phonemes, like adding, deleting or moving phonemes. For instance, a child might be asked to say '*monkey'* without the '*/k/*'. Skills at the phoneme level (third, fourth, and fifth level) are better predictors of reading than onset-rhyming skills (first and second level; e.g., Hulme et al., 2002).

Rapid naming is also a less obvious predictor and refers to the ability to retrieve phonological codes stored in long-term memory (Allor, 2002). The rapid-naming ability is measured by the amount of time a child needs to name stimuli, like digits, letters, colors or pictures. Rapid naming is associated with reading, since both skills require the child to learn arbitrary associations between symbols and sounds (Manis, Seidenberg, & Doi, 1999). Some other required abilities are also similar for rapid naming and reading, like visual-motor coordination, serial scanning of text, accessing word names and meanings rapidly from memory, and articulation.

Working memory appears to be one of the best predictors for spelling, and to a lower extent for reading. However, recent studies have shown that this aspect of cognition appears to add to the understanding of both reading and spelling skills. Working memory is considered to span both the storage and processing of information. To be able to read, one has to keep track of the coupling of letters to phonemes in the right order, that is, from left to right with respect to its graphemes and from first to last with respect to its phonemes. If this process does not proceed properly, reading and spelling may be hampered.

An important conclusion from the above is that the main predictors of early reading and spelling in normally developing children are all language-related skills: letter knowledge, phonological awareness, rapid naming, and working memory. Children who have deficits in this area are children with language and communication problems. These children are at risk for developing reading and spelling problems. In the Netherlands, these children are either attending a special-education school for language and

communication problems or are taking part in a special-remediation program within a regular-education school. Children at these special-education schools can have deficits in all kind of language and communication related domains (e.g., semantic, syntax, vocabulary, articulation). Children who are deaf or hearing impaired attend separate departments of these schools.

The present study focused on children at special-education schools for language and communication problems; deaf and hearing impaired children were excluded from the study. The group of children with language and communication problems is rather heterogeneous. Some, but not all children have Specific Language Impairment (SLI), which refers to a failure of normal language development despite the absence of a mental or physical handicap, hearing impairment, emotional disorder or environmental deprivation (Bishop, 1992; Leonard, 1998). Interestingly, however, not all children with SLI develop literacy problems (Van Weerdenburg, 2006). Approximately fifty percent of the children with SLI develop a normal reading level in first and second grade (Catts, Fey, Tomblin, & Zhang, 1993; Catts et al., 2002).

As said before, the main predictors of the level of early reading and spelling are letter knowledge, phonological awareness, rapid naming, and working memory. However, according to different studies, the predictive value of phonological awareness on word reading is only for a limited developmental period (De Jong & Van der Leij, 1999; Verhagen, Aarnoutse, & Van Leeuwe, 2008). De Jong and Van der Leij (1999) studied Dutch children from kindergarten through second grade. It appeared that the importance of phonological awareness for the acquisition of reading was limited to first grade. After first grade, phonological awareness did not have any effect on reading. Verhagen et al. (2008) also studied Dutch children from kindergarten though second grade. This study also showed the predictive value of phonological awareness to word reading at the end of first grade, but not at the end of second grade.

Not only is the predictive value of reading and spelling skill from language-related factors in Dutch-speaking children limited to a period of one or two years, the explained amount of variance hardly ever exceeds 25% for the best predictor, namely, letter knowledge. Moreover, research has shown that reading and spelling skills reveal a rather consistent pattern over time. Students with good reading and spelling skills in the lower grades are good readers and spellers in higher grades, and the ones who start out as poor readers and spellers usually remain poor readers and spellers (Stanovich, 1986; Verhoeven & Van Leeuwe, 2003). This phenomenon is known as the Matthew effect, the rich get richer and the poor are getting poorer.

These facts led to a somewhat different view on the issue of predicting reading and spelling. Rather than focusing on predicting reading and spelling level, we chose to investigate the predictive value of a wide range of kindergarten skills for reading and spelling progress. Stated differently, not the literacy skill at one moment in time, but the progress of that skill over time served as the focus of this study. We

are unaware of a study that investigated the more dynamic issue of literacy progress rather than the relative static skill of reading and spelling at one point in time.

Thus the focus of the present study is the predictive value of factors that explain reading and spelling progress in children with language and communication problems. To investigate the main predictors of *progress* in reading and spelling development in children with language and communication problems, second-year kindergartners were followed until the end of first grade. The present study had four measures to assess early literacy, namely, letter reading, word reading, letter spelling, and word spelling. Different tests for linguistic, phonological, and orthographic skills were used as possible predictors. Earlier research typically focused on both linguistic and phonological skills, whereas research on orthographic predictors of reading and spelling is rare. Children with language and communication problems usually are impaired in the domain of linguistic and phonological skills. Consequently, it might be interesting to study the influence of orthographic skills on the early literacy process for these children. In addition to these predictors, we also tested some general variables, such as intelligence and memory.

Before we focus on the predictors of *progress* in reading and spelling abilities, we will first investigate the predictors of the *level* in these abilities. This way we make sure that the main predictors we have chosen are actually predicting reading and spelling skills at certain points in time. Thus predictive values of various linguistic, phonological and orthographic skills at four points in time in addition to the predictive values of these skill over time will be studied. Because there is evidence from studies on children with SLI that revealed that reading level at a later point in time is best predicted by reading level at an earlier point in time, we chose to include reading and spelling skills as predictors in the regressing analyses (Botting, Simkin, & Conti-Ramsden, 2006; Catts et al., 2002; Van Weerdenburg, 2006).

To analyze the data, different kinds of regression techniques were used. To identify the main predictors of the *levels* of letter reading, word reading, letter spelling, and word spelling, two linear models were used to accomplish the analyses, namely, the linear model and the linear-interaction model. We also used one linear model that encloses the level of the same skill at an earlier point in time, namely, the pretest-posttest model. The letter reading, word reading, letter spelling, and word-spelling skills were used as criterion variables, whereas the possible predictors were used as independent variables.

To identify the main predictors of the *progress* in the early-literacy skills, the same models were used to accomplish the analyses, including the linear, linear interaction, and pretest-posttest model. However, to be sure of taken into account all possible kind of processes, we also used a nonlinear model to determine the main predictors of the *progress* in early literacy. The nonlinear cusp-catastrophe model was used, since it accounts for both continuous and discontinuous change of the criterion variable. This model encloses all three linear models that were used. The cusp-catastrophe model has been used in

Table 1. *Overview of the Predictors of Reading in Normally Developing Children.*

Study	*Task/predictors*	*Factor*	R^2
Bradley & Bryant (1983)	Sound categorization	Phonological awareness	.04 - .10
Blachman (1984)[1]	Rapid naming of colors and objects	Rapid naming	.03 - .37
	Syllable segmentation, rhyming, phoneme segmentation	Phonological awareness	.04 - .27
	Rapid naming of letters	Letter knowledge	.45
Wolf, Bally, & Morris (1986)	Rapid naming of letters, numbers, colors, and objects	Rapid naming	.03 - .44
Walsh, Price, & Gillingham (1988)	Letter naming	Letter knowledge	.64 - .79
Muter & Snowling (1998)	Phoneme deletion	Phonological awareness	.30
	Non-word repetition	Working memory	.28
	Letter naming	Letter knowledge	.24
O'Connor & Jenkins (1999)	Segmenting phonemes	Phonological awareness	
	Rapid naming of letters	Letter knowledge	
De Jong & Van der Leij (1999)	Rhyme categorization, first-sound categorization, last-sound categorization	Phonological awareness	
	Rapid naming of objects	Rapid naming	
	Word span, interference span, non-word repetition	Working memory	
Lonigan, Burgess, & Anthony (2000)	Rhyme and alliteration oddity, blending and elision of words, syllables, and phonemes	Phonological awareness	
	Letter naming	Letter knowledge	
Hammill, Mather, Allen, & Roberts (2002)	Sound deletion, rhyming sequences, sound blending	Phonological awareness	
	Rapid letter naming, rapid word naming	Rapid naming	
Kirby, Parrila, & Pfeiffer (2003)	Sound isolation, phoneme elision, blending onset and rime, blending phonemes	Phonological awareness	
	Rapid naming of colors and pictures	Rapid naming	

[1] Children in this study tended to cluster in the lower end of the average range of intellectual ability.

Parrila, Kirby, & McQuarrie (2004)	Sound isolation, blending phonemes	Phonological awareness	
	Rapid naming of colors	Rapid naming	
Blaiklock (2004)	Phoneme deletion	Phonological awareness	
	Letter naming	Letter knowledge	
Schatschneider, Fletcher, Francis, Carlson, &	Letter-name and letter-sound knowledge	Letter knowledge	.25 - .31
Floorman (2004)	Rapid naming of objects and letters	Rapid naming	.24 - .43
	Blending onset and rime, blending phonemes into words, blending phonemes into nonwords, first sound comparison, phoneme elision, phoneme segmentation, sound categorization	Phonological awareness	.25 - .29
Gijsel, Bosman, & Verhoeven (2006)	Letter naming	Letter knowledge	.28
	Rapid naming of colors	Rapid naming	.02
Jongejan, Verhoeven, & Siegel (2007)	Initial phoneme recognition, phoneme recognition and location, phoneme deletion and substitution, strip initial consonant, sound mimicry	Phonological awareness	.47
	Working memory for sentences	Working memory	.40
	Rapid naming of objects	Rapid naming	.30
	Syntactic error judgment task	Syntax	.13
Verhagen, Aarnoutse, & Van Leeuwe (2008)	Rapid naming of letters, digits, colors, and pictures	Naming speed	.09 - .34
	Phonological analyses of pseudowords, phonological synthesis of words and pseudowords	Phonological awareness	.06 - .36
Furnes & Samuelsson (2009)	Syllable and phoneme blending, word, syllable, and phoneme elision, isolating and comparing phonemic segments, rhyme and final sound, phoneme-identity training	Phonological awareness	
	Knowledge of print in an environmental context, letter recognition from names and sounds, concepts about print	Orthographic awareness	
	Rapid naming of objects and colors	Rapid naming	

Table 2. *Overview of the Predictors of Spelling in Normally Developing Children.*

Study	*Task/predictors*	*Factor*	R^2
Bradley & Bryant (1983)	Sound categorization	Phonological awareness	.06 - .08
Stage & Wagner (1992)	Sound categorization	Phonological awareness	
	Letter span	Working memory	
Caravolas, Hulme, & Snowling (2001)	Phoneme isolation	Phonological awareness	
	Letter-name and letter-sound knowledge	Letter knowledge	
	Phonological spelling	Spelling	
	Word reading	Reading	
Jongejan, Verhoeven, & Siegel (2007)	Initial phoneme recognition, phoneme recognition and location, phoneme deletion and substitution, strip initial consonant, sound mimicry	Phonological awareness	.51
	Working memory for sentences	Working memory	.36
Fraser & Conti-Ramsden (2008)	Phoneme deletion	Phonological awareness	
	Non-word recall	Working memory	
	Expressive vocabulary	Vocabulary	
Ouellette & 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

different fields, but it has never been used in the field of early word reading and spelling (for a detailed explanation see the Method section). The progress in letter reading, word reading, letter spelling, and word spelling was used as criterion variable, whereas the possible predictors were used as independent variables. The progress was defined by subtracting the level of a skill at an earlier point in time from the level of the same skill at a later point in time.

The first aim of this study was to answer the following questions concerning the *level* of early reading and spelling: (a) What are the best predictors of letter-reading level at the end of first grade? (b) What are the best predictors of word-reading level at the end of first grade? (c) What are the best predictors of letter-spelling level at the end of first grade? (d) What are the best predictors of word-spelling level at the end of first grade?

The second aim of this study was to answer the following questions concerning the *progress* in the development of early reading and spelling: (a) What are the best predictors of progress in letter reading? (b) What are the best predictors of progress in word reading? (c) What are the best predictors of progress in letter spelling? (d) What are the best predictors of progress in word spelling?

Method

Participants

Second-year kindergartners were recruited from nine classes of three special-education schools for children with language and communication problems. At the start of the study, the sample contained 78 kindergartners (24 girls, 54 boys) between the ages of 57 and 90 months (M = 74;5, SD = 6;5). At the end of the study, 13 children had dropped out, so the sample contained 65 kindergartners (22 girls, 43 boys) between 64 and 90 months (M = 75;6, SD = 5;8)[2]. An F-test revealed that participants of School A were significantly older than those of Schools B and C, $F(4, 93) = 3.17$, $p < .05$ (Bonferroni correction). Table 3 presents the number of kindergartners and the mean age in months at the start of the study. All children were at the level of second year of kindergarten.

Materials

This section covers the didactics and the different tests that were used to measure linguistic, phonological, orthographic, and memory skills, intelligence, and reading and spelling skills.

[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 = 68;9) than the group that participated in the study (M = 75;6) ($p < .01$).

Table 3. *Sex and Mean Age on the Different Schools.*

	N		*Age (months)*	
	boys	*girls*	*M*	*SD*
School A	21	9	77;0	5;11
School B	21	8	71;7	6;2
School C	12	7	73;7	6;5

Didactics. In kindergarten, teachers of all schools used a variety of different didactics for early literacy education. To improve the phonological awareness skills of children, they practiced with begin rhyme, end rhyme, and auditory synthesis and analysis of word parts and letter sounds (by clapping). The teachers also had different materials and exercises for children to practice with letters, like typing, claying, or flashing letters, writing letters in sand, using letter boxes, foam letters, or sandpaper. All three schools made use of letter-sound gestures to stimulate the letter knowledge of children. A letter-sound gesture is a gesture that is mostly connected to both the sound and the shape of the letter. Because of the letter-sound gestures, the children experienced auditory, visual, and kinesthetic support during the process of learning the letters. There are different methods for letter-sound gestures. To improve the writing skills of children, teachers made use of preparatory writing exercises. Teachers also spent time to read and discuss books. In first grade, teachers of all schools made use of different didactics for literacy education. All schools made use of *Nederlands met Gebaren [Sign Supported Dutch]*. *Nederlands met Gebaren* is the spoken Dutch language assisted with signs. The teachers spoke Dutch but emphasized the important words by using signs. The signs visualized the spoken language.

Linguistic skills. They were assessed on three different aspects. The first one was *Linearity of spoken language awareness*, which was measured by the subtest 'Laatste en eerste woord horen' [Hearing the last and first word] from Taal voor Kleuters (Van Kuyk, 1996 [Language for infants]). The child had to point to the drawing corresponding to the first or last word that was said by the experimenter. The child had to choose the correct drawing out of four drawings. The score equaled the number of correct items. The lowest possible score was zero and the highest possible score was eight.

The second one was *Articulation skills*, they were measured by the 'Utrechts Articulatie Onderzoek, verkorte vorm 5;0-6;0 jarigen' (Peddemors-Boon, van der Meulen, & de Vries, 1977 [Utrecht's articulation research, short version for children of 5;0-6;0 years old]). The child received a booklet and had to name the image on each page. Examples of items are *'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. Two successive items contained the same (combination of) consonants. The score equaled the number of correctly pronounced consonants or combinations of consonants. The lowest possible score was zero and the highest possible score was 44.

The third type of tasks were measuring *Rapid-naming abilities* by means of the subtests color naming, number naming, and picture naming of the test 'Serieel Benoemen en Woorden Lezen' (Van den Bos, 2004 [Serial Naming and Word Reading]). The child had to name colors, numbers, and pictures as quickly as possible. The card with colors contains compartments of the colors black, yellow, red, green, and blue. The card with numbers contains the numbers two, four, eight, five, and nine. The card with pictures contains pictures of a tree, duck, chair, pair of scissors, and a bicycle. Each card contains five rows with each ten items. The experimenter recorded the time it took for 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).

Phonological skills. They were assessed on two different aspects. The first one was *Sound awareness and rhyming skills*, measured by the subtest 'Klank en rijm' [Sound and rhyme] from Taal voor Kleuters (Van Kuyk, 1996 [Language for infants]). The experimenter named the drawings of 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 does not rhyme, or the drawings that rhymed with each other. The child had to choose the correct drawing(s) out of four drawings. The score equaled the number of correct items. The test contained four sound-awareness items and four rhyme items; thus, the lowest possible score was zero and the highest possible score was eight.

Auditory synthesis. It was measured by two tests. The first one was *Auditory synthesis I,* measured by the subtest 'Auditieve synthese' [Auditory synthesis] from Taal voor Kleuters (Van Kuyk, 1996 [Language for infants]). The child had to point to the drawing corresponding to the word that was named in separate 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 zero and the highest possible score was eight. 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 said in separate sounds, but now the sounds were pronounced long and they flew over in each other. 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 zero and the highest possible score was eight.

Orthographic skills. They 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 (Van Kuyk, 1996 [Language for infants]). 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 consist of a sentence in which the child had to underscore a particular part of the sentence; one item that consist of a word, in which the child had to underscore the grapheme in the middle; three items in which the child had to choose the drawings that were related to written language out of four drawings; and one item that consist of twelve graphemes in which the child had to underscore all graphemes that were the same as the first grapheme. The instructions were, respectively: underscore the letter, the beginning of the sentence, the final word, the letter in the middle, the two children that are reading, the two things you can read (two times), and all similar letters. The score equaled the number of correct items. The lowest possible score was zero and the highest possible score was eight.

The second one was *Letter-symbol distinction*, which was 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 also a symbol. The child responded on a button box by pushing a green or a red key. If the stimulus contained only real letters, the children had to push the green key, in all other cases, that is if there was a symbol that was not a letter in the string, they had to push the red key. The score equaled the number of correct items. The lowest possible score was zero and the highest possible score was 60.

In this task, sixty stimuli were used: Thirty letter strings and thirty 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 in each task. These items were used to correct the children when they gave the wrong answer. Half of the children started with the first task and the other half with the second task. Appendix A presents the stimuli used in the letter-symbol distinction task.

The stimuli were presented in lowercase letters of Arial Black font, point size 40. The string was located at a fixed point in the center of the screen. The stimuli remained visible until the child responded by pushing the green or the red key. For the right-handed children, the green

key was on the right and the red key on the left, and for the left-handed children, this was reversed. Each trial started with a fixation point in the center of the screen (a plus-sign, Arial bold, point size 18) 1000 ms prior to presentation of the stimulus. The software program E-prime controlled for stimulus presentation, stimulus randomization, response latency registration, and data recording.

The third one was *Wordiness judgment*, which was measured by a task in which each item contained three stimuli; a pseudoword, a nonword, and a string of letters with a symbol. Pseudowords are non-existing words that only include graphemes and combinations of graphemes that exist in the Dutch language, for example *'nit'* or *'biek'*. Thus, a pseudoword is easily pronounceable for speakers of the Dutch language. The pseudowords are matched with existing words in their bigram frequencies. Nonwords exist of a string of only vowels or consonants and consequently, these words are not pronounceable, for example *'hvk'* or *'oaau'*. An example of a string of letters with a symbol is *'%oe'* or *'hj#'*. A stimulus contained two till four characters. The children had to point to a stimulus that looked most like a real word.

The stimuli were presented in lowercase letters of Arial Black font, point size 40. The task was printed on paper and each item had its own page. There were fifteen versions in which the order of the items differed. Prior to the task, there were four practice items. These items were used to correct the children when they gave a wrong answer. 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 three, multiplying the number of nonwords by two, and the number of strings of letters with a symbol by one. The lowest possible score was 30 and the highest possible score was 90.

Memory skills. They were assessed on three different aspects. The first one was the *Long-term memory*, which was measured by the '12-woordentest' developed by Tom Braams of Braams & Partners [12-words test]). The child had to remember words that were named by the experimenter. Appendix C 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 this first trial, the second trial started with the experimenter naming all twelve words for the second time and again the child was asked to repeat the words he or she remembered. The same procedure was repeated for the third, fourth, and fifth trial. After twenty minutes, the child was asked to repeat the words he or she still remembered from the first five trials. This was the recall session. The score equaled the number of words the child named in the recall session. The lowest possible score for long-term memory was zero and the highest possible score was 12.

The second one was the *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). The child had to repeat a string of numbers said by the experimenter. For instance, the experimenter named the string '4 6 9', after which the child had to repeat this string by saying '4 6 9'. The strings that had to be repeated increase in the number of digits they contain. Thus, the task started with a string containing two digits, the second string contained also two digits, the third and the fourth string contained three digits, the fifth and sixth string contained four digits, and so on until strings that contained nine digits. When a child had two strings of the same number of digits wrong, the test was finished. The score was the number of correctly named strings. The lowest possible score was zero and the highest possible score was 18.

The third one was *Working memory*, which was 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 now the final two strings contain eight digits. Prior to the 'backward digit recall', there were two practice items. The lowest possible score was zero and the highest possible score was 16.

Intelligence. This was assessed on *Nonverbal-deductive reasoning*, which was measured by the 'RAVEN's Standard Progressive Matrices' (Raven, 2003). Deductive ability is the ability to gain new perceptions, the ability to discover meaning in chaos, the ability to observe, and the ability to make connections (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 pieces, and drew a circle around it. The score equaled the number of correct circled items. Consequently, the lowest possible score was zero and the highest possible score was 60.

Reading skills. They were assessed on two different aspects. The first one was *Letter reading*, which was measured by 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 'a' and 'aa', 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 possible combinations of vowels. After 18 stimuli there was a pause and the child was able to decide when it 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, that is the numbers 1 until 5. Appendix D presents the graphemes used in the letter-naming tasks. The score equaled the number of correctly named graphemes. Because all 36 graphemes appeared twice, the lowest possible score was zero and the highest possible score was 72.

The letter was located at a fixed point in the center of the screen. The stimuli remained visible until the child responded by naming the letter. Each trial started with a fixation point in the center of the screen (a plus-sign, Arial, point size 46) 750 ms prior to presentation of the stimulus. After the fixation point there was a delay of 150 ms before the stimulus was presented. Naming times were registered with a voice key. The experimenter evaluated the correctness of the response by pushing a key on the button box, thereby initiating the next trial. The software program E-prime controlled stimulus presentation, stimulus randomization, response latency registration, and data recording.

The second one was *Word reading*, which was measured by the 'Drie-Minuten-Toets versie 1C' (Verhoeven, 1995 [Three-Minutes-Test version 1C]). The child had to read one-syllable words, with a 'vc' (vowel-consonant), 'cv', and 'cvc' structure. The score equaled the number of words read correctly in one minute. The lowest possible score was zero and the highest possible score was 150.

Spelling skills. They were assessed on two different aspects. The first one was the *Letter spelling*, which was measured by a test to investigate the ability to write graphemes. The child had to write a grapheme named by the experimenter. The experimenter named the grapheme and mentioned a word that contains the particular grapheme. Appendix E presents the graphemes used in this test. The score equaled the number of correctly written graphemes. The lowest possible score was zero and the highest possible score was 34.

The second one was *Word spelling*, which was measured by the 'Schaal Vorderingen in Spellingvaardigheid 1 Dictee 2' (Van den Bosch, Gillijns, Krom, & Moelands, 1991 [Scale Progression in Spelling Abilities 1 Dictation 2]). 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. Since the test contained 22 items, the lowest possible score was zero and the highest possible score was 22.

Procedure

Schools were asked to participate through sending all special-education schools for children with language and communication problems information letters with a reply card. From the schools that were willing to participate, three schools were selected based on their distance to the University of Nijmegen.

The first author, with the help of research assistants, tested each child individually, except for the test for nonverbal-deductive reasoning, the test for word spelling, and the test for letter spelling at the end of first grade. These tests were administered collectively. After the instruction, the children in a classroom were working on the test independently. All individual test sessions took place in a separate quiet room in the school building. Table 4 presents the time table for each test that was administered.

Table 4. *Overview of the Different Tests at Each Moment of Measurement.*

	Kindergarten February 2008	October 2008	Grade 1 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			
Memory skills				
Long-term memory		x		
Short-term memory		x		
Working memory		x		
Intelligence				
Nonverbal-deductive reasoning			x	
Reading				
Letter reading	x		x	x
Word reading			x	x
Spelling				
Letter spelling		x		x
Word spelling			x	x

Data analysis

This section covers a description of the models that were used in the regression analyses. A distinction is made between the models used for the analyses of the *level* of letter reading, word reading, letter spelling, and word spelling and the models used for the analyses of the *progress* in these early literacy skills.

Predicting level of early literacy skills. To predict the level of letter reading, word reading, letter spelling, and word spelling, three models were used: The linear model, the linear-interaction model, and the pretest-posttest model. To determine the strongest predictors of the level of these early literacy skills, these three models were compared with each other. For all models, the criterion Y_2-variable was the level of letter reading, word reading, letter spelling, and word spelling at the middle or the end of first grade. The predictor Y_1-variable was the level of letter reading, word reading, letter spelling, and word spelling at an earlier point in time. The predictor b-variable was the school of the children. All literacy skill tests served as a separate predictor and are referred to as the a-variable in the different models. The first model that was tested was the linear model (1). The Y_2-criterion variable and two predictor variables (a and b) were used.

Linear $Y_2 = a + b$ (1)

The second model was the linear-interaction model (2), which includes the same variables as the linear model with the addition of an interaction term. When two variables interact, one predictor variable influences the relationship between the other predictor variable and the criterion variable. Thus, the relationship between one predictor variable and the criterion variable may differ for different groups of the other predictor variable.

Linear interaction $Y_2 = a + b + a*b$ (2)

The third model was the pretest-posttest model (3). Again Y_2 serves as the criterion variable, but now Y_1 is added to the model, constituting a model with three predictor variables (a, b, Y_1). The Y_1-variable represents the score of the criterion variable of the participant on an earlier moment in time.

Pretest-posttest $Y_2 = a + b + Y_1$ (3)

Predicting progress in early literacy skills. To asses which model best predicts progress in letter reading, word reading, letter spelling, and word spelling, four models were compared: The linear model, the linear-interaction model, the pretest-posttest model, and the cusp-catastrophe model (see below for an explanation). In all models, ΔY (i.e., progress over time) served as the criterion variable. It was computed by subtracting the pretest value on an early literacy skill (Y_1) from its posttest value on that particular skill (Y_2). Like in the analyses on predicting the levels of literacy skills, the Y_2-variable was the level of letter reading, word reading, letter spelling, and word spelling at the middle or the end of first grade. The predictor Y_1-variable was the level of letter reading, word reading, letter spelling, and word spelling at an earlier point in time (i.e. middle of kindergarten or beginning or middle of first grade). The predictor b-variable was again school. In these analyses, all literacy skill tests also served as a separate predictor and are referred to as the a-variable in the different models. The first model that was tested was the linear model (1). The criterion variable (ΔY) and two predictor variables (a and b) were used.

Linear $\Delta Y = a + b$ (1)

The second model was the linear-interaction model (2), which includes the same variables as the linear model in addition to an interactive term.

Linear interaction $\Delta Y = a + b + a*b$ (2)

The third model was the pretest-posttest model (3), which includes a criterion variable (ΔY) and three predictor variables (a, b, Y_1).

Pretest-posttest $\Delta Y = a + b + Y_1$ (3)

These three linear models were compared with a fourth, non-linear model: The cusp-catastrophe model (4). Catastrophe models can serve as regression models that allow for non-linear or discontinuous changes in the behavior of systems. Catastrophe-theory models relate a criterion variable to independent control variables (Van der Maas & Molenaar, 1992). These models concern discontinuities in the criterion variable, behavior development, as a function of continuous changes or variation in the independent control variables (Ho & Saunders, 1980; Van der Maas & Molenaar, 1992). According to this theory, the criterion variable will be affected by

the control variables, and will change until it reaches an equilibrium or stable state (Van der Maas & Molenaar, 1992).

Figure 1 shows one of the most popular catastrophe models: The cusp-catastrophe model (Van der Maas & Molenaar, 1992). This model has been applied in several fields (e.g., Guastello, 1982; Ho & Saunders, 1980; Zeeman, 1976), but it has never been applied in the field of the prediction of early reading and spelling development. This model contains three variables; the criterion variable Y, and two independent control variables, the splitting variable *a*, and the normal variable *b* (Van der Maas & Molenaar, 1992). For a continuum of values substituted for the a- and b-variable, a range of values for Y is obtained. The relation between Y, a, and b can be represented in a three-dimensional space, as is represented by the axes in Figure 1. The region defined by a and b is the *control plane*. A combination of values of a and b, belongs to a value of the criterion variable Y, which is represented by a point on the smooth, *equilibrium surface*. The *control plane* contains a *bifurcation set*. In the bifurcation set exists a specific range of the control variables, that entails the possibility of more than one value of the criterion variable Y. This bifurcation set corresponds with the folded part of the smooth surface. As a result, the smooth surface contains an *inaccessible region*. Consequently, on the smooth surface, two paths are possible. *Path A* involves a discontinuous change, or a *sudden jump*, while *path B* involves a continuous change. Paths A and B are visible in Figure 1 both on the *equilibrium surface* and on the *control plane*. A path can also start around the *neutral point* and then it could go its way over the fold or under the fold. This means, a small difference in the start point of the path, could become a large difference at the end of the path, when entering the bifurcation set.

To summarize, the cusp-catastrophe model accounts for both continuous and discontinuous change of the criterion variable. Consequently, the model encloses all three linear models. In this study, the cusp-catastrophe model was the fourth model we used to determine the strongest predictors of the progress in letter reading, word reading, letter spelling, and word spelling.

$$\text{Cusp-catastrophe model } \Delta Y = a + Y_1 * b + Y_1^2 + Y_1^3 \qquad (4)$$

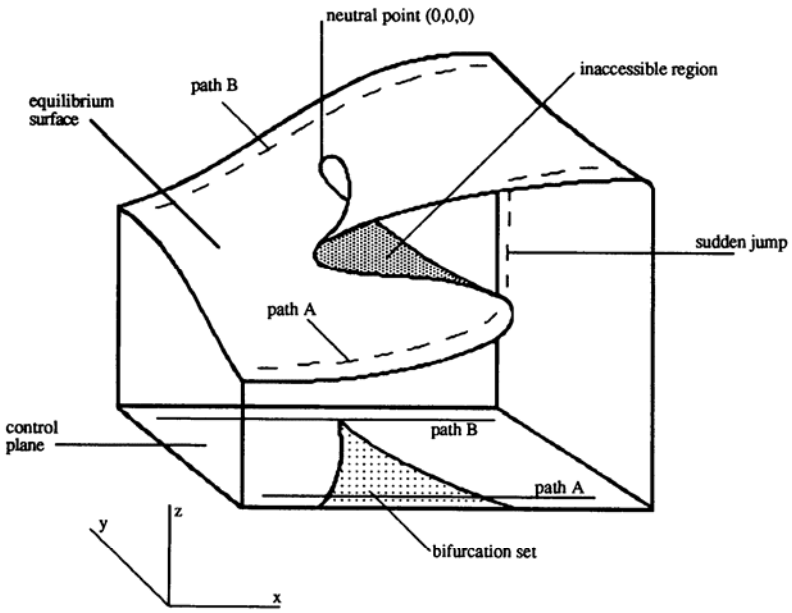

Figure 1. The cusp-catastrophe model.

Results

This section covers comparisons of school performance and the prediction of the level of and the progress in letter reading, word reading, letter spelling, and word spelling.

Comparisons of school performance

Means and standard deviations, split by school are shown in Table 5. The scores on the tests were converted into percentages of correct answers, except for the reading test. The number of correctly read words was used as the score for the reading test. Before the letter-naming data were analyzed, the following type of 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). One-way analyses of variance with school as between subject variable were conducted on all tests for linguistic skills, phonological skills, orthographic skills, memory skills, intelligence, reading, and spelling. Only four significant differences emerged between schools. The effect of auditory synthesis II on the first moment of measurement was significant. With respect to this variable only the data of school B and C were gathered, $F(1, 33) = 4.72$, $p < .05$. School C scored significantly higher than School B. The effect of awareness of written language on the first moment of measurement was also significant, $F(2, 63) = 11.58$, $p < .001$. Subsequent post-hoc analyses revealed that School A had a significantly

Table 5. *Overview of the Means and Standard Deviations of the Different Tests.*

	School A			School B			School C		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Linguistic skills									
Linearity awareness of spoken language	31	73.4	26.2	17	63.2	29.1	18	72.2	28.0
Articulation	26	82.2	17.2	22	87.7	8.3	17	76.6	20.1
Rapid naming Colors	23	85.8	45.3	23	77.6	19.3	16	79.8	25.9
Rapid naming Numbers	25	69.2	32.0	23	71.3	36.9	16	68.7	31.7
Rapid naming Pictures	25	85.9	24.0	23	79.7	20.0	16	85.7	27.1
Phonological skills									
Sound awareness and rhyming	31	49.6	27.7	17	47.8	21.8	18	56.9	25.1
Auditory synthesis I	31	70.2	26.0	17	63.2	23.2	18	72.2	26.6
Auditory synthesis II	0	-	-	17	80.2	18.8	18	92.4	14.3
Orthographic skills									
Awareness of written language	31	47.6	24.5	17	77.9	19.0	18	69.4	22.0
Letter-symbol distinction – perc correct	29	83.9	13.4	25	83.5	11.9	16	97.6	17.0
Letter-symbol distinction – reaction time	29	2099	977	25	1939	761	16	1759	625
Wordiness judgement	29	48.6	15.4	25	44.5	9.9	19	46.8	12.9
Memory skills									
Long-term memory	26	23.4	18.6	22	23.9	24.0	17	23.0	22.0
Short-term memory	26	26.9	8.1	22	29.3	7.3	17	29.8	7.2
Working memory	26	8.5	7.6	22	4.9	7.8	17	10.9	9.8
Intelligence									
Nonverbal-deductive reasoning	26	22.3	9.5	21	19.5	7.6	15	19.6	4.9
Reading									
Kindergarten									
Letter reading – perc correct	29	33.0	15.6	25	35.8	21.1	16	23.2	19.3
Letter reading – reaction time	29	1492	359	24	1299	444	12	1529	819
Middle of first grade									
Letter reading – perc correct	26	82.6	11.5	23	79.8	14.3	17	76.1	15.3
Letter reading – reaction time	26	1157	274	23	1019	250	17	1069	225
Reading	26	7.0	4.7	23	6.5	8.5	17	8.1	7.1
End of first grade									
Letter reading – perc correct	26	93.0	8.7	23	91.1	7.7	16	87.8	13.5
Letter reading - reaction time	26	832	157	23	798	208	16	892	221
Reading	26	26.4	20.1	23	20.4	15.4	16	20.3	19.2
Spelling									
Beginning of first grade									
Letter spelling	26	54.1	13.9	22	45.3	23.9	17	45.7	15.9
Middle of first grade									
Word spelling	26	65.1	25.6	21	47.0	32.0	15	59.8	30.1
End of first grade									
Letter spelling	26	88.9	13.4	21	76.1	20.0	17	84.9	15.9
Word spelling	26	85.3	12.5	21	56.3	29.7	16	76.0	26.5

lower mean score than Schools B and C (p's < .01; Bonferonni corrected). No significant difference emerged between Schools B and C. The final significant results emerged on the last moment of measurement (end of first grade). The main effect of letter spelling was $F(2, 61) = 3.61$, $p < .05$. Post-hoc analyses showed that School A scored significantly higher on letter spelling at the end of first grade than school B ($p < .05$; Bonferroni corrected). No other significant differences emerged. The main effect of word spelling was also significant, $F(2, 60) = 9.29$, $p < .001$. It also appeared that Schools A and C scored significantly higher on word spelling at the end of first grade than school B ($p < .05$; Bonferroni corrected). None of the other comparisons reached significant levels.

Note that a multivariate test would have been the best statistical solution if all children had a score on each variable. On almost every test, the score of one or two children was missing. Since this concerned different children, a multivariate test was not a feasible option. The fact that a larger number of F-tests was performed increases the chance of finding significant results. We are therefore hesitant interpreting the few significant finding that emerged among the schools. Because the schools did not differ significantly for most of the tests, we decided to collapse over all three schools for the regression analyses.

Predicting level of early literacy skills

Three different regression analyses, linear, linear-interaction, and a pretest-posttest model were conducted to investigate the best predictors of the level of letter reading, word reading, letter spelling, and word spelling. The criterion variable was the Y_2-variable, the level of letter reading, word reading, letter spelling, and word spelling at the middle or the end of first grade. The predictor b-variable was always the school of the children. All literacy skill tests served as a separate predictor and are referred to as the a-variable in the different models. The R^2 coefficient describes how well the data fits the different models.

Letter reading. The first analyses pertained to the predictive value of all literacy skills at the middle of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of correctly named letters in kindergarten. The criterion or Y_2-variable was the percentage of correctly named letters in the middle of first grade. The results are presented in Table 6. With respect to the linear model, 56% of the analyses appeared to be significant, in the linear-interaction model it was 63%, and in the pretest-posttest model it was 100% (all p's < .05). The R^2's of the pretest-posttest model were all remarkably higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models.

The second set of analyses concerned the predictive value of all literacy skills at the end of first grade. The predictor or Y_1-variable in the pretest-posttest model was the percentage of correctly named letters in kindergarten. The criterion or Y_2-variable was the percentage of correctly named letters at the end of first grade. The results are presented in Table 7. With respect to the linear model, 69% of the analyses appeared to be significant, in the linear-interaction model it was 63%, and in the pretest-posttest model it was 94% (all *p*'s < .05). The R^2's of the pretest-posttest model were all higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models.

The final set of analyses pertained to the predictive value of all literacy skills at the end of first grade. The predictor or Y_1-variable in the pretest-posttest model was the percentage of correctly named letters in the middle of first grade. The criterion or Y_2-variable was the percentage of correctly named letters at the end of first grade. The results are presented in Table 8. With respect to the linear model, 69% of the analyses appeared to be significant, in the linear-interaction model it was 69%, and in the pretest-posttest model it was 100% (all *p*'s < .05). The R^2's of the pretest-posttest model were all remarkably higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models.

Word reading. The analyses pertained to the predictive value of all literacy skills at the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the number of correctly read words at the middle of first grade. The criterion or Y_2-variable was the number of correctly read words at the end of first grade. The results are presented in Table 9. With respect to the linear model, 63% of the analyses appeared to be significant, in the linear-interaction model it was 56%, and in the pretest-posttest model it was 100% (all *p*'s < .05). The R^2's of the pretest-posttest model were all remarkably higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models.

Letter spelling. The analyses pertained to the predictive value of all literacy skills at the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of correctly written letters at the beginning of first grade. The criterion or Y_2-variable was the percentage of correctly written letters at the end of first grade. The results are presented in Table 10. With respect to the linear model, 47% of the analyses appeared to be significant, in the linear-interaction model it was 40%, and in the pretest-posttest model it was 100% (all *p*'s < .05). The R^2's of the pretest-posttest model were all remarkably higher than the R^2's of the other models.

There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models.

Word spelling. The analyses pertained to the predictive value of all literacy skills at the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of the score on the word spelling test in the middle of first grade. The criterion or Y_2-variable was the percentage of the score on the word spelling test in the end of first grade. The results are presented in Table 11. With respect to the linear model, 63% of the analyses appeared to be significant, in the linear-interaction model it was 56%, and in the pretest-posttest model it was 100% (all *p*'s < .05). The R^2's of the pretest-posttest model were all remarkably higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models.

Predicting progress in early literacy skills

Three different regression analyses, linear, linear-interaction, and a pretest-posttest model were conducted to investigate the best predictors of the progress in letter reading, word reading, letter spelling, and word spelling. The criterion variable was the ΔY –variable, the progress in letter reading, word reading, letter spelling, and word spelling. The predictor b-variable was always the school of the children. All literacy skill tests served as a separate predictor and are referred to as the a-variable in the different models. The R^2 coefficient describes how well the data fits the different models.

Letter reading. The first analyses pertained to the predictive value of all literacy skills at the progress in letter reading between kindergarten and the middle of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of correctly named letters at the letter-naming experiment in kindergarten. The Y_2-variable was the percentage of correctly named letters in the middle of first grade. Consequently, the criterion ΔY-variable was the difference between the percentage of correctly named letters in the middle of first grade and the percentage of correctly named letters in kindergarten. The results are presented in Table 12. With respect to the linear model, 13% of the analyses appeared to be significant, in the linear-interaction model it was also 13%, in the pretest-posttest model it was 94%, and in the cusp-catastrophe model it was also 94% (all *p*'s < .05). The R^2's of the pretest-posttest model and the cusp-catastrophe model were all remarkably higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models and also not between the R^2's among the analyses of the different cusp-catastrophe predictor models.

Table 6. *Predicting Letter-Reading Level at the Middle of First Grade (Y_1 = Middle of Kindergarten)*

	Linear			Linear interaction			Pretest-posttest		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills									
Linearity of spoken language awareness	.27	(2,53)=9.66	.001	.30	(3,52)=7.38	.001	.49	(3,48)=15.08	.001
Articulation	.10	(2,62)=3.35	.03	.11	(3,61)=2.31	.07	.45	(3,54)=14.53	.001
Rapid naming Colors	.15	(2,59)=5.13	.01	.21	(3,58)=5.24	.001	.46	(3,51)=14.40	.001
Rapid naming Numbers	.38	(2,61)=18.40	.001	.40	(3,60)=13.02	.001	.62	(3,53)=29.38	.001
Rapid naming Pictures	.21	(2,61)=8.06	.001	.22	(3,60)=5.65	.001	.51	(3,53)=18.50	.001
Phonological skills									
Sound awareness and rhyming	.38	(2,53)=16.17	.001	.38	(3,52)=10.76	.001	.53	(3,48)=17.75	.001
Auditory synthesis I	.27	(2,53)=9.85	.001	.32	(3,52)=8.01	.001	.46	(3,48)=13.47	.001
Auditory synthesis II	.12	(2,27)=1.79	.19	.13	(3,26)=1.31	.29	.46	(3,23)=6.50	.001
Orthographic skills									
Awareness of written language	.07	(2,53)=2.12	.13	.08	(3,52)=1.44	.24	.43	(3,48)=11.88	.001
Letter-symbol distinction	.20	(2,56)=7.17	.001	.22	(3,55)=5.02	.001	.45	(3,55)=15.24	.001
Wordiness judgement	.06	(2,59)=1.81	.17	.08	(3,58)=1.64	.19	.41	(3,55)=12.97	.001
Memory skills									
Long-term memory	.04	(2,62)=1.21	.31	.05	(3,61)=1.15	.34	.44	(3,54)=14.22	.001
Short-term memory	.19	(2,62)=7.19	.001	.25	(3,61)=6.76	.001	.47	(3,54)=15.94	.001
Working memory	.28	(2,62)=11.90	.001	.28	(3,61)=7.82	.001	.57	(3,54)=24.12	.001
Intelligence									
Nonverbal-deductive reasoning	.07	(2,59)=2.19	.12	.07	(3,58)=1.43	.24	.40	(3,52)=11.58	.001
Spelling									
Letter spelling	.50	(2,62)=30.62	.001	.50	(3,61)=20.10	.001	.56	(3,54)=22.45	.001

Table 7. *Predicting Letter-Reading Level at the End of First Grade (Y_1 = Middle of Kindergarten).*

	Linear			Linear interaction			Pretest-posttest		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills									
Linearity of spoken language awareness	.23	(2,52)=7.54	.001	.27	(3,51)=6.37	.001	.36	(3,47)=8.96	.001
Articulation	.11	(2,61)=3.59	.03	.11	(3,60)=2.37	.08	.28	(3,53)=6.81	.001
Rapid naming Colors	.16	(2,58)=5.49	.01	.22	(3,57)=5.35	.001	.31	(3,50)=7.46	.001
Rapid naming Numbers	.40	(2,60)=20.32	.001	.44	(3,59)=15.15	.001	.51	(3,52)=18.23	.001
Rapid naming Pictures	.27	(2,60)=10.88	.001	.27	(3,59)=7.13	.001	.44	(3,52)=13.57	.001
Phonological skills									
Sound awareness and rhyming	.29	(2,52)=10.41	.001	.30	(3,51)=7.27	.001	.38	(3,47)=9.74	.001
Auditory synthesis I	.24	(2,52)=8.03	.001	.28	(3,51)=6.68	.001	.33	(3,47)=7.72	.001
Auditory synthesis II	.14	(2,26)=2.09	.14	.27	(3,25)=3.07	.05	.32	(3,22)=3.38	.04
Orthographic skills									
Awareness of written language	.08	(2,52)=2.23	.12	.08	(3,51)=1.51	.22	.30	(3,47)=6.75	.001
Letter-symbol distinction	.20	(2,55)=6.95	.001	.24	(3,54)=5.60	.001	.30	(3,54)=7.64	.001
Wordiness judgement	.07	(2,58)=2.19	.12	.08	(3,57)=1.71	.18	.25	(3,54)=5.94	.001
Memory skills									
Long-term memory	.05	(2,61)=1.55	.22	.06	(3,60)=1.34	.27	.28	(3,53)=6.98	.001
Short-term memory	.17	(2,61)=6.17	.001	.27	(3,60)=7.20	.001	.30	(3,53)=7.45	.001
Working memory	.20	(2,61)=7.58	.001	.20	(3,60)=5.11	.001	.33	(3,53)=8.65	.001
Intelligence									
Nonverbal-deductive reasoning	.04	(2,58)=1.27	.29	.04	(3,57)=.83	.48	.20	(3,51)=4.26	.01
Spelling									
Letter spelling	.29	(2,61)=12.58	.001	.29	(3,60)=8.25	.001	.32	(3,53)=8.12	.001

Table 8. *Predicting Letter-Reading Level at the End of First Grade (Y_1 = Middle of First Grade)*

	Linear			Linear interaction			Pretest-posttest		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills									
Linearity of spoken language awareness	.23	(2,52)=7.54	.001	.27	(3,51)=6.37	.001	.71	(3,51)=41.16	.001
Articulation	.11	(2,61)=3.59	.03	.11	(3,60)=2.37	.08	.68	(3,60)=43.27	.001
Rapid naming Colors	.16	(2,58)=5.49	.01	.22	(3,57)=5.35	.001	.70	(3,57)=44.77	.001
Rapid naming Numbers	.40	(2,60)=20.32	.001	.44	(3,59)=15.15	.001	.73	(3,59)=51.75	.001
Rapid naming Pictures	.27	(2,60)=10.88	.001	.27	(3,59)=7.13	.001	.69	(3,59)=43.24	.001
Phonological skills									
Sound awareness and rhyming	.29	(2,52)=10.41	.001	.30	(3,51)=7.27	.001	.71	(3,51)=41.11	.001
Auditory synthesis I	.24	(2,52)=8.03	.001	.28	(3,51)=6.68	.001	.71	(3,51)=41.33	.001
Auditory synthesis II	.14	(2,26)=2.09	.14	.27	(3,25)=3.07	.05	.77	(3,25)=27.32	.001
Orthographic skills									
Awareness of written language	.08	(2,52)=2.23	.12	.08	(3,51)=1.51	.22	.71	(3,51)=41.27	.001
Letter-symbol distinction	.20	(2,55)=6.95	.001	.24	(3,54)=5.60	.001	.70	(3,54)=41.82	.001
Wordiness judgement	.07	(2,58)=2.19	.12	.08	(3,57)=1.71	.18	.69	(3,57)=41.75	.001
Memory skills									
Long-term memory	.05	(2,61)=1.55	.22	.06	(3,60)=1.34	.27	.68	(3,60)=42.94	.001
Short-term memory	.17	(2,61)=6.17	.001	.27	(3,60)=7.20	.001	.68	(3,60)=43.10	.001
Working memory	.20	(2,61)=7.58	.001	.20	(3,60)=5.11	.001	.68	(3,60)=42.81	.001
Intelligence									
Nonverbal-deductive reasoning	.04	(2,58)=1.27	.29	.04	(3,57)=.83	.48	.64	(3,57)=34.34	.001
Spelling									
Letter spelling	.29	(2,61)=12.58	.001	.29	(3,60)=8.25	.001	.69	(3,60)=43.79	.001

Table 9. *Predicting Word-Reading Level at the End of First Grade (Y_1 = Middle of First Grade).*

	Linear			Linear interaction			Pretest-posttest		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills									
Linearity of spoken language awareness	.20	(2,52)=6.54	.001	.21	(3,51)=4.38	.01	.70	(3,51)=39.18	.001
Articulation	.10	(2,61)=3.38	.04	.10	(3,60)=2.22	.10	.71	(3,60)=49.30	.001
Rapid naming Colors	.24	(2,58)=9.03	.001	.27	(3,57)=6.96	.001	.74	(3,57)=54.73	.001
Rapid naming Numbers	.29	(2,60)=12.35	.001	.29	(3,59)=8.17	.001	.72	(3,59)=51.67	.001
Rapid naming Pictures	.30	(2,60)=12.78	.001	.30	(3,59)=8.41	.001	.72	(3,59)=49.42	.001
Phonological skills									
Sound awareness and rhyming	.14	(2,52)=4.08	.02	.15	(3,51)=2.92	.04	.69	(3,51)=37.93	.001
Auditory synthesis I	.09	(2,52)=2.70	.08	.10	(3,51)=1.97	.13	.69	(3,51)=38.46	.001
Auditory synthesis II	.05	(2,26)=.70	.51	.10	(3,25)=.85	.48	.83	(3,25)=40.49	.001
Orthographic skills									
Awareness of written language	.05	(2,52)=1.33	.28	.08	(3,51)=1.38	.26	.69	(3,51)=37.72	.001
Letter-symbol distinction	.25	(2,55)=9.06	.001	.25	(3,54)=6.00	.001	.73	(3,54)=47.94	.001
Wordiness judgement	.04	(2,58)=1.15	.32	.04	(3,57)=.77	.52	.70	(3,57)=43.67	.001
Memory skills									
Long-term memory	.02	(2,61)=.69	.50	.09	(3,60)=1.90	.14	.70	(3,60)=46.00	.001
Short-term memory	.12	(2,61)=3.61	.03	.17	(3,60)=4.08	.01	.70	(3,60)=46.02	.001
Working memory	.15	(2,61)=5.46	.01	.15	(3,60)=3.58	.02	.70	(3,60)=45.94	.001
Intelligence									
Nonverbal-deductive reasoning	.02	(2,58)=.53	.60	.10	(3,57)=1.98	.13	.69	(3,57)=42.61	.001
Spelling									
Letter spelling	.41	(2,61)=21.16	.001	.41	(3,60)=.41	.001	.71	(3,60)=48.36	.001

Table 10. *Predicting Letter-Spelling Level at the End of First Grade (Y_1 = Beginning of First Grade).*

	Linear			Linear interaction			Pretest-posttest		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills									
Linearity of spoken language awareness	.18	(2,52)=5.57	.01	.19	(3,51)=3.88	.01	.70	(3,51)=16.45	.001
Articulation	.05	(2,60)=1.65	.20	.06	(3,59)=1.18	.32	.47	(3,59)=17.11	.001
Rapid naming Colors	.14	(2,57)=4.47	.02	.21	(3,56)=4.89	.001	.53	(3,55)=20.47	.001
Rapid naming Numbers	.16	(2,59)=5.71	.01	.18	(3,58)=4.33	.01	.51	(3,57)=19.94	.001
Rapid naming Pictures	.11	(2,59)=3.56	.04	.12	(3,58)=2.66	.06	.47	(3,57)=17.11	.001
Phonological skills									
Sound awareness and rhyming	.13	(2,52)=3.93	.03	.16	(3,51)=3.19	.03	.47	(3,51)=15.13	.001
Auditory synthesis I	.14	(2,52)=4.28	.02	.19	(3,51)=4.06	.01	.48	(3,51)=15.63	.001
Auditory synthesis II	.16	(2,26)=2.38	.11	.19	(3,25)=1.96	.15	.59	(3,25)=11.88	.001
Orthographic skills									
Awareness of written language	.03	(2,52)=.81	.45	.03	(3,51)=.59	.63	.46	(3,51)=14.72	.001
Letter-symbol distinction	.09	(2,54)=2.67	.08	.10	(3,53)=1.86	.15	.50	(3,52)=17.10	.001
Wordiness judgement	.02	(2,57)=.45	.64	.02	(3,56)=.33	.80	.48	(3,55)=16.89	.001
Memory skills									
Long-term memory	.02	(2,60)=.52	.60	.02	(3,59)=.37	.78	.48	(3,59)=18.14	.001
Short-term memory	.05	(2,60)=1.61	.21	.11	(3,59)=2.36	.08	.46	(3,59)=17.05	.001
Working memory	.23	(2,60)=9.03	.001	.23	(3,59)=5.92	.001	.50	(3,59)=19.62	.001
Intelligence									
Nonverbal-deductive reasoning	.03	(2,57)=.99	.38	.04	(3,56)=.68	.59	.47	(3,55)=16.20	.001

Table 11. *Predicting Word-Spelling Level at the End of First Grade (Y_1 = Middle of First Grade).*

	Linear			Linear interaction			Pretest-posttest		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills									
Linearity of spoken language awareness	.38	(2,51)=15.37	.001	.45	(3,50)=13.36	.001	.66	(3,47)=30.68	.001
Articulation	.05	(2,59)=1.45	.24	.05	(3,58)=1.11	.35	.69	(3,54)=39.59	.001
Rapid naming Colors	.11	(2,56)=3.40	.04	.14	(3,55)=2.88	.04	.71	(3,51)=41.16	.001
Rapid naming Numbers	.21	(2,58)=7.59	.001	.23	(3,57)=5.58	.001	.70	(3,53)=41.40	.001
Rapid naming Pictures	.13	(2,58)=4.49	.02	.14	(3,57)=3.01	.04	.68	(3,53)=37.23	.001
Phonological skills									
Sound awareness and rhyming	.23	(2,51)=7.49	.001	.28	(3,50)=6.44	.001	.65	(3,47)=29.17	.001
Auditory synthesis I	.30	(2,51)=11.01	.001	.38	(3,50)=10.37	.001	.64	(3,47)=27.66	.001
Auditory synthesis II	.15	(2,25)=2.27	.12	.18	(3,24)=1.77	.18	.79	(3,21)=25.98	.001
Orthographic skills									
Awareness of written language	.05	(2,51)=1.40	.26	.12	(3,50)=2.33	.09	.65	(3,47)=29.17	.001
Letter-symbol distinction	.12	(2,53)=3.54	.04	.12	(3,52)=2.35	.08	.77	(3,49)=53.33	.001
Wordiness judgement	.04	(2,56)=1.28	.29	.05	(3,55)=.95	.42	.72	(3,52)=43.57	.001
Memory skills									
Long-term memory	.04	(2,59)=1.36	.27	.04	(3,58)=.89	.45	.68	(3,54)=38.22	.001
Short-term memory	.13	(2,59)=4.49	.02	.20	(3,58)=4.93	.001	.69	(3,54)=39.25	.001
Working memory	.28	(2,59)=11.61	.001	.29	(3,58)=7.90	.001	.68	(3,54)=37.36	.001
Intelligence									
Nonverbal-deductive reasoning	.05	(2,56)=1.58	.21	.06	(3,55)=1.10	.36	.67	(3,55)=37.53	.001
Spelling									
Letter spelling	.45	(2,59)=24.28	.001	.45	(3,58)=15.92	.001	.68	(3,54)=38.35	.001

The second set of analyses pertained to the predictive value of all literacy skills at the progress in letter reading between kindergarten and the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of correctly named letters at the letter-naming experiment in kindergarten. The Y_2-variable was the percentage of correctly named letters in the end of first grade. Consequently, the criterion ΔY-variable was the difference between the percentage of correctly named letters in the end of first grade and the percentage of correctly named letters in kindergarten. The results are presented in Table 13. With respect to the linear model, 6% of the analyses appeared to be significant, in the linear-interaction model it was also 6%, in the pretest-posttest model it was 94%, and in the cusp-catastrophe model it was also 94% (all p's < .05). The R^2's of the pretest-posttest model and the cusp-catastrophe model were all remarkably higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models and also not between the R^2's among the analyses of the different cusp-catastrophe predictor models.

The final set of analyses pertained to the predictive value of all literacy skills at the progress in letter reading between the middle and the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of correctly named letters at the letter-naming experiment in the middle of first grade. The Y_2-variable was the percentage of correctly named letters in the end of first grade. Consequently, the criterion ΔY-variable was the difference between the percentage of correctly named letters in the end and in the middle of first grade. The results are presented in Table 14. With respect to the linear model, 0% of the analyses appeared to be significant, in the linear-interaction model it was also 0%, in the pretest-posttest model it was 25%, and in the cusp-catastrophe model it was 100% (all p's < .05). The R^2's of the cusp-catastrophe model were almost all higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different cusp-catastrophe predictor models.

Word reading. The analyses pertained to the predictive value of all literacy skills at the progress in word reading between the middle and the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the number of correctly read words at the middle of first grade. The Y_2-variable was the number of correctly read words at the end of first grade. Consequently, the criterion ΔY-variable was the difference between the number of correctly read words in the end and in the middle of first grade. The results are presented in Table 15. With respect to the linear model, 6% of the analyses appeared to be significant, in the linear-interaction model it was 13%, in the pretest-posttest model it was 44%, and in the cusp-catastrophe model it was 100% (all p's < .05). The R^2's of the cusp-catastrophe model were all higher than the R^2's of

the other models. There were hardly any differences between the R^2's among the analyses of the different cusp-catastrophe predictor models.

Letter spelling. The analyses pertained to the predictive value of all literacy skills at the progress in letter spelling between the beginning and the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of correctly written letters in the beginning of first grade. The Y_2-variable was the percentage of correctly written letters in the end of first grade. Consequently, the criterion ΔY-variable was the difference between the percentage of correctly written letters in the end and in the beginning of first grade. The results are presented in Table 16. With respect to the linear model, 0% of the analyses appeared to be significant, in the linear-interaction model it was also 0%, in the pretest-posttest model it was 93%, and in the cusp-catastrophe model it was also 93% (all p's < .05). The R^2's of the pretest-posttest model and the cusp-catastrophe model were almost all higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models and also not between the different analyses of the different cusp-catastrophe predictor models.

Word spelling. The analyses pertained to the predictive value of all literacy skills at the progress in word spelling between the middle and the end of first grade. In the pretest-posttest model, the predictor or Y_1-variable was the percentage of the score on the word spelling test in the middle of first grade. The Y_2-variable was the percentage of the score on the word spelling test in the end of first grade. Consequently, the criterion ΔY-variable was the difference between the percentage of the score on the word spelling test in the end and in the middle of first grade. The results are presented in Table 17. With respect to the linear model, 25% of the analyses appeared to be significant, in the linear-interaction model it was 19%, in the pretest-posttest model it was 69%, and in the cusp-catastrophe model it was 63% (all p's < .05). The R^2's of the pretest-posttest model and the cusp-catastrophe model were almost all higher than the R^2's of the other models. There were hardly any differences between the R^2's among the analyses of the different pretest-posttest predictor models and also not between the R^2's among the different analyses of the cusp-catastrophe predictor models.

Note, all of the regression analyses were also conducted with different variables for the *b* predictor and the remaining variables served as the set of *a* predictors. In all cases, R^2's and patterns of results were highly similar.

Table 12. *Predicting Letter-Reading Progress Between Kindergarten and the Middle of First Grade.*

	Linear			Linear interaction			Pretest-posttest			Cusp		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills												
Linearity of spoken language awareness	.04	(2,49)=1.05	.36	.05	(3,48)=.83	.48	.28	(3,48)=6.35	.001	.28	(4,47)=4.56	.001
Articulation	.01	(2,55)=.29	.75	.01	(3,54)=.19	.90	.23	(3,54)=5.48	.001	.24	(4,53)=4.20	.01
Rapid naming Colors	.04	(2,52)=1.19	.31	.12	(3,51)=2.23	.10	.29	(3,51)=6.88	.001	.27	(4,50)=4.60	.001
Rapid naming Numbers	.18	(2,54)=5.93	.01	.19	(3,53)=4.05	.01	.48	(3,53)=16.38	.001	.49	(4,52)=12.59	.001
Rapid naming Pictures	.06	(2,54)=1.56	.22	.06	(3,53)=1.02	.39	.36	(3,53)=9.91	.001	.37	(4,52)=7.57	.001
Phonological skills												
Sound awareness and rhyming	.04	(2,49)=1.00	.38	.04	(3,48)=.65	.59	.34	(3,48)=8.27	.001	.32	(4,47)=5.48	.001
Auditory synthesis I	.03	(2,49)=.62	.54	.07	(3,48)=1.27	.29	.25	(3,48)=5.19	.001	.23	(4,47)=3.45	.02
Auditory synthesis II	.06	(2,24)=.78	.47	.06	(3,23)=.51	.68	.14	(3,23)=1.29	.30	.17	(4,22)=1.13	.37
Orthographic skills												
Awareness of written language	.03	(2,49)=.77	.47	.14	(3,48)=2.63	.06	.20	(3,48)=4.05	.01	.20	(4,47)=2.85	.03
Letter-symbol distinction	.02	(2,56)=.44	.64	.05	(3,55)=.93	.43	.27	(3,55)=6.75	.001	.27	(4,54)=5.01	.001
Wordiness judgement	.01	(2,56)=.34	.71	.01	(3,55)=.23	.87	.21	(3,55)=5.05	.001	.22	(4,54)=3.90	.01
Memory skills												
Long-term memory	.06	(2,55)=1.65	.20	.06	(3,54)=1.08	.37	.44	(3,54)=14.22	.001	.23	(4,53)=3.93	.01
Short-term memory	.02	(2,55)=.59	.56	.08	(3,54)=1.51	.22	.27	(3,54)=6.50	.001	.28	(4,53)=5.04	.001
Working memory	.14	(2,55)=4.31	.02	.16	(3,54)=3.41	.02	.41	(3,54)=12.41	.001	.40	(4,53)=8.92	.001
Intelligence												
Nonverbal-deductive reasoning	.01	(2,53)=.12	.89	.01	(3,52)=.25	.86	.25	(3,52)=5.91	.001	.26	(4,51)=4.55	.001
Spelling												
Letter spelling	.02	(2,55)=.41	.67	.03	(3,54)=.49	.69	.38	(3,54)=11.20	.001	.37	(4,53)=7.88	.001

Table 13. *Predicting Letter-Reading Progress Between Kindergarten and the End of First Grade.*

	Linear			Linear interaction			Pretest-posttest			Cusp		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills												
Linearity of spoken language awareness	.05	(2,48)=1.20	.31	.07	(3,47)=1.19	.33	.31	(3,47)=7.13	.001	.29	(4,46)=4.68	.001
Articulation	.02	(2,54)=.41	.66	.02	(3,53)=.27	.84	.32	(3,53)=8.16	.001	.30	(4,52)=5.64	.001
Rapid naming Colors	.04	(2,51)=1.16	.32	.09	(3,50)=1.59	.20	.38	(3,50)=10.22	.001	.35	(4,49)=6.64	.001
Rapid naming Numbers	.15	(2,53)=4.53	.02	.16	(3,52)=3.26	.03	.55	(3,52)=21.06	.001	.54	(4,51)=15.02	.001
Rapid naming Pictures	.07	(2,53)=2.11	.13	.08	(3,52)=1.60	.20	.50	(3,52)=17.40	.001	.50	(4,51)=12.52	.001
Phonological skills												
Sound awareness and rhyming	.04	(2,48)=.98	.38	.05	(3,47)=.73	.54	.33	(3,47)=7.85	.001	.29	(4,46)=4.68	.001
Auditory synthesis I	.04	(2,48)=.98	.38	.07	(3,47)=1.19	.33	.28	(3,47)=5.98	.001	.24	(4,46)=3.62	.01
Auditory synthesis II	.03	(2,23)=.38	.69	.13	(3,22)=1.07	.38	.19	(3,22)=1.77	.18	.17	(4,21)=1.07	.40
Orthographic skills												
Awareness of written language	.19	(2,48)=.92	.41	.06	(3,47)=.93	.43	.25	(3,47)=5.08	.001	.21	(4,46)=3.11	.02
Letter-symbol distinction	.02	(2,55)=.45	.64	.05	(3,54)=1.03	.39	.35	(3,54)=9.86	.001	.34	(4,53)=6.78	.001
Wordiness judgement	.02	(2,55)=.44	.65	.02	(3,54)=.29	.83	.31	(3,54)=8.01	.001	.30	(4,53)=5.59	.001
Memory skills												
Long-term memory	.08	(2,54)=2.46	.10	.09	(3,53)=1.77	.16	.28	(3,53)=6.98	.001	.30	(4,52)=5.67	.001
Short-term memory	.02	(2,54)=.44	.65	.06	(3,53)=1.14	.34	.33	(3,53)=8.84	.001	.32	(4,52)=6.12	.001
Working memory	.03	(2,54)=.96	.39	.06	(3,53)=1.13	.34	.36	(3,53)=10.11	.001	.35	(4,52)=6.89	.001
Intelligence												
Nonverbal-deductive reasoning	.01	(2,52)=.24	.79	.04	(3,51)=.71	.55	.34	(3,51)=8.91	.001	.34	(4,50)=6.49	.001
Spelling												
Letter spelling	.09	(2,54)=2.51	.09	.10	(3,53)=1.89	.14	.35	(3,53)=9.54	.001	.33	(4,52)=6.47	.001

Table 14. *Predicting Letter-Reading Progress Between the Middle and the End of First Grade.*

	Linear			Linear interaction			Pretest-posttest			Cusp		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills												
Linearity of spoken language awareness	.01	(2,52)=.15	.87	.01	(3,51)=.19	.91	.04	(3,51)=.78	.51	.26	(4,50)=4.34	.001
Articulation	.01	(2,61)=.01	.99	.01	(3,60)=.17	.92	.10	(3,60)=2.21	.10	.23	(4,59)=4.51	.001
Rapid naming Colors	.01	(2,58)=.36	.70	.01	(3,57)=.25	.87	.11	(3,57)=2.32	.09	.28	(4,56)=5.54	.001
Rapid naming Numbers	.01	(2,60)=.16	.85	.01	(3,59)=.23	.87	.16	(3,59)=3.71	.02	.30	(4,58)=6.11	.001
Rapid naming Pictures	.02	(2,60)=.50	.61	.04	(3,59)=.88	.46	.20	(3,59)=4.75	.01	.35	(4,58)=7.79	.001
Phonological skills												
Sound awareness and rhyming	.02	(2,52)=.50	.61	.03	(3,51)=.47	.70	.04	(3,51)=.77	.52	.26	(4,50)=4.35	.001
Auditory synthesis I	.00	(2,52)=.06	.94	.00	(3,51)=.05	.99	.05	(3,51)=.83	.48	.26	(4,50)=4.34	.001
Auditory synthesis II	.03	(2,26)=.38	.69	.16	(3,25)=1.61	.21	.05	(3,25)=.41	.75	.33	(4,24)=2.94	.04
Orthographic skills												
Awareness of written language	.01	(2,52)=.25	.78	.01	(3,51)=.17	.92	.05	(3,51)=.82	.49	.27	(4,50)=4.65	.001
Letter-symbol distinction	.00	(2,55)=.03	.97	.03	(3,54)=.59	.62	.10	(3,54)=1.97	.13	.24	(4,53)=4.16	.01
Wordiness judgement	.01	(2,58)=.14	.87	.01	(3,57)=.13	.94	.09	(3,57)=1.90	.14	.22	(4,56)=4.03	.01
Memory skills												
Long-term memory	.00	(2,61)=.03	.98	.00	(3,60)=.04	.99	.68	(3,60)=42.94	.001	.23	(4,59)=4.45	.001
Short-term memory	.00	(2,61)=.12	.89	.02	(3,60)=.34	.80	.10	(3,60)=2.15	.10	.23	(4,59)=4.48	.001
Working memory	.02	(2,61)=.59	.56	.04	(3,60)=.88	.46	.09	(3,60)=2.05	.12	.23	(4,59)=4.45	.001
Intelligence												
Nonverbal-deductive reasoning	.01	(2,58)=.31	.73	.01	(3,57)=.22	.88	.14	(3,57)=2.98	.04	.26	(4,56)=4.85	.001
Spelling												
Letter spelling	.09	(2,61)=2.93	.06	.09	(3,60)=1.93	.14	.11	(3,60)=2.39	.08	.23	(4,59)=4.47	.001

Table 15. *Predicting Word-Reading Progress Between the Middle and the End of First Grade.*

	Linear			Linear interaction			Pretest-posttest			Cusp		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills												
Linearity of spoken language awareness	.06	(2,52)=1.53	.23	.06	(3,51)=1.13	.35	.11	(3,51)=2.00	.13	.28	(4,50)=4.79	.001
Articulation	.09	(2,61)=2.83	.07	.09	(3,60)=1.86	.15	.14	(3,60)=3.34	.03	.30	(4,59)=6.31	.001
Rapid naming Colors	.13	(2,58)=4.35	.02	.14	(3,57)=3.02	.04	.23	(3,57)=5.53	.001	.35	(4,56)=7.44	.001
Rapid naming Numbers	.07	(2,60)=2.33	.11	.09	(3,59)=2.00	.12	.16	(3,59)=3.81	.01	.31	(4,58)=6.51	.001
Rapid naming Pictures	.07	(2,60)=2.27	.11	.13	(3,59)=2.93	.04	.17	(3,59)=4.04	.01	.31	(4,58)=6.58	.001
Phonological skills												
Sound awareness and rhyming	.05	(2,52)=1.41	.25	.05	(3,51)=.95	.43	.09	(3,51)=1.57	.21	.27	(4,50)=4.69	.001
Auditory synthesis I	.06	(2,52)=1.51	.23	.06	(3,51)=1.10	.36	.09	(3,51)=1.76	.17	.26	(4,50)=4.34	.001
Auditory synthesis II	.04	(2,26)=.58	.57	.07	(3,25)=.67	.58	.31	(3,25)=3.74	.02	.46	(4,24)=5.09	.001
Orthographic skills												
Awareness of written language	.05	(2,52)=1.46	.24	.06	(3,51)=1.17	.33	.08	(3,51)=1.51	.22	.21	(4,46)=3.14	.02
Letter-symbol distinction	.07	(2,55)=2.04	.14	.08	(3,54)=1.58	.21	.16	(3,54)=3.54	.02	.30	(4,53)=5.71	.001
Wordiness judgement	.06	(2,58)=1.83	.17	.06	(3,57)=1.30	.28	.10	(3,57)=2.19	.10	.26	(4,56)=5.03	.001
Memory skills												
Long-term memory	.06	(2,61)=1.89	.16	.09	(3,60)=1.89	.14	.10	(3,60)=2.23	.10	.28	(4,59)=5.59	.001
Short-term memory	.07	(2,61)=2.27	.11	.08	(3,60)=1.63	.19	.10	(3,60)=2.24	.10	.26	(4,59)=5.27	.001
Working memory	.07	(2,61)=2.17	.12	.07	(3,60)=1.55	.21	.10	(3,60)=2.21	.10	.26	(4,59)=5.27	.001
Intelligence												
Nonverbal-deductive reasoning	.06	(2,58)=1.98	.15	.10	(3,57)=1.99	.13	.10	(3,57)=2.20	.10	.28	(4,56)=5.30	.001
Spelling												
Letter spelling	.06	(2,61)=1.87	.16	.07	(3,60)=1.42	.25	.13	(3,60)=3.03	.04	.29	(4,59)=6.00	.001

Table 16. *Predicting Letter-Spelling Progress Between the Beginning and the End of First Grade.*

	Linear			Linear interaction			Pretest-posttest			Cusp		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills												
Linearity of spoken language awareness	.01	(2,52)=.14	.87	.01	(3,51)=.17	.92	.20	(3,51)=4.11	.01	.29	(4,50)=5.04	.001
Articulation	.01	(2,60)=.29	.75	.01	(3,59)=.19	.90	.17	(3,59)=3.91	.01	.24	(4,58)=4.45	.003
Rapid naming Colors	.01	(2,56)=.37	.70	.03	(3,55)=.48	.70	.24	(3,55)=5.76	.001	.33	(4,54)=6.70	.001
Rapid naming Numbers	.01	(2,58)=.16	.85	.02	(3,57)=.35	.79	.16	(3,57)=3.62	.02	.24	(4,56)=4.38	.001
Rapid naming Pictures	.02	(2,58)=.66	.52	.02	(3,57)=.44	.73	.22	(3,57)=5.21	.001	.29	(4,56)=5.64	.001
Phonological skills												
Sound awareness and rhyming	.00	(2,52)=.09	.92	.01	(3,51)=.10	.96	.16	(3,51)=3.28	.03	.25	(4,50)=4.17	.01
Auditory synthesis I	.00	(2,52)=.04	.96	.04	(3,51)=.63	.60	.17	(3,51)=3.59	.02	.26	(4,50)=4.45	.001
Auditory synthesis II	.10	(2,26)=1.39	.27	.17	(3,25)=1.74	.18	.25	(3,25)=2.80	.06	.23	(4,24)=1.75	.17
Orthographic skills												
Awareness of written language	.00	(2,52)=.04	.96	.02	(3,51)=.33	.80	.15	(3,51)=3.02	.04	.25	(4,50)=.4.16	.01
Letter-symbol distinction	.03	(2,53)=.83	.44	.03	(3,52)=.57	.64	.20	(3,52)=4.41	.01	.25	(4,51)=4.21	.01
Wordiness judgement	.03	(2,56)=.82	.45	.03	(3,55)=.55	.65	.20	(3,55)=4.61	.01	.26	(4,54)=4.70	.001
Memory skills												
Long-term memory	.06	(2,60)=1.93	.15	.09	(3,59)=1.85	.15	.19	(3,59)=4.57	.01	.25	(4,58)=4.78	.001
Short-term memory	.04	(2,60)=1.32	.28	.06	(3,59)=1.35	.27	.16	(3,59)=3.87	.01	.23	(4,58)=4.27	.001
Working memory	.01	(2,60)=.35	.71	.03	(3,59)=.57	.64	.22	(3,59)=5.52	.001	.28	(4,58)=5.73	.001
Intelligence												
Nonverbal-deductive reasoning	.02	(2,56)=.53	.59	.07	(3,55)=1.36	.26	.19	(3,55)=4.32	.01	.26	(4,54)=4.78	.001

Table 17. *Predicting Word-Spelling Progress Between the Middle and the End of First Grade.*

	Linear			Linear interaction			Pretest-posttest			Cusp		
	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*	R^2	*F* (df)	*p*
Linguistic skills												
Linearity of spoken language awareness	.00	(2,48)=.08	.92	.04	(3,47)=.62	.60	.29	(3,47)=6.44	.001	.29	(4,46)=4.65	.001
Articulation	.07	(2,55)=2.00	.15	.07	(3,54)=1.32	.28	.18	(3,54)=4.06	.01	.20	(4,53)=3.22	.02
Rapid naming Colors	.06	(2,52)=1.51	.23	.06	(3,51)=1.00	.40	.09	(3,51)=1.72	.18	.10	(4,50)=1.40	.25
Rapid naming Numbers	.05	(2,54)=1.32	.28	.05	(3,53)=.90	.45	.10	(3,53)=1.91	.14	.10	(4,52)=1.40	.25
Rapid naming Pictures	.01	(2,54)=.21	.81	.01	(3,53)=.24	.87	.08	(3,53)=1.50	.23	.09	(4,52)=1.28	.29
Phonological skills												
Sound awareness and rhyming	.19	(2,48)=5.43	.01	.22	(3,47)=4.36	.01	.27	(3,47)=5.72	.001	.27	(4,46)=4.15	.01
Auditory synthesis I	.09	(2,48)=2.33	.11	.16	(3,47)=2.91	.04	.24	(3,47)=5.00	.001	.24	(4,46)=3.59	.01
Auditory synthesis II	.35	(2,22)=6.04	.01	.37	(3,21)=4.06	.02	.43	(3,21)=5.20	.01	.18	(4,20)=1.13	.37
Orthographic skills												
Awareness of written language	.04	(2,48)=.92	.41	.05	(3,47)=.89	.45	.27	(3,47)=5.72	.001	.27	(4,46)=4.29	.01
Letter-symbol distinction	.30	(2,50)=10.55	.001	.30	(3,49)=7.00	.001	.30	(3,49)=6.98	.001	.33	(4,48)=5.92	.001
Wordiness judgement	.09	(2,53)=2.70	.08	.09	(3,52)=1.77	.17	.13	(3,52)=2.64	.06	.15	(4,51)=2.21	.08
Memory skills												
Long-term memory	.02	(2,55)=.60	.55	.02	(3,54)=.40	.76	.16	(3,54)=3.54	.02	.17	(4,53)=2.78	.04
Short-term memory	.12	(2,55)=3.77	.03	.12	(3,54)=2.50	.07	.18	(3,54)=3.93	.01	.20	(4,53)=3.21	.02
Working memory	.02	(2,55)=.64	.53	.03	(3,54)=.45	.72	.15	(3,54)=3.21	.03	.16	(4,53)=2.52	.05
Intelligence												
Nonverbal-deductive reasoning	.05	(2,56)=1.45	.24	.05	(3,55)=.95	.42	.12	(3,55)=2.39	.08	.12	(4,54)=1.80	.14
Spelling												
Letter spelling	.04	(2,55)=1.10	.34	.04	(3,54)=.72	.54	.17	(3,54)=3.59	.02	.18	(4,53)=2.91	.03

Discussion

This study was designed to investigate the main predictors of the *level of* and the *progress* in letter reading, word reading, letter spelling, and word-spelling abilities in first grade for children with language and communication problems. Although a lot of studies have focused on the predictors of the *level* of early literacy skills, we are unaware of a study that has focused on the predictors of *progress* in these skills. Moreover, in the vast majority of cases standard procedures of linear regression analyses were conducted to predict literacy levels. In the present study, we used three linear and one nonlinear regression models to examine relationships between various literacy measures over a period of one and a half year. They were first tested when they were in the middle of second year of kindergarten. Tests to examine their linguistic, phonological, orthographic, and reading skills were administered. The second moment of measurement took place when the children were in the beginning of first grade. At this moment of measurement, tests for linguistic, memory, and spelling skills were examined. The third moment of measurement took place when the children were in the middle of first grade. At this moment, tests for linguistic, reading, and spelling skills and for intelligence were examined. The fourth moment of measurement took place when the children were in the end of first grade, and they were tested on reading and spelling.

Predicting levels of early literacy skills

The first aim of the present study was to investigate the predictors of the *level* of letter reading, word reading, letter spelling, and word spelling for children with language and communication problems. It appeared that for all these literacy skills, the pretest-posttest model best fitted the data. There were no large differences between the R^2's among the different analyses of the model. This means, it does not matter which predictor was put into the model (i.e., which *a* variable), the fit of the model remained approximately the same. Consequently, all predictors seem to have some influence on the prediction of the literacy skills. However, there was a huge difference between the R^2's of the pretest-posttest model and the R^2's of the other models. The crucial difference between the pretest-posttest model and the other models is the inclusion of the Y_1-variable, the pretest value, into the model. The substantial increase of the values of R^2 when adding the pretest to the model, implied that by far the best predictor of the level of the literacy skill, was the same literacy skills at an earlier point in time. Thus, the best predictor of letter reading, word reading, letter spelling, and word-spelling level in first grade is the same skill at an earlier point in time (i.e., the middle of kindergarten, the beginning of first

grade, and the middle of first grade). We take these outcomes as a signature of autocatalytic processes regarding the acquisition of letter learning, learning to read, and learning to spell. These results are in line with results of recent research on children with SLI. Van Weerdenburg (2006) concluded that word reading at age 8 was predicted by word reading at age 7. According to the results of Botting, Simkin, and Conti-Ramsden (2006), reading at age 7 predicted reading at age 11. Catts et al. (2002) concluded that the best predictor of reading level at fourth grade was reading level at second grade.

Predicting progress in early literacy skills

The second and main aim of the present study was to investigate the predictors of *progress* in letter reading, word reading, letter spelling, and word spelling for children with language and communication problems. With respect to progress in letter reading between kindergarten and first grade, and letter spelling and word spelling in first grade, it is clear that the pretest-posttest model and the cusp-catastrophe model best fitted the data. Almost all analyses of these models were significant, whereas none or very few of the linear and the linear-interaction model reached significant levels. The crucial difference between the pretest-posttest and cusp-catastrophe model on the one hand and the linear and linear-interaction models on the other hand is the inclusion of the Y_1-variable or the pretest value to the model. The increase of the values of R^2 when adding the pretest to the model, implied that the best predictor of progress in letter reading, letter spelling, word reading, and word spelling was the same skill at an earlier point in time. There were no large differences between the R^2's among the different analyses of the pretest-posttest and cusp-catastrophe predictor models, which means that all predictors have some influence on the prediction of the progress in letter reading, letter spelling, and word spelling. However, this influence is negligible compared to the predictive value of the literacy skills itself. The fact that progress in letter reading, letter spelling, and word spelling was best predicted by both the pretest-posttest model and the cusp-catastrophe model means that the pattern of progress is not necessarily nonlinear. It seems that literacy progress of these special-education students in these skills between kindergarten and first grade follows a linear pattern, also referred to as a continuous change. This continuous change is represented by Path B in Figure 1.

The progress in letter reading and word reading, both between the middle and the end of first grade, is clearly best described by the cusp-catastrophe model. Since the linear models do not fit the data very well. The pattern of progress is clearly nonlinear, which means that progress of students may reveal a discontinuous change, or a sudden jump. This discontinuous change is represented by Path A in Figure 1. It is important to note that children who started with a similar

level of letter reading or word reading may follow different developmental trajectories. That is, literacy development of one child may reveal a continuous path, whereas that of another child shows clear signs of a discontinuous path. Two nonlinearly developing children who start with almost the same literacy levels may end up quite differently in the end: one who is a relatively good and the other who is a relatively poor reader. From our data, it appears that this discontinuous change took mainly place between the middle and the end of first grade.

Progress of different groups

Additional inspection of the data revealed some interesting effects. We have split the group of children into three different groups, based on their beginning level of letter reading, word reading, letter spelling, and word spelling. Each group (i.e., low, moderate, and high starting level) contains approximately the same number of children. For word reading, a significant interaction effect emerged, $F(2,62) = 10.43$, $p < .001$. The high-starting level group made significantly more progress than the low and the moderate-starting level group (all p's $< .001$). No significant differences existed between the low and the moderate-starting level group. This finding for word reading is in line with the Matthew effect (Stanovich, 1986; Verhoeven & Van Leeuwe, 2003). Children with a high reading level are getting better, whereas the children with a low reading level are getting poorer. In contrast, for letter reading, letter spelling, and word spelling, the children with a low starting level made the most progress compared to children with a high starting level (all p's $< .001$). This is possibly explained by the ceiling effects of the tests for letter knowledge and for spelling. When children know all the letters, they can not reach a higher level.

Implications for future research

The results of the present study revealed a substantial progress in the number of letters children can read and spell between kindergarten or the beginning of first grade and the end of first grade. For letter reading, letter spelling, and word spelling, the results of the present study show that even children with a low beginning level made subtsantial progress, and consequently reached a high level at the end of first grade. Based on these results, we hypothesize that by means of proper literacy education, even children with a low starting level can reach a high ending level. After all, children who knew only a few letters at the beginning as compared to their peers who knew three times as many letters, still performed at an almost similar level as their precocious classmates (85% correct for letter knowledge and 68% for letter spelling at the end of first grade). We believe that it is possible for all children with language and communication

problems to learn all letters in one year. The results of the present study indicate that the predictive value of letter knowledge, phonological awareness, rapid naming and working memory is negligible compared to the predictive value of the early literacy skills itself. Consequently, it is important that future research will focus on the early literacy skills itself in stead of focusing on predictors that have scarcely any predictive value.

The results of the present study are based on children with language and communication problems. However, the results are most probably also applicable for children from mainstream education. Future research is necessary to confirm this assumption. Note that, the present results are based on the Dutch orthography. However, we hypothesize that the results of the present study also apply to other alphabetic languages, which asks for cross-linguistic studies in the future.

Implications for educational practice

Our findings also have implications for educational practice. Kindergarten teachers serve their students best when they practice skills that are directly related to the literacy. That is, teaching them to recognize and write down letters, and segment and blend letters and sounds. Bosman (2007) and Vernooy (2007) both acknowledge and have proven that dedicated and knowledgeable teachers can make all the difference. Bosman (2007) showed that special-education students can reach a reading and spelling level that is not different from that of regular-education students once teachers devote themselves to the task according to evidence-based didactics.

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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	$u
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	$u
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. 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 D. 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 E. Letter 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]