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Predicting Delayed Letter Knowledge Development and its Relation to Grade 1 Reading Achievement among Children with and without Familial Risk for Dyslexia

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Abstract

The developmental trajectories of children's early letter knowledge in relation to measures spanning and encompassing their prior language-related and cognitive measures and environmental factors and their subsequent Grade 1 reading achievement were examined. Letter knowledge was assessed longitudinally at ages 4.5, 5.0, 5.5, and 6.5 years, the preceding language skills and environmental factors at ages 3.5 and 4.5 years, and reading achievement at the beginning and end of Grade 1. The analyses were conducted on a longitudinal data set involving children with and without familial risk for dyslexia. Three separate clusters emerged from the trajectory analysis of letter knowledge; delayed (N =63), linearly growing (N = 73), and precocious (N = 51). The members of the delayed cluster were predominantly children with familial risk for dyslexia and the members of the precocious cluster were predominantly non-risk group children. In terms of language and cognitive skills, phonological sensitivity, phonological memory and rapid naming skills predicted delayed letter knowledge. Environmental predictors included level of maternal education and the amount of home-based letter name teaching. Familial risk for dyslexia made a significant contribution to the predictive relationships. Membership of the delayed cluster was a better predictor of poor reading performance at Grade 1 than membership of any of the alternative clusters.

Keywords: Letter knowledge development, home environment, language skills, familial dyslexia risk, and beginning reading

Predicting Delayed Letter Knowledge Development and its Relation to Grade 1 Reading Achievement

Mastery of the basic mechanics of reading, that is, in terms of associating sounds with letters and using these components to form words, requires both language skills and letter knowledge (Bowman & Treiman, 2004; Byrne, 1998; Lonigan, Burgess, & Anthony, 2000; Whitehurst & Lonigan, 1999, 2001). Of the language skills, phonological sensitivity or awareness (i.e. a child's readiness to attend to the phonological structure of spoken words, rather than their meanings and syntactic roles) has received wide attention because of its documented links to both reading development (Bradley & Bryant, 1983; Bryant, MacLean, Bradley, & Crossland, 1990; Lonigan et al., 2000; Lundberg, Olofsson, & Wall, 1980; Snow, Burns, & Griffin, 1998; Wagner & Torgesen, 1987) and reading difficulties (Byrne, 1998; Elbro, Borstrom, & Petersen, 1998; Gallagher, Frith, & Snowling, 2000; Pennington & Lefly, 2001; Puolakanaho, Poikkeus, Ahonen, Lyytinen, 2004; Snowling, Gallagher, & Frith, 2003). While phonological sensitivity has long been acknowledged as having strong associations with later reading skills, letter knowledge is also credited with such strong (or even stronger) associations (Adams 1990; Byrne, Fieldings-Barnsley, & Ashley, 2000; Aro, Tolvanen, Poikkeus, & Lyytinen, 2003; Cardoso-Martins, 1995; de Jong & van der Leij, 1999; Elbro et al., 1998; Gallagher et al., 2000; Lonigan et al., 2000; McBride-Chang, 1999; Pennington & Lefly, 2001; Scarborough, 2001; Shatil, Share, & Levin, 2000; Snow et al., 1998). Indeed, Snow et al. (1998) have suggested that letter naming ability is almost as successful at predicting future reading as is an entire reading readiness test.

Considering the plethora of evidence relating letter knowledge to subsequent reading skill, it is surprising that research concerning the cognitive basis of letter knowledge is so scarce (de Jong & Olson, 2004). De Jong and Olson suggest that one potential reason for this lack of research may be traced to an assumption, also backed by findings from both correlational (e.g. Aram & Levin, 2004; Burgess, Hecht, & Lonigan, 2002; Bus, van IJzendoorn, & Pellegrini, 1995; Byrne, et al., 2002; Cunningham & Stanovich, 1993, 2001; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002, Shatil et al., 2000) and twin studies (e.g. Samuelsson, et al., 2005; Samuelsson & Lundberg, 1996), that orthographic knowledge is very strongly reliant upon environmental input. Admittedly, letter knowledge requires environmental exposure to printed material, but environmental factors do not appear to explain the total variability in letter knowledge. In addition to initial exposure to letters, cognitive processing skills are required in order to facilitate the storage of permanent memory representations of letters. Individual variation in letter knowledge has been explained as relating to differences in children's abilities in, for example, phonological sensitivity (Burgess & Lonigan, 1998; Lonigan et al., 2000), vocabulary (Lonigan et al., 2000), rapid naming, and phonological (verbal short term) memory (de Jong & Olson, 2004).

To our knowledge, only two studies have directly examined the effect of individual differences in early cognitive abilities on the development of letter knowledge. Lonigan et al. (2000) found that letter knowledge was predicted by earlier measures of phonological sensitivity (see also Burgess & Lonigan, 1998; Wagner, Torgesen, & Rashotte, 1994) and oral language composites (for other positive correlations see de Jong & Olson, 2004; Frijters, Barron, & Brunello, 2000; Lonigan et al., 2000, but note zero correlation between letter knowledge and vocabulary in Sénéchal & LeFevre, 2002). Measures of children's non-verbal IQ, concepts of print, or ability to "read" environmental print (signs etc.), did not predict letter knowledge in the study by Lonigan et al. (2000). In a more recent study, de Jong and Olson (2004) found that phonological memory (particularly nonword repetition) predicted letter knowledge, and rapid serial naming also exerted a small independent effect on letter knowledge. Vocabulary knowledge, however, did not predict letter knowledge after phonological memory was controlled for. Although the above-mentioned studies provide a basis for theoretical understanding, replications in order to corroborate the findings are clearly required.

The present study extends earlier empirical work by investigating longitudinally the development of letter knowledge in a sample of children with and without familial risk of dyslexia. Furthermore, the study focuses on individual development with several measurements within an age range that has the potential to capture the learning process and includes a comprehensive set of known letter knowledge predictors. It has been claimed that, with their emphasis on group means, and variances, the variable oriented methods may lead to inaccurate or even erroneous conclusions, particularly when there is heterogeneity in the development (Bergman, 2001; Bergman, Magnusson, & El-Khouri, 2003; Magnusson, 2001). In a design that contains an at-risk population, the focus on differences in individual development is particularly important as different developmental subgroups with different learning process are expected to exist. In the present study, we employed trajectory analysis which allowed us to analyze developmental data at an individual level and to search for similarities and differences among individuals in their letter knowledge development. As the next step, we aimed to identify both relevant early predictors of letter name learning and developmental paths leading to poor beginning reading skills. As predictors of letter knowledge, we included not only those employed in the previous studies (de Jong & Olson, 2004; Lonigan et al., 2000) i.e., phonological sensitivity, phonological memory, vocabulary, and rapid serial naming, but also aspects of the home literacy environment and the impact of familial risk for dyslexia. Next, we review the rationale behind the predictive associations that we expect to emerge concerning these predictors.

The link between phonological awareness (particularly phonemic awareness) and letter name learning is easy to understand since letters are used to represent phonemes in written language. An association between phonological sensitivity and letter knowledge has been shown in several studies and appears to be reciprocal in nature (e.g. Bowey, 1994; Burgess & Lonigan, 1998; Carroll, et al., 2003; Johnston, Anderson, & Holligan, 1996; Lonigan et al., 2000; Morais, 1991; Wagner et al., 1994; Pennigton & Lefly, 2001). Children who have no knowledge of letters also have low levels of phonemic awareness (Bowey, 1994; Johnston et al., 1996). In accordance with this, we have also observed that the letter knowledge of the 3.5 year-old children in our sample was very modest (Laakso, Poikkeus, Eklund, & Lyytinen, 2004) and correspondingly, the children had little ability to deal with phonemes (Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2003) although they manifested phonological sensitivity with respect to larger units, such as words and syllables (for similar developmental patterns see also e.g. Burgess & Lonigan, 1998; Carroll et al., 2003; Lonigan et al., 2000).

Short-term memory for sound-based information, referred to as phonological memory (Baddeley, Gathercole, & Papagno, 1998), or verbal short-term memory, has also been associated with the learning of letters (de Jong & Olson, 2004). Phonological memory has typically been elicited with tasks such as nonword repetition, digit span, and sentence or word repetition (e.g. Baddeley et al., 1998; Bowey, 2001; de Jong & Olson, 2004). Baddeley et al. (1998) have suggested that nonword repetition may be the purest measure of phonological memory (or the phonological loop) because a child cannot rely on lexical support for this task. On the other hand, it has been noted that nonword repetition is a complex measure that involves several other phonological processing abilities in addition to memory capacity (for more details, see Bowey, 2001) and beginning with accuracy of speech perception. According to Bowey (2001), the association between vocabulary and nonword repetition may reflect a latent phonological processing factor that also manifests in phonological sensitivity. In the present study, the predictive value of the most common measures of phonological memory (i.e. nonword repetition, sentence repetition, and digit span) in relation to subsequent letter knowledge development can be examined.

The relation between letter name learning and phonological memory is not surprising if, as suggested by Share (1995), we consider letter names as novel words. The formation of representations for novel words in long term memory requires a good temporary representation of the novel word in the phonological loop (see e.g. Baddeley et al., 1998), and the learning of novel items in vocabulary has been shown to be associated with phonological memory (e.g. Gathercole & Baddeley, 1989, 1990a, 1990b; Papagno &Vallar, 1992; Service, 1992). Advocates of the lexical restructuring account dispute a direct causal connection from phonological memory capacity towards vocabulary development (e.g. Fowler, 1991; Metsala & Walley, 1998), preferring to argue that phonological processing abilities develop in line with the increased storage system efficiency in the course of vocabulary growth. Views concerning the direction of causality between vocabulary and phonological processing aside, we expect, following the reasoning of de Jong & Olson (2004), that both vocabulary and phonological memory measures reflect the current state of phonological representations. Based on de Jong and Olson’s finding of no significant predictive relation between vocabulary knowledge and letter naming after controlling for phonological memory, we suspect that it is the common part shared by vocabulary skills and phonological memory that reflects the level of phonological representations necessary for letter name learning.

One more potential predictor of letter knowledge development is the efficiency and automaticity with which phonological information from long-term memory, tapped by rapid serial naming tasks (RAN with colors, objects, digits, or letters) is retrieved. Serial naming skills have been shown to be associated with reading acquisition (Manis, Seidenberg, & Doi, 1999; Wolf & Bowers, 1999), and particularly with reading fluency (Holopainen et al., 2002; Wimmer & Mayringer, 2002; Wimmer, Mayringer, & Landerl, 2000). These associations are understandable since rapid naming of objects requires visual processing of targets and rapid retrieval of their names from memory. Some researchers view RAN tasks as representing a sub-domain of phonological processing (e.g., Whitehurst & Lonigan, 2001), while others consider the processes measured by RAN tasks to be independent of phonological processing (Manis et al., 1999; Wolf & Bowers, 1999). De Jong and Olson (2004) found that rapid naming of objects had an independent effect on letter knowledge, even after controlling for nonword repetition. However, the effect was smaller than that of phonological memory. De Jong and Olson interpreted their finding as support for Manis et al.'s (1999) view that RAN partly reflects the ability to learn arbitrary relations. In line with de Jong and Olson, we expect an association between RAN and letter knowledge, independently of phonological sensitivity, phonological memory and vocabulary.

The literature contains strong assumptions and substantial documentation of environmental influences on the development of orthographic skills, such as letter knowledge (e.g. Aram & Levin, 2004; Burgess, Hecht, & Lonigan, 2002; Byrne, et al., 2002; Cunningham & Stanovich, 1993, 2001; Samuelsson, et al., 2005; Samuelsson & Lundberg, 1996; Sénéchal & LeFevre, 2002, Shatil et al., 2000). Findings with regard to the strength of environmental effects are, however, somewhat mixed due to differences in the ages of children and wide variation in the environmental measures (see reviews by Bus, van IJzendoorn, & Pellegrini, 1995; Scarborough & Dobrich, 1994). Using an indirect measure of child's print exposure (parental recognition test of children's books, titles and authors' names), Cunningham and Stanovich (1993, 2001), for example, showed that print exposure had an independent effect on orthographic processing after the variance in phonological awareness was accounted for. Frijters et al. (2000) used a composite measure of home literacy environment (HLE, including e.g. parental reports on library visits, frequency of book reading, and number of books at home) and found that phonological awareness mediated the HLE's relationship with written language. Children in the Cunningham and Stanovich study had already received several years of reading instruction (aged around 7 to 8 years) whereas the children in the Frijters et al. (2000) study were at the entry phase (aged around 5 to 6 years). According to the studies by Sénéchal and others (Sénéchal & LeFevre, 2002; Sénéchal, LeFevre, Thomas & Daley, 1998), mere exposure to books is insufficient to support letter knowledge. Their findings indicated that parental teaching of reading and writing, rather than the amount of shared reading, is associated with first grade children's written language skills (i.e., print concept, letter knowledge, invented spelling and word identification). Also, the quality of the assistance provided by the mother for writing (Aram & Levin, 2004) and the children's own interest in reading (Frijters et al., 2000) is found to be associated with kindergartners' literacy skills. Of the typically used HLE measures, we included in our model the amount of parental teaching of letter names, and the degree of shared reading exposure. Parental report on child's literacy interest and parent's education level were also included. In line with earlier findings, we expected parental teaching of letter names to show the largest effect on emerging letter knowledge (see Sénéchal & LeFevre, 2002; Sénéchal, LeFevre, Thomas & Daley, 1998).

The development of letter knowledge is of particular interest in regular languages such as Finnish where the grapheme-phoneme correspondence is highly consistent (e.g. Lyytinen, Aro, & Holopainen, 2004). In contrast to more opaque languages (such as English), there are no idiosyncrasies in the Finnish language and each letter indicates only one phoneme, independent of the context in writing. This regularity is complete with only one exception (the only two letter Finnish grapheme, 'ng'). The relations between letter names and sounds are contractual in the case of consonants. In Finnish, a consonant letter name contains the phoneme that the consonant represents and an additional vowel sound which is placed either before or after the consonant sound to ease the pronunciation (e.g., the letter name for the phoneme /k/ is pronounced as /koo/). In the case of vowels, the letter name is always identical with the phoneme. Furthermore, the number of Finnish letter-sound correspondences is relatively small (23) and learning to decode is thus a faster process in Finnish than in many more complex orthographies (e.g. Seymour, Aro, & Erskine, 2003). While learning of the letter-sound correspondences effectively predicts the acquisition of decoding skill in the context of the Finnish language (e.g. Holopainen, Ahonen, Lyytinen, 2001), not all children learn such correspondences with ease and a proportion of children encounter problems in subsequent phases of assembly and fluency (e.g. Aro & Wimmer, 2003). Consequently, it is of great interest to examine why the learning of these few letter-sound correspondences can be so difficult for some children in a language devoid of rules of exceptions, irregularities, or inconsistencies.

One such group with high incidence of problems in learning letter names and sounds are children with familial risk for dyslexia (e.g. Elbro et al., 1998; Lyytinen et al., 2004; Pennington & Lefly, 2001; Scarborough, 1990; Snowling et al., 2003). Children from families where several members have reading disabilities run a higher than normal risk of facing difficulties in learning to read (Gilger, Pennington, & DeFries, 1991; Pennington et al., 1991; Scarborough, Dobrich, & Hager, 1991; Snow et al. , 1998; Snowling et al., 2003), and behavioral and molecular genetic research has confirmed that dyslexia has a hereditary basis (e.g. Cardon et al., 1994; Finucci, Guthrie, Childs, Abbey, & Childs, 1976; Fisher et al., 1999; Hallgren, 1950; Olson, Datta, Gayan, & DeFries, 1999; Taipale, et al., 2003). It should be noted, however, that complex skills such as reading, develop in the interplay between shared genetic and shared environmental factors (e.g. Plomin, 1994, Rutter et al., 1997) and both cognitive and environmental compensation is possible. In addition to problems in reading and letter knowledge, children with familial risk of dyslexia have been found to have higher than normal incidence of difficulties in several language skills (Lyytinen et al., 2004; Lyytinen & Lyytinen, 2004; Scarborough, 1990; Snowling et al., 2003). These findings support the suggestion presented by several researchers (Byrne, 1998; Catts, 1996; Elbro et al.,

1998) that dyslexia has its basis in language skills. Our prospective longitudinal study that compares children born to dyslexic parents and their age-matched controls, afforded us the opportunity to include information of familial dyslexia risk into our analyses concerning difficulties in letter knowledge development. If language skills mediate the effect of familial risk on letter name learning, as we suspect, the language basis of reading difficulties receives further support.

Our first goal was to examine how letter knowledge develops before entry to formal instruction and the extent to which individual variability is seen around the average developmental curve. We aimed to identify potential subgroups of children with distinct paths of letter knowledge development. A rapid and heterogeneous growth of letter knowledge within the age window of interest here (4.5 - 6.5 years) was expected (see e.g. Burgess et al., 2002; Carroll et al., 2003; Pennington & Lefly, 2001). Second, we were interested in how children with heightened risk for problems in reading and pre-reading skills (i.e. children with familial risk for dyslexia), learn letter names as compared to children without such risk. Children with familial risk of dyslexia were expected to show slower letter name learning than children without such risk (Elbro, et al., 1998; Gallager, et al., 2000; Pennington & Lefly, 2001). Third, we examined which preceding language skills and environmental factors differentiate children with differing paths in letter knowledge development. We hypothesized that slow letter knowledge development would be predicted by less optimal skills in phonological sensitivity, phonological memory, vocabulary and rapid naming (de Jong & Olson, 2004; Lonigan, et al., 2000). The measures tapping children's skills in phonological processing, i.e. phonological sensitivity and memory were expected to mediate the predictive association between vocabulary and letter name learning (de Jong & Olson, 2004). Based on earlier research (c.f., Sénéchal & LeFevre, 2002; Sénéchal et al., 1998), parental teaching of letters was expected to emerge as the most influential environmental factor, but children's interest in reading was also expected to show a predictive relationship with the development of letter knowledge (Frijters et al., 2000). Furthermore, we expected to find that familial risk for dyslexia is associated with problems in language skills, particularly in terms of at-risk children with difficulties in language skills showing less optimal letter knowledge development with negative effects on emergent reading preparedness. Fourth, we examined the predictive association between children's letter knowledge trajectories and reading development during Grade 1. Children with slow letter knowledge development were expected to perform at a lower level in beginning reading (Adams 1990; Elbro, et al., 1998; Gallagher, et al., 2000; Lonigan, et al., 2000; Pennington & Lefly, 2001; Scarborough, 2001; Snow, et al., 1998).

Method

Participants

Data for this study were drawn from the Jyväskylä Longitudinal Study of Dyslexia (JLD), a prospective follow up of children from birth to school age. The JLD seeks to identify early language development and precursors of dyslexia (for the most recent review of results, see Lyytinen, et al., 2004). From four successive age cohorts of families invited for screening, a total of 214 families from the city of Jyväskylä and its surrounding communities in the Province of Central Finland joined the study prior to the birth of their children. Half of the participating families include a parent who has been diagnosed with dyslexia and who reports similar problems among immediate relatives. The children from these families are referred to as the at-risk group. The non-risk group comprises children from families whose parents gave no personal or familial report of reading or spelling difficulties. Parents also underwent extensive cognitive and literacy-based assessment (see Leinonen, et al., 2001 for full details). In terms of distribution, the level of parental education is representative of the Finnish population. All the children are native Finnish speakers and have no mental, physical, or sensory difficulties.

This study includes data for 186 children, 96 at-risk children (50 girls, 46 boys) and 90 non-risk children (40 girls and 50 boys), for whom a reasonably full data set of measures was available from the assessment phases between ages 3.5 and 6.5 years. At the present stage of the JLD study whereby the youngest of the four cohorts is now entering 3rd grade in school, attrition rate is low with 199 of 214 families continuing to participate in the project, including all children comprising the current data set.

Measures

Letter knowledge

For the younger children, age 4.5, 5.0 and 5.5 years, four ‘sets’ (/A S I K E M/, /O P N T U H/, /L R J V Ö Ä/, /G Y B D F/) of 23 upper case letters were organized according to the order taught in Finnish ABC books. This order is based on the order of their frequency of occurrence in Finnish words and also reflects the ease of pronunciation. It should also be noted that Finnish children do not receive formal instruction in the alphabet before 6 years of age. Furthermore, they are not exposed to any rote learning of the alphabet, such as typically occurs in the teaching of the English alphabet embedded in an ‘ABC song’. The reason for using only upper case letters stems from this same background: in Finnish kindergarten education, children are exposed only to capital letters and lower case letters are rarely introduced before 1st grade.

Beginning first with the letter comprising the first letter of the particular child’s name, each child was presented with each letter singly on its own page and proceeding through the order of the sets. At age 6.5 years, children were presented with all 29 letters, including 5 letters which occur only in loan words (e.g. ‘pizza’; C, Q, W, X, Z) and, as Swedish is the second official language of Finland, the letter Å (A with Swedish umlaut; although unlikely to be encountered before formal instruction). None of the six letters excluded from the younger children’s battery have their own phoneme in the language. The task requirement was to name each of the letters, with one point awarded for each correct response (the provision of either a phoneme or letter name was accepted as a correct response). Testing was discontinued if the child was unable to name any items within a given set of letters with the rationale that, if the child did not recognize any letters of the easier set (e.g. the first letter of their own name and those with the highest frequency of occurrence), it was unlikely that she/he would be able to name the less frequently occurring letters. Also, experiences from piloting supported the use of a discontinuation rule to avoid potential anxiety and frustration caused by long testing sessions. To create identical measures for the trajectory analysis, only responses to the 23 letters presented at all ages were used in the analyses.

Vocabulary

Measures of the children's vocabulary skills at 3.5 years of age were obtained using tests of word production and language comprehension. Cronbach's alpha for the composite of the tasks was .72. A composite mean was calculated from subtest scores which were standardized with respect to the non-risk group's mean and standard deviation.

Word Production. The Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1983) is a measure of visual confrontation naming which taps word retrieval skills and is often used to diagnose word-finding problems (see Kirk, 1992). The Finnish translation of the BNT (Laine, Koivuselkä-Sallinen, Hänninen, & Niemi, 1997; for process of adaptation see Laine, Goodglass, Niemi, Koivuselkä-Sallinen, Tuomainen, & Marttila, 1993) contains 60 pictured items which the child is asked to name. Testing is continued until six consecutive errors are incurred. The score is based on the total number of items that are spontaneously correct plus the number of items correctly identified following a semantic stimulus cue (e.g., violin – an instrument, tennis racket – you play a game with it).

Language Comprehension. The Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981) is an individually administered measure of receptive vocabulary. Each test item contains four black-and-white illustrations. The child is asked to point to the picture which best represents the meaning of the word presented orally by the examiner: "Each time I say a word, you say the number of the picture, or point to the picture that best describes the meaning of the word. Now show me/where is ...". The level of difficulty of the test items (75 in the Finnish version) ranges from easy for 2-year-olds (e.g., bed) to difficult for adults (e.g., cornea, perpendicular). The starting point is based on the participant's age, and the test is interrupted after 6 errors in 8 consecutive items. Because the PPVT-R has not yet been standardized in Finland, the raw sum score of correct items (Form L) was used (Cronbach's alpha = .98).

Phonological sensitivity

Performance in phonological sensitivity was assessed at age 3.5 with tasks requiring identification of word and sub-word segments, synthesis and continuation. All of the tasks were computer based and the child's responses were recorded automatically via touch screen or the child's oral responses were coded on-line by the experimenter and recorded in digital sound files (for details see Puolakanaho et al., 2003). Cronbach's alpha for the composite of the four phonological sensitivity tasks was .54. A composite mean was calculated from subtest scores which were standardized with respect to the non-risk group's mean and standard deviation.

Identification of word size segments from compound words (8 items). The child was presented with three pictures of objects with simultaneous pronunciation of the name of the illustrated objects (e.g. 'lentokone' [aeroplane]; 'soutuvene' [rowing boat]; 'polkupyörä' [bicycle]). All targets were compound words and the child was required to identify the picture on-screen containing a specified part of the compound (e.g. in which picture can you hear the sound 'kone' (plane)?). Two practice items were administered for each child, and a third practice followed automatically if the child failed the first two. Of the children, 87.7 % performed above chance level.

Identification of subword segments (8 items). The task was the same as in the word level identification task but with the requirement to identify sub-word level units within the target (e.g. the /koi/ in the word 'koira' (dog)). In two items, a bi-syllabic target was used and in six items, the target unit consisted of one syllable. No practice items were given as the procedure was identical to the previous task. Of the children, 81.5 % performed above chance level.

Synthesis (12 items). The child was presented with segments (words, syllables, or phonemes), each separated by 750 msec. with the task requirement to blend the segments and to pronounce the resulting word that was presented in small pieces (e.g. *per-ho-nen* (butterfly)). One test item consisted of a compound word, eight items required synthesis of syllables, and three items required synthesis of syllables and phonemes. Only a response containing the correctly assembled form was coded as correct and one point was awarded for each correct answer. The principle of assembly was reinforced in two practice items.

Continuation (8 items). The child was presented with the onset of a "secret" word and asked to guess how the word would continue (e.g. 'mu-?). In some of the items, the syllable easily elicited a word known by most children (e.g. "veit-" -> "veitsi" (knife) whereas in others, the syllable could mark the beginning of a number of words (e.g., "mu-" -> "muna", "muki", "muumi", "musta").

Only continuations producing meaningful words were coded as correct. There were two practice items.

Phonological memory

Children's phonological memory was measured through tasks of sentence and nonword repetition obtained at 3.5 years of age. Cronbach's alpha for the composite of the measures was .58. A composite mean was calculated from subtest scores which were standardized with respect to the non-risk group's mean and standard deviation.

The sentence repetition task was administered in association with the Developmental Neuropsychological Assessment (NEPSY; Korkman, Kirk, & Kemp, 1998), a neuropsychological test battery designed for children aged 3 to 12 years. In this test, the child is required to repeat sentences that are read aloud by the examiner. One point was awarded for each correct repetition.

The nonword repetition task is also a subtest of the Finnish version of the NEPSY whereby the child is required to repeat verbatim, verbally-presented meaningless words. The stimuli are arranged in series of increasing complexity and length from monosyllabic items (e.g., nas) to polysyllabic items (e.g., plotsiskäntsigis). One point was awarded for each correct repetition.

Digit span was assessed at 3.5 years of age using the typical procedure described in the literature (e.g., Gathercole & Adams, 1994) whereby the child is required to repeat a series of spoken digits of increasing length. Beginning with two digit lengths, two lists were administered at each length, with a third issued when only one of the two lists was recalled. Test cut-off followed two consecutive failures at a similar length. The score used in the analyses was the number of correctly repeated lists.

Rapid naming

Rapid serial naming was assessed at age 3.5 years using the standard procedure (see Denckla & Rudel, 1976) in which the child was asked to name as rapidly as possible a series of 5 visual stimuli with which they had become familiarized. The score at this age was based solely on rapid naming of objects within a reduced (30-item; 5 stimuli by 6 times random presentation) matrix. Total matrix completion time (seconds) was used as the measure.

Performance IQ

A short-form of the WPPSI-R (Wechsler Preschool and Primary Scale of Intelligence-R; Wechsler, 1989) was administered at 5.0 years of age. The three performance quotient subtests (Block Design, Object Assembly, and Picture Completion) comprised the performance IQ measure. The children's performance IQ was estimated based on these subtests according to the standard guidelines outlined in the manual.

Home literacy environment and child's literacy interest

When the children were 4.0 years old, we asked the parents to complete the Reading Habits Questionnaire. This covered various features of the home literacy environment (e.g., access to written language and the amount of shared reading) and the child's foci of interests. In addition, during the child's laboratory visit at age 4.5, parents' reported on how often they taught letters to their children. Parental education was assessed during the initial participation within the JLD project.

Shared reading. To form a composite score of shared reading, we derived parental reports concerning both the frequency and amount of time devoted to the child's reading activities in the home. Shared reading frequency included: 1) mother reads to the child, and 2) father reads to the child. Parents responded to the items using a five-point scale (1 = not at all/seldom, … , 5 = several times a day). The amount of time spent with print materials included: 1) the typical duration of a reading episode when the child is reading with an adult, 2) the total amount of time in a day that the child spends reading a book with an adult. Responses to these items were allocated using a 3–point Likert scale (1 = less than 15 min/day, … , 3 = longer than 45 min/day). A shared reading composite was calculated from the sum of the scores on these four items.

Children's literacy interest. Parents were asked to estimate their child's interest in various activities with a 5-point Likert scale (1 = not at all interested, … , 5 = very interested). Altogether, 11 different activities were listed. Of these activities, two concerned reading: 1) picture books and children's magazines, and 2) listening to storytelling. To estimate child's interest, we created an interest preference score by dividing the mean of the items concerning reading activities by the mean of the items concerning all listed activities. In using this contrast between reading activities and other types of activities, we obtained the parent's view on their child's level of interest in reading proportioned to the amount of interest reported in general. This method allowed us to reduce the error variance caused by the differing ways in which to interpret or answer such multiple-choice questions entailing less precise choices (e.g., interested or very interested). The value '1' indicates parental evaluation of the child's equivalent interest in reading materials and in other activities. Values below 1 are indicative of less interest in reading activities and above 1 values indicate special interest in reading activities.

Teaching letter names. When the child reached 4.5 years of age, the parents were asked to estimate the extent of letter name and reading instruction provided to the child in the home. Responses to the questions, "How often do you teach your child letters names at home", and "How often does the child ask you about letters?" comprised the measure on how often a child receives teaching on letter names. In both of these questions, a 5 point Likert scale (1 = Not at all,…, 5 = Every day) was provided. However, an additional alternative (6 = Not anymore because the child already knows most or all letters) was also provided, because some families indicated that the original alternatives were no longer applicable. The alternative '6' generated a problem because it did not tap the same scale as the other 5 alternatives and we were thus forced to code these values of '6' as missing information. After so doing, we created a composite variable by calculating an average of responses to these two questions. This resulted in a total sample size of 163 instead of 186 (84 at-risk group children and 78 non-risk group children). We were unwilling to use imputation techniques in this case due to the amount of missing information and also because it was systematically derived from children with good knowledge of letters. Consequently, the analyses including this measure were performed with the reduced sample size.

Parental education. Parental education was classified using a 7-point scale. This scale was constructed by combining the information that the parents had given concerning their general education (originally classified using a 3-point scale: e.g., 1 = old comprehensive school education including only primary education grades,…, 3 = comprehensive school education comprising of primary and lower secondary education grades 1 through 9 plus upper secondary general school) and their upper secondary vocational education and tertiary education (originally classified using a 5-point scale: e.g., 0 = no vocational education,…, 5 = higher university degree). The final 7-point scale combined these two scales into one scale in the following way: 1 = comprehensive school education without any vocational education; 2 = comprehensive school education combined with short-term vocational courses; 3 = comprehensive school education combined with a vocational school degree; 4 = comprehensive school education combined with a vocational college degree; 5 = comprehensive school education combined with a lower university degree (Bachelor's) or a degree at a polytechnic; 6 = upper secondary general school diploma combined with a lower university degree (Bachelor's) or a degree at a polytechnic; 7 = comprehensive school or upper secondary general school diploma combined with a higher university degree (Master's or a Doctorate-level degree).

Beginning reading

Brief synopsis of the Finnish school system and reading instruction. Finnish children commence preschool in the August of the year in which they turn 6 years of age and Grade 1 in the August of the year in which they turn 7 years of age. The preschool curriculum in Finland emphasizes social skills and school readiness skills. The goal of preschool education is to evoke an interest in reading (e.g. by nursery rhymes or reading books with children) but not to teach children to read. Preschool education does not usually involve explicit training of phonemic awareness or letter names. Reading instruction in Grade 1 relies on a synthetic phonics approach. All letters are taught during the fall semester of Grade 1 and children are expected to read short stories accurately at moderate speed by the spring term of the first grade. However, almost everyone progresses to highly accurate decoding skills within the first four months of reading instruction at the latest (Seymour, et al., 2003).

The children participating in the JLD project entered normal elementary school classrooms. Since the sample was drawn from a wide area, the whole province of Central Finland, and there were four cohorts of children, very few participating children ended up as classmates (in a very rare instance four participating children attended the same class). The schools in Finland follow the same national curriculum and variation exists only with regard to specifics of instruction or practical decisions. Reading fluency was assessed twice during the first school year (November and April – 3 and 8 months after the start of formal reading instruction) and comprehension once (April). Group assessments were administered to all children within a class that included a child participating in the JLD during the normal school day and were administered by the classroom teachers with or without an assistant provided by the project.

Fluency of word decoding and sentence decoding were assessed with a nationally-normed group-administered reading achievement test (Lindeman, 2000). These are speeded word decoding tests in which the child is asked to select the correct word from four (phonologically similar) alternatives and link this to a picture by drawing a line between the two. In the word decoding fluency task, a maximum of eighty trials can be attempted within the test duration of 5 minutes. The score is the number of correct responses marked within the time limit.

Reading comprehension of sentences was a group-administered test which included 12 pictures, each with four sentences for the child to read (time limit 10 minutes). The four sentences and the associated picture form a coherent story but one of the sentences in each item contains a word with either a semantic or syntactic error (e.g. the rat jumps out of the father's shoe not his pocket, or the man holds the box with his hand not hands). The task required the child to draw a vertical line at the locus within the erroneous word in the sentence. The children's responses were coded as 0 = incorrect; 1 = detection of the sentence containing the error; 2= detection of the word with the error.

Results

Descriptive Statistics

Table 1 displays the descriptive information relating to all variables. With the exception of letter knowledge, distributions were close to normal and the incidence of ceiling and floor effects was low. As shown by Table 1, the mean performance in letter knowledge increased rapidly across the years. Changes in the distribution of letter knowledge scores (starting with a rightward skew at age 4.5 years and changing gradually towards a leftward skew) highlighted its rapid development at the group level. Examination of the individual developmental trajectories across all four time points revealed, however, that not all children were learning letters at a rapid pace. There was a great deal of individual variability around the mean curve in both the level and shape of the learning curves. The correlations between letter knowledge measured at different ages were strong (ranging between .63 and .90; see Appendix for correlation table across all the variables), but any interpretations concerning these coefficients should be approached with caution as the letter knowledge distributions are unavoidably very skewed due to the rapid and heterogeneous development.

Insert Table 1 about here.

Examination of Heterogeneity in Individual Letter Knowledge Development: Trajectory Analysis

Individual differences in letter knowledge development were examined with a trajectory analysis. There were several reasons for choosing this rather novel methodological approach. In contrast to more variable oriented methods such as traditional regression analytic techniques (which assume normally distributed variables and linear associations, and focus on means and variances of variables), a trajectory analysis can give a more accurate and detailed picture of the growth process as it is based on longitudinal data of individuals. The distribution of letter knowledge also supported the choice of this approach. As described above, letter knowledge distributions across ages and individual patterns of development showed marked heterogeneity. . Trajectory analysis identifies similarities among individual growth curves in both level and shape and calculates the amount of distinct clusters and the average growth trajectory for each cluster. The model best fitting the data (i.e. comprising an optimal number of clusters and best fitting average curve for each cluster) is selected based on the Bayesian information criteria (BIC). Trajectory analysis provides cluster membership as well as the probabilities of belonging to each cluster for each participant (see for more detailed description of the analysis method e.g. Jones, Nagin, & Roeder, 2001; Nagin, 1999; Nagin & Tremblay, 2001).

In the present study, data were analyzed with the SAS system for windows V8 (PROC TRAJ). A three-cluster model of letter knowledge development emerged as the best fitting model.

This model was defined by one trajectory cluster following a quadratic function and two trajectory clusters following a linear model (see Figure 1).

Insert Figure 1 about here

The cluster with low level and low growth is hereafter referred to as the *delayed cluster* (n = 73), the cluster with low starting level but rapid linear growth is referred to as the *linear growth cluster* (n = 62), and the cluster with high level of skill already at age 4.5 years and with a low growth rate is referred to as the *precocious cluster* (n = 51). The average probabilities for individual membership of a trajectory cluster in our final solution were convincing: prob. (delayed) =.96, prob. (linear growth) =.92, and prob. (precocious) = .97. The individual growth trajectories fitted the cluster model well (see Figure 2), and the clustering solution was similar in the children with and without familial risk of dyslexia. The gender distributions within the clusters were observed to be similar ($\chi^2(2) = 1.22$, $p = .545$). The cluster membership for each participant was saved and subsequent data analysis was performed with SPSS 11.0.

Insert Figure 2 about here

Letter Knowledge Development of Children with and without Familial Risk of Dyslexia

Cross-tabulations (see Table 2) showed significant differences in the at-risk and non-risk group children's distribution within the clusters (χ^2 (2) = 10.64, $p = .005$). Children belonging to the at-risk group children were over-represented in the delayed cluster whereas the precocious cluster comprised mainly children from the non-risk group. In the linear growth cluster, there was almost equal representation of the at-risk group and non-risk group children. Half of the at-risk group children were members of the delayed cluster and only 19 % were members of the precocious cluster. The non-risk-group children were more equally distributed across the three clusters, yet, they were somewhat under-represented in the delayed cluster compared to the linearly growing and precocious cluster. In terms of letter knowledge development, it is notable that no group differences between at-risk and non-risk children emerged within the clusters. At the group level (using analysis of variance), however, the at-risk children, performed on average at a lower level than non-risk children in letter knowledge at each time point. This was also the case for phonological sensitivity, phonological memory, and vocabulary although no other measures differentiated the groups, including performance IQ, rapid naming or any of the measures used to describe the children's home environment (see Table 3).

Insert Table 2 about here.

Examination of Differences between the Clusters

The next procedure entailed examination of differences between children belonging to the three clusters on language skill composites and variables, performance IQ, and home environment factors. The results of the analysis of variance are reported in Table 3.

Insert Table 3 about here

All of the measures, with the exception of frequency of shared reading, child's reported interest in reading, and father's education, differentiated the precocious cluster from the delayed cluster. In addition to the letter knowledge at each time point, phonological memory, vocabulary, and rapid naming differentiated all the clusters from each other. Measures of phonological awareness, teaching of letter names, and mother's education level differentiated the delayed cluster from both the linearly growing cluster and the precocious cluster but not the linearly growing cluster from the precocious cluster. The obtained differences between the clusters also remained significant in a covariance analysis when the performance IQ was set as a covariate.

We also carried out corresponding analyses of variance within the familial dyslexia risk and non-risk groups and found largely similar results as was observed with the whole data. However, in the analyses conducted separately within the groups, children in the delayed and precocious clusters were found to differ in performance IQ, only among children with familial risk of dyslexia ($F(2, 90) = 3.92$, $p = .023$ for the at-risk group, and $F(2, 86) = 1.47$, $p = .237$ for the non-risk group). On the other hand, the difference between delayed and precocious clusters in maternal education was statistically significant only among non-risk children ($F(2, 93) = 3.36$, $p = .070$ for the at-risk group, and $F(2, 87) = 3.29$, $p = .042$ for the non-risk group).

Prediction of Delayed Letter Knowledge Development

Because children belonging to the linearly growing cluster appeared to be catching up with the development of the precocious cluster children with respect to letter knowledge before school entry (See Fig. 1), it was among the children of the delayed cluster where we expected to find the children at highest risk for reading difficulties at first grade. Our next step was therefore to apply logistic regression analysis to examine which of the earlier language skills and environmental factors explained membership in the delayed cluster. We conducted the logistic regression analysis with four hierarchical steps in which we first entered the familial dyslexia risk, and second, the performance IQ. On the third step we entered home environment factors (i.e. teaching of letter names, shared reading, child's interest in reading, mother's education and father's education) and on fourth step, the language skills (i.e. phonological sensitivity, phonological memory, rapid naming, and vocabulary). In steps with several predictors, a stepwise method was used in which probability for entry was .05 with .10 for exclusion. The results of this analysis are presented in Table 4.

Insert Table 4 about here

The logistic regression analysis provided a model that fitted the data well (χ^2 (7) = 63.90, p = .000), and explained 45.0 % of the variance (Nagelkerke R^2). The model correctly classified 75.6 % of the children (71.0 % of the delayed cluster children and 79.3 % of the non-delayed children). Phonological sensitivity, phonological memory, rapid naming, mother's education and the amount of teaching of letter names were the significant predictors of a child being identified as a member of the delayed cluster in letter knowledge development. These were also the measures in which the strongest group differences emerged in the analysis of variance. Phonological sensitivity at age 3.5 showed the largest effect. When phonological sensitivity increased by one standard deviation, the odds of a child being a member of a linearly growing or precocious cluster were found to increase almost threefold (odds ratio = 2.728). A χ^2–difference testing of nested models further confirmed that language skill measures had an independent effect on letter name learning, even after controlling for the effects of risk group membership, performance IQ, and home environment factors.

To examine which of the other predictors mediated the effect of vocabulary and familial risk on the development of letter knowledge, we conducted a series of logistic regression analyses by adding each of the other predictors one by one into the model and holding performance IQ as a covariate (e.g., the effect of phonological memory on the association between delayed letter learning and vocabulary was examined with a model with performance IQ as a covariate and vocabulary entered on the first step and phonological memory entered on the second step). We found that both phonological memory and phonological sensitivity mediated the effect of vocabulary. In a series of similar regression analyses for familial risk of dyslexia, mediator effects were found only for phonological sensitivity, and for maternal education and teaching of letter names, but only when these environmental measures were added into the model together.

We also conducted logistic regression analyses within the at-risk and non-risk groups to see which measures would be the primary predictors of delayed letter knowledge development when the groups were considered separately. Performance IQ was also entered as a covariate into these within group analyses. Interesting differences were found (see Table 4). For the at-risk group, the resulting stepwise logistic regression model included two significant predictors (letter name teaching and phonological sensitivity) and explained 29.2 % of the variance (Nagelkerke R^2). The model correctly classified 71.3 % of the children (79.5 % of the delayed cluster children and 61.1 % of the non-delayed children). For the non-risk group, there were four significant predictors; phonological memory, rapid naming, letter name teaching, and maternal education. The non-risk group model explained 48.4 % of the variance (Nagelkerke R^2) and correctly classified 80.3 % of the children (64.0 % of the delayed cluster children and 88.2 % of the non-delayed children). These models fitted the data well (χ^2 (3) = 19.72, p = .000 for the at-risk group and χ^2 (5) = 32.481, p = .000 for the non-risk group).

Prediction of Beginning Reading Skills at Grade 1

The predictive value of cluster membership on beginning reading was examined by comparing the number of children within each cluster scoring one standard deviation below the mean level of the non-risk group (see Figure 3). Over half of the delayed cluster members were found to be delayed in reading fluency and reading comprehension at first grade. In the precocious cluster, the reading fluency of only one child belonging to the at-risk group was one standard deviation below the mean after three months of schooling. After four more months of schooling, even this child was performing at an average level in reading fluency, but lower than average in reading comprehension. Of the children in the linearly growing cluster, five showed low scores in reading fluency in November, three showed low scores in reading fluency in April, and nine showed low scores in reading comprehension in April.

The analysis of variance also showed significant differences in the clusters' mean levels in all the beginning reading indicators. The performance of the delayed cluster was the lowest although the mean of the linearly growing cluster was also significantly lower in all the beginning reading tasks than the mean of the precocious cluster. For the delayed cluster, almost 90% of the children scored below non-risk group mean level in all the beginning reading measures. Although children with serious problems in reading were among the members of the delayed cluster, about 70 % of the linearly growing cluster members were in fact performing somewhat below the non-risk group mean in reading fluency in November, and about half in April. In the precocious cluster, only about 20 % of the children scored below the non-risk group mean level on each of these beginning reading measures.

Insert Figure 3 about here.

Although the percentage of children with problems in beginning reading was higher in the at-risk group than in the non-risk group (percentage of at-risk children scoring one standard deviation below the non-risk group mean was 39 % in fluency in November, 26 % in fluency in April, and 39 % in comprehension, while the respective percentages in the non-risk group were 17%, 13%, and 21 %), there were no group differences in the percentages of children showing beginning reading problems within the letter knowledge clusters.

Discussion

The present study investigated letter knowledge development in children between ages 4.5 – 6.5 years and its associations to their prior language skills, home environment, familial dyslexia risk, and beginning reading achievement. To our knowledge, this is the first time that familial dyslexia risk and so many cognitive and environmental predictors of letter knowledge have been incorporated into a single study. Furthermore, the focus of this study in terms of individual development in a longitudinal data set of four measurements of letter knowledge in a highly transparent language is unprecedented. We posed four distinct questions: First, we were interested in whether there is heterogeneity in the individual development of letter knowledge. By applying a trajectory analysis on four repeated measures of letter naming we identified three distinct clusters of children; a cluster with a delayed learning curve, a cluster with an approximately linear growth curve, and a cluster with precocious development (already showing high ability by age 4.5). Second, we examined the effect of familial dyslexia risk on the course of letter knowledge development. High risk for dyslexia (i.e., at least one of the parents with diagnosed dyslexia) was found to be associated with slow letter name learning, as well as poorer skills in phonological awareness, phonological memory, vocabulary and a poorer beginning reading outcome. Third, when the whole sample was taken into consideration, delayed letter name learning was predicted by phonological sensitivity, phonological memory, rapid naming, maternal education, and letter name teaching but the effect of vocabulary was mediated through phonological sensitivity and phonological memory. Analyses conducted separately within the at-risk and non-risk groups revealed a set of somewhat different significant predictors for the groups. For the at-risk group, delayed letter knowledge development was predicted by phonological sensitivity and letter name teaching while for the non-risk group, it was predicted by phonological memory, rapid naming, letter name teaching, and maternal education. Fourth, we asked whether cluster membership predicts beginning reading development. We found that almost all the children who subsequently experienced difficulties in beginning reading were children with a delayed letter name learning curve, irrespective of whether they belonged to the at-risk or the non-risk group.

Our results support the suggestion by earlier research that certain aspects of home environment have an impact on letter name learning (e.g. Burgess, Hecht, & Lonigan, 2002; Bus, van IJzendoorn, & Pellegrini, 1995; Scarborough & Dobrich, 1994; Cunningham & Stanovich, 1993; Sénéchal & LeFevre, 2002). It is noteworthy that, as expected (Sénéchal & LeFevre, 2002; Sénéchal et al., 1998), only environmental exposure in the form of direct letter teaching, but not amount of shared story reading, was associated with letter knowledge development; both the linearly growing and precocious cluster members were shown to have received more letter name teaching at home than the delayed cluster children. Contrary to the results by Frijters et al. (2000), children's interest in reading was not found to be associated with letter knowledge development. The measure of reading interest that we used was based on parental report, whereas the measure employed by Frijters et al. (2000) entailed the child's own report, and this may have contributed to the difference in the results.

The strongest predictor of delayed letter knowledge was not, however, parental teaching of letter names but children's skills in phonological sensitivity, phonological memory and rapid naming. In children with familial risk of dyslexia, delayed learning of letter names was strongly predicted by low level of phonological sensitivity. However, in children without such risk, it was predicted by skills in tasks that require memory capacity and visual processing of targets and rapid retrieval of their names from memory (phonological memory and RAN). The strong role of memory skills in letter knowledge development of non-risk children is in accordance with the findings of de Jong and Olson (2004) with a sample of somewhat older children. The strong association between phonological memory tasks and delayed letter knowledge development was sustained even after accounting for phonological sensitivity indicating that phonological memory has predictive value, independently of phonological sensitivity. The association between rapid naming and letter knowledge development supports the view that naming speed also has a contribution to letter knowledge and is somewhat independent of phonological sensitivity and phonological memory (Manis et al., 1999; Wolf & Bowers, 1999).

The core assumptions concerning the basis of dyslexia were reflected in the finding that, within the at-risk group, phonological sensitivity emerged as the strongest predictor of delayed letter knowledge development. The strong association between early phonological sensitivity and letter knowledge development was not surprising in view of previous findings that show strong associations between these factors at about the same age (e.g., Lonigan et al., 2000) and at later ages (Bowey, 1994; Burgess & Lonigan, 1998; Carroll et al., 2003; Johnston et al., 1996; Wagner et al., 1994; Pennigton & Lefly, 2001). Phonological sensitivity was also found to mediate the effect of familial risk to letter knowledge. These findings fit nicely with the wide body of evidence concerning associations between phonological sensitivity and reading difficulties (Byrne, 1998; Elbro, Borstrom, & Petersen, 1998; Gallagher, Frith, & Snowling, 2000; Pennington & Lefly, 2001; Snowling, Gallagher, & Frith, 2003).

Some other interesting findings were found in comparisons of clusters conducted separately within the at-risk and non-risk group. Maternal educational level tended to be somewhat lower in the delayed cluster than in the other clusters: this difference was significant among the non-risk children but marginally failed to reach significance among the at-risk children. This tendency is in line with earlier findings purporting the advantages of high maternal education in relation to language development (e.g., see Laakso, Poikkeus, Eklund & Lyytinen, 1999). It should be noted, however, that higher maternal education was not found to be directly linked with more parental letter name teaching in the home. Interestingly, performance IQ was found to differentiate between the precocious and delayed clusters within the at-risk group, but not within the non-risk group. This suggests that performance IQ may work as a compensatory factor in the at-risk group while, in the non-risk group, compensation may not be necessary to the same extent.

Vocabulary showed a different pattern of association with letter name learning than phonological sensitivity, phonological memory, and rapid naming. Vocabulary differentiated letter knowledge clusters but did not emerge as a significant predictor in the logistic regression analyses. This finding is in accordance with that of de Jong and Olson (2004) who found that vocabulary knowledge did not predict letter knowledge after phonological memory was controlled for. The analyses of the present study showed that, in addition to phonological memory, phonological sensitivity also mediated the effect of vocabulary on letter knowledge. Thus, the view that phonological processing is an important component of both vocabulary and letter knowledge development (e.g. Share, 1995), also gained indirect support in the present analyses.

Our fourth question concerned the prediction of beginning reading. As expected, letter name learning was observed to be associated with beginning reading scores at the first grade (e.g. Adams 1990; Aro, Tolvanen, Poikkeus, & Lyytinen, 2003; Elbro, Borstrom, & Petersen, 1998; Gallagher, Frith, & Snowling, 2000; Lonigan, Burgess, & Anthony, 2000; Pennington & Lefly, 2001; Scarborough, 2001; Snow, Burns, & Griffin, 1998). Almost all of the children who encountered problems in reading fluency and/or comprehension during the first grade belonged to the delayed letter learning cluster. It should be noted that membership of the delayed cluster predicted difficulties in beginning reading, irrespective of familial risk for dyslexia.

Despite the fact that correlations between beginning reading skills and letter knowledge as early as 4.5 or 5.0 years of age were high, the analysis of individual trajectories showed that the information with regard to the number of letter names known by a child at an early age did not yield highly reliable predictions at the level of the individual. This is because the shapes of individual growth trajectories vary and, once begun, growth may be extremely rapid. Furthermore, problems in beginning reading did not characterize all children in the delayed cluster: in fact, 8 of the 72 children were able to perform above the average level. In short,, even though letter name knowledge is an easily administered tool and had strong correlations with beginning reading scores, it should be noted that, at the early ages, it may not identify all the children with subsequent beginning reading problems. A more accurate prediction is possible by taking account of the growth pattern and by emphasizing the later assessment points. Consequently, based on our findings, assessment of letter naming is highly recommended for early screening to identify those children who require extra support around 5.5 and 6 years of age.

There were some limitations to the present study. First, the testing of letter naming was conducted in four sets of letters, and testing was discontinued if the child was unable to name any items within a set of letters. This procedure may have caused some bias in the results in that children’s full mastery was possibly not captured in all cases. However, since our main interest was in the developmental growth of letter naming skills rather than in the frequencies of letter named correctly as such, we do not think that the procedure greatly affected our results. Second, the measurement of letter knowledge was based on naming only the names of upper case letters due to the specific features of our educational system which does not introduce lower case letters before 7 years of age. Third, earlier literature has indicated that development of letter sound knowledge may be different from that of letter name knowledge (McBride-Chang, 1999; Treiman & Kessler, 2003). Although these were not treated separately in our measurements, in a highly transparent language such as Finnish, letter sounds and names are close to identical, and consequently, differences are not expected to the same extent as would be observed in more opaque languages.

In summary, this study endorses the view that letter name knowledge development is, by far, not solely dependent upon the amount of letter name teaching or other types of environmental exposure. Instead, a variety of language and cognitive capacities, in particular, phonological processing, play an integral part in the optimal learning of letter names. The findings underline the effect of familial risk of dyslexia which appears to be mediated through phonological sensitivity. For children with familial risk for dyslexia, genetic vulnerability appears to manifest early in problems of phonological processing which, in turn, leads to delayed letter learning and a high probability of subsequent problems in beginning reading. It should be noted, however, that there were also several at-risk children without problems, either in language skills or in letter name learning, and some non-risk children following the delayed letter name learning curve. The findings of the present study suggest that parental teaching of letter names and, to a lesser extent, high IQ, may, however, compensate for the risk. For children without familial risk for language and reading problems, memory skills and rapid processing and retrieval of symbols, along with a rich literacy environment, appear to take precedence to phonological sensitivity as central pre-requisites to the acquisition of letter knowledge. The whole causal story is not, however, so simplistic. Reciprocal effects between language measures and letter knowledge were not the main focus of interest here although in our future analyses, the complicated relationship between letter knowledge and phonological awareness (e.g. Bowey, 1994; Burgess & Lonigan, 1998; Carroll, et al., 2003; Johnston, Anderson, & Holligan, 1996; Lonigan et al., 2000; Wagner et al., 1994; Pennington &

Lefly, 2001) will be a central issue to complement our related considerations (Lyytinen, et al., 2005).

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Table 1. Descriptive Statistics for the Measures of Letter Knowledge, Language Skills, Performance IQ, Home Environment, and Beginning Reading Skills.

	Range	Mean	SD	Amount of floor values	Amount of ceiling values	Skewedness	Kurtosis	N
Letter knowledge								
Letter naming 4.5 y	0 - 23	7.72	7.49	17.7 %	3.2 %	0.63	- 1.03	186
Letter naming 5.0 y	0 - 23	10.27	7.80	9.1 %	4.8 %	0.21	- 1.44	186
Letter naming 5.5 y	0 - 23	13.11	7.61	3.8 %	10.8 %	- 0.26	- 1.35	186
Letter naming 6.5 y	0 - 23	17.74	6.22	0.5 %	32.8 %	- 1.14	0.17	186
Language skills and IQ								
Phonol. sensitivity 3.5 y								
Word identification	1 - 8	6.19	1.89	0.0 %	33.9 %	- 0.80	- 0.56	179
Segment identification	0 - 8	5.23	1.75	0.6 %	8.4 %	- 0.31	- 0.62	178
Synthesis	0 - 12	7.13	2.84	3.0 %	1.8 %	- 0.69	- 0.10	166
Continuation	0 - 8	4.46	2.70	13.3 %	17.6 %	- 0.31	- 1.16	165
Phonol. memory 3.5 y								
Nonword repetition	0 - 18	12.57	3.24	0.6 %	3.0 %	- 0.64	0.47	166
Sentence repetition	1 - 24	12.15	4.33	0.0 %	0.5 %	0.15	- 0.15	159
Digit span	0 - 8	5.17	1.65	0.6 %	0.0 %	- 0.13	- 0.28	168
Rapid naming 4.5 y	21.1 -148.0	73.61	24.36	-	-	0.86	0.48	176
Vocabulary 3.5 y								
Production	7 - 37	18.63	5.80	0.0 %	0.0 %	0.64	0.27	185
Comprehension	11 - 74	37.20	14.92	0.0 %	0.0 %	0.44	- 0.27	168
Performance IQ 5.0 y	70 - 139	102.14	13.82	-	-	0.03	- 0.43	182
Home environment and interest								
Shared reading 4.0 y	4 - 16	9.54	2.24	1.6 %	0.5 %	0.12	0.36	174
Interest in reading 4.0 y	0.7 - 1.4	1.04	0.14	0.0 %	0.0 %	- 0.37	0.23	174
Teaching of letters 4.5 y	1 - 5	3.16	1.26	5.6 %	17.3 %	0.04	- 1.17	162
Mother education	1 - 7	4.27	1.44	4.3 %	11.8 %	0.15	0.04	186
Father education	1 - 7	3.74	1.34	4.3 %	5.4 %	0.66	0.44	186
Beginning reading skills								
Reading fluency (1st grade Nov.)	1 - 79	27.69	19.44	1.1 %	0.0 %	0.88	- 0.09	173
Reading fluency (1st grade April)	8 - 80	44.15	19.38	0.0 %	5.9 %	0.35	- 0.89	178
Reading compr. (1st grade April)	0 - 24	14.38	7.67	2.8 %	16.0 %	- 0.29	- 1.26	178

Table 2. Cross tabulation of Familial Dyslexia Risk Group Membership and Letter Knowledge Clustering Membership.

Group		Cluster			
		Delayed	Linear	Precocious	Total
At-risk	Count	48	29	19	96
	% within group	50.0 %	30.2 %	19.8 %	100.0 %
	% within cluster	65.8 %	46.8 %	37.3 %	51.6 %
Non-risk	Count	25	33	32	90
	% within group	27.8 %	36.7 %	35.6 %	100.0 %
	% within cluster	34.2 %	53.2 %	62.7 %	48.4 %
	Total	73	62	51	186
		39.2 %	33.3 %	27.4 %	100.0 %

Note. χ^2 (2) = 10.64, p = .005

Table 3. Multiple Comparisons between the Clusters of Letter Knowledge Development and Groups with and without Risk for Familial Dyslexia.

	Cluster comparisons						Group comparisons				
	Delayed		Linear growth		Precocious		At-risk		Non-risk		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Sig.
Letter knowledge											
Letter naming 4.5 y	1.32[a]	1.64	6.79[b]	4.31	18.02[c]	3.47	6.60	7.26	8.91	7.59	< .05
Letter naming 5.0 y	2.53[a]	2.27	11.13[b]	4.30	20.31[c]	1.96	8.99	7.89	11.64	7.50	< .05
Letter naming 5.5 y	4.85[a]	3.38	16.03[b]	3.55	21.37[c]	1.64	11.41	8.05	14.92	6.69	≤ .001
Letter naming 6.5 y	11.90[a]	5.87	20.44[b]	2.58	22.80[c]	0.60	16.31	6.85	19.26	5.08	≤ .001
Language skills and IQ											
Phonological sensitivity[z] 3.5 y	-0.60[a]	0.70	-0.06[b]	0.65	0.16[b]	0.59	- 0.39	0.74	- 0.03	0.68	≤ .001
Phonological memory[z] 3.5 y	-0.65[a]	0.82	-0.16[b]	0.83	0.33[c]	0.58	- 0.39	0.89	- 0.03	0.78	< .01
Rapid naming 3.5 y	84.54[a]	24.41	72.33[b]	22.71	59.50[c]	18.11	75.71	23.72	71.37	24.95	ns
Vocabulary[z] 3.5 y	-0.35[a]	0.74	0.00[b]	0.67	0.46[c]	0.78	- 0.16	0.78	0.16	0.79	< .01
Performance IQ 5.0 y	99.00[a]	14.56	102.08[a, b]	12.79	106.66[b]	12.92	102.02	14.56	102.26	13.08	ns
Home environment and interest											
Shared reading 4.0 y	9.23[a]	2.38	9.68[a]	2.26	9.80[a]	1.96	9.37	2.32	9.71	2.14	ns
Interest in reading 4.0 y	1.03[a]	0.13	1.02[a]	0.15	1.06[a]	1.61	1.04	0.13	1.03	0.15	ns
Teaching of letters 4.5 y	2.75[a]	1.34	3.31[b]	1.25	3.74[b]	1.05	2.99	1.29	3.34	1.20	ns
Mother's education	3.79[a]	1.37	4.53[b]	1.40	4.65[b]	1.43	4.08	1.51	4.48	1.34	ns
Father's education	3.59[a]	1.22	3.63[a]	1.40	4.09[a]	1.38	3.70	1.28	3.79	1.40	ns
Beginning reading skills											
Reading fluency (1st grade Nov.)	14.02[a]	10.23	28.33[b]	15.78	45.37[c]	18.43	22.24	16.49	33.74	20.72	< .001
Reading fluency (1st grade April)	30.96[a]	13.65	45.93[b]	16.15	60.55[c]	16.48	39.41	17.84	49.45	19.76	< .001
Reading compr. (1st grade April)	8.22[a]	6.23	16.78[b]	5.87	20.10[c]	4.96	12.58	7.92	16.43	6.87	≤ .001

Note. For the cluster comparisons the pairs with same subscript letters do not differ significantly ($p > .05$) based on ANOVA post hoc (Bonferroni corrected) paired comparisons. [z] = Mean composites of z –scored values.

Table 4. Prediction of Delayed Cluster Membership with Logistic Regression Analysis across All Participants and within At-Risk and Non-Risk Groups.

	Across all participants			Within the at-risk group			Within the non-risk group		
	B (s.e.)	Sig.	Odds ratio	B (s.e.)	Sig.	Odds ratio	B (s.e.)	Sig.	Odds ratio
Constant	0.05 (1.73)	.977	1.05	- 0.88 (2.09)	.544	0.28	0.76 (2.28)	.739	2.14
Step 1 (enter):									
Dyslexia risk group	0.27 (0.42)	.513	1.31	-	-	-	-	-	-
Step 2 (enter):									
Performance IQ	0.01 (0.02)	.670	1.01	0.02 (0.02)	.379	1.02	0.01 (0.02)	.757	1.01
Step 3 (stepwise):									
Teaching of letters	0.64 (0.21)	.003	1.89	0.53 (0.25)	.034	1.70	0.87 (0.38)	.023	2.39
Mother's education	0.42 (0.20)	.039	1.51	-	-	-	0.76 (0.38)	.046	2.13
Step 4 (stepwise):									
Phonological	1.00 (0.33)	.003	2.73	1.27 (0.44)	.004	3.57	-	-	-
Phonological memory	0.81 (0.27)	.003	2.26	-	-	-	1.70 (0.55)	.002	5.48
Rapid naming	0.49 (0.22)	.023	1.64	-	-	-	0.75 (0.31)	.016	2.11

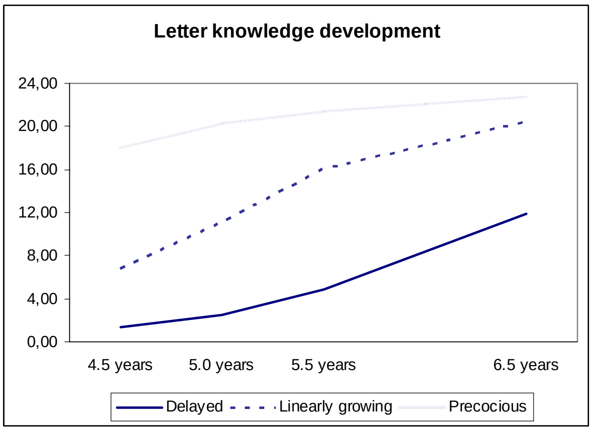
Note. The independent variable in the analysis was 0 = delayed, and 1 = linearly growing and precocious cluster. Variables were entered in four steps: 1. familial dyslexia risk, 2. performance IQ, 3. teaching of letters, shared reading, child's interest in reading, mother's and father's education, 4. phonological sensitivity, phonological memory, vocabulary, and RAN. In steps with several predictors a stepwise method was used with probability for entry set at .05 and at .10 for exclusion. List-wise n =156 (80 at-risk and 76 non-risk children).

Figure Captions

Figure 1. Letter knowledge development in three clusters obtained with trajectory analysis.

Figure 2. Letter knowledge development within the three clusters at the individual level.

Figure 3. Percentage of children scoring below 1SD of the non-risk group mean in reading skills at Grade 1.


Letter knowledge development
24,00
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16,00
12,00
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4.5 years
5.0 years
5.5 years
6.5 years
Delayed
Linearly growing
Precocious

Figure 1.

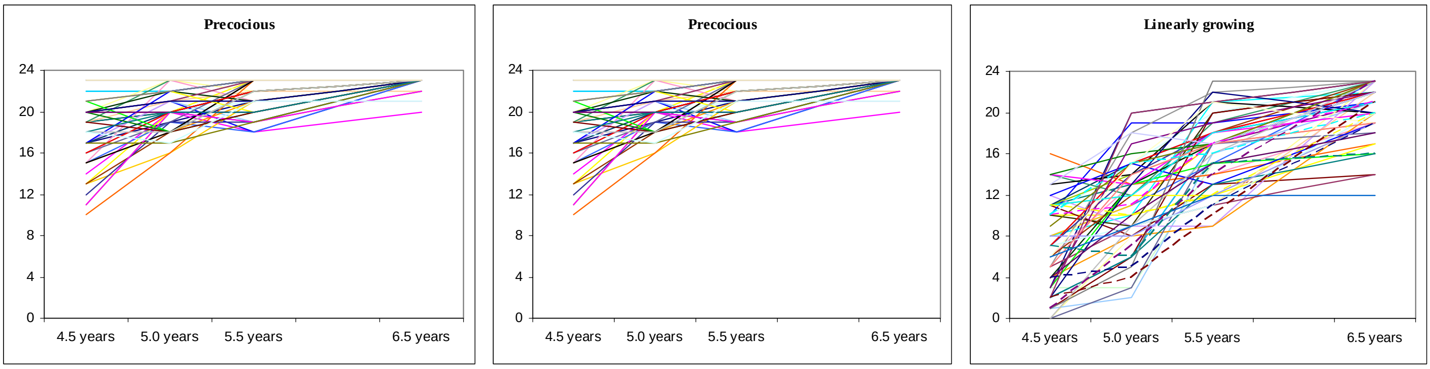
Precocious
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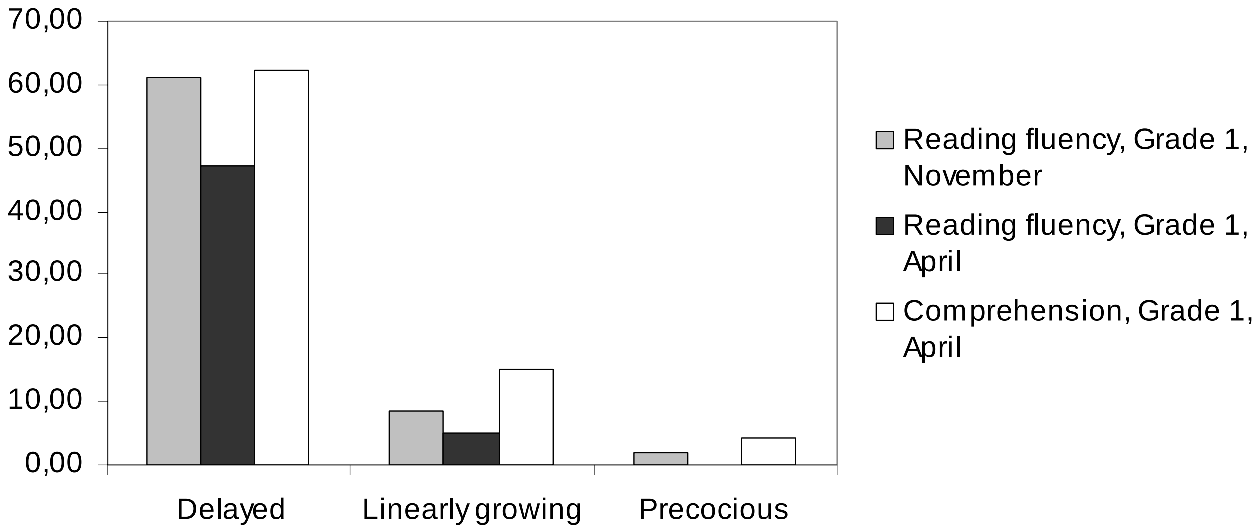
Figure 2.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Delayed
Linearly growing
Precocious
Reading fluency, Grade 1, November
Reading fluency, Grade 1, April
Comprehension, Grade 1, April

Figure 3.

APPENDIX

Correlations between Letter Knowledge, Language Skills, Home Environment, and Beginning Reading

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
1.	Letter naming, 4.5 y																						
2.	Letter naming, 5.0 y	.90																					
3.	Letter naming, 5.5 y	.78	.89																				
4.	Letter naming, 6.5 y	.63	.74	.82																			
5.	Rapid naming speed	.40	.38	.39	.33																		
6.	Nonword repetition	.33	.33	.33	.33	.21																	
7.	Sentence repetition	.29	.36	.32	.26	.26	.30																
8.	Digit span	.30	.33	.31	.32	.14	.25	.50															
9.	Word identification	.24	.21	.23	.22	.26	.13	.28	.22														
10.	Segment identification	.25	.29	.36	.30	.30	.13	.25	.17	.58													
11.	Synthesis	.17	.17	.24	.20	.19	.25	.19	.25	.05	.05												
12.	Continuation	.28	.26	.31	.23	.26	.29	.22	.18	.18	.19	.43											
13.	Vocabulary, prod.	.30	.34	.33	.30	.17	.28	.47	.37	.20	.23	.34	.33										
14.	Vocabulary, compr.	.29	.33	.34	.26	.19	.10	.39	.35	.22	.24	.25	.26	.56									
15.	Performance IQ	.22	.20	.25	.21	.21	.01	.22	.22	.25	.21	.21	.27	.25	.33								
16.	Shared reading	.13	.12	.11	.14	.11	.02	.18	.17	.16	.12	.13	.12	.33	.22	.18							
17.	Interest in reading	.10	.06	.11	.03	.07	-.01	.14	.10	.09	.09	.06	.12	.16	.22	.20	.33						
18.	Teaching of letters	.36	.31	.30	.29	.20	.16	-.05	-.10	.09	.17	-.02	.08	.10	.03	.08	.20	.02					
19.	Mother’s education	.21	.23	.23	.26	.09	.15	.28	.31	.12	.10	.14	.05	.14	.11	.12	.04	.00	-.10				
20.	Father’s education	.17	.17	.13	.08	.10	.13	.10	.24	.06	.11	.11	.06	.17	.17	.08	.08	.01	.03	.29			
21.	Reading fluency (Nov.)	.62	.68	.63	.62	.32	.28	.24	.27	.22	.25	.14	.29	.32	.25	.20	.17	.12	.19	.09	.07		
22.	Reading fluency (April)	.59	.64	.60	.58	.27	.26	.21	.25	.19	.23	.12	.29	.33	.16	.15	.09	.02	.21	.08	.14	.87	
23.	Reading compr. (April)	.56	.60	.62	.61	.43	.20	.34	.27	.33	.34	.23	.32	.29	.36	.32	.21	.13	.12	.16	.13	.61	.60

Note. $R > .15$, $p < .05$, $R > .20$, $p < .01$, and $R > .26$, $p < .001$