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Running head: MODELING PHONOLOGICAL AWARENESS

Modeling the Early Paths of Phonological Awareness and Factors Supporting Its Development in Children With and Without Familial Risk of Dyslexia

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Abstract

The development of phonological awareness (PA) before school-age was modeled in association with the development of vocabulary and letter knowledge, home literacy environment (HLE), children's reading interest, and beginning reading skill in children with and without familial risk of dyslexia. A total of 186 children were followed from birth to the age of 6.5 years. Of these children, about half had a familial background of reading difficulties (the at-risk group), and the other half came from families without such background (the control group). The data with several measures and assessment time points were analyzed within an SEM framework and a latent analysis of growth curves was employed. Vocabulary and letter knowledge were found to predict PA development, and vice versa PA predicted them. The effect of HLE on PA was mediated by vocabulary skills, and of the HLE variables the only variable predicting vocabulary development was shared reading. In spite of the difference in level, favoring the controls, the pattern of effects of vocabulary and letter knowledge on PA development was highly similar in children with and without familial risk for dyslexia. However, in the at risk group the HLE variables and children's reading interest had stronger associations with each other and with skill development than in the control group, and vocabulary predicted parental report on children's reading interest in the at-risk group only.

Modeling the Early Paths of Phonological Awareness and Factors Supporting Its Development in Children With and Without Familial Risk of Dyslexia

The search for factors and mechanisms in the child and in his/her environment which provide the strongest predictions of children's language and literacy development is of continuing interest (e.g. (Burgess, 1997, 2002; Bus, van IJzendoorn, & Pellegrini, 1995; Cooper, Roth, Speece, & Schatschneider, 2002; Crain-Thoreson & Dale, 1992; Frijters, Barron, & Brunello, 2000; Griffin & Morrison, 1997; Laakso, Poikkeus, Eklund, & Lyytinen, 2004; Lyytinen, Laakso, & Poikkeus, 1998; Payne, Whitehurst, & Angell, 1994; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002; Sénéchal, LeFevre, Thomas, & Daley, 1998). A large body of literature exists concerning individual factors, but forming a coherent picture based on the sometimes contrasting findings is difficult. For example, early literacy experience at home (HLE) has been found to be associated with children's phonological awareness (Burgess, 1997, 2002; Crain-Thoreson & Dale, 1992; Frijters et al., 2000; Sénéchal et al., 1998) but, in other studies, the role of HLE has been shown to be relatively smaller in the development of phonological awareness (PA) than in the development of vocabulary or written language skills (Bus et al., 1995; Cunningham, Stanovich, & West, 1994; Olson, Wise, Conners, & Rack, 1989; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002). It has been suggested that environmental factors influence PA development indirectly through vocabulary and literacy skills development (e.g. Chaney, 1994; Cooper et al., 2002; Frijters et al., 2000; Sénéchal & LeFevre, 2002).

Longitudinal studies that involve multiple assessments of the children's skills and HLE across the critical preschool years which enable one to examine the reciprocity in skill development and to test for direct and indirect environmental effects on children's phonological development continue to be rare. Some of these questions have been addressed previously by employing a series of hierarchical regressions (Burgess, 2002; Cooper et al., 2002; Sénéchal & LeFevre, 2002). The present study aims to add to the literature by employing a structural equation modeling (SEM) approach with repeated measurements to build a developmental model of PA that takes into account the contribution of vocabulary, letter knowledge, and beginning reading before formal reading instruction. The advantages of the SEM approach are its possibilities for flexible, theory-based model building with several latent factors (taking into account measurement error), examination of direct and indirect effects, and estimation of all associations between factors in the model simultaneously. Our longitudinal sample (the Jyväskylä Longitudinal Study of Dyslexia) provided us an opportunity to study the largely under-researched role of supportive individual and environmental factors in the language development of children with familial risk for dyslexia (Elbro, Borstrom, & Petersen, 1998).

Performance in tasks measuring PA has been shown to be a strong predictor of both reading (e.g. Bradley & Bryant, 1983; Bryant, MacLean, Bradley, & Crossland, 1990; Lundberg, Olofsson, & Wall, 1980; Scarborough, 2001; Snow et al., 1998; Wagner & Torgesen, 1987), and reading difficulties (Byrne, 1998; Elbro et al., 1998; Gallagher, Frith, & Snowling, 2000; Hatcher, Hulme, & Snowling, 2004; Pennington & Lefly, 2001; Snowling, Gallagher, & Frith, 2003; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Emerging literacy skills, most importantly knowledge of letters, have been shown to facilitate the development of PA and vice versa (e.g. Burgess & Lonigan, 1998; Carroll, Snowling, Stevenson, & Hulme, 2003; Johnston, Anderson, & Holligan, 1996; Pennington & Lefly, 2001). The relationship between PA and reading is also seen to be reciprocal in nature (e.g. Wagner, Torgesen, & Rashotte, 1994). The close association of the written and spoken language is especially evident in transparent languages such as Finnish, where there are no idiosyncrasies and each letter indicates only one phoneme, independent of the context in writing (see Lyytinen, Aro, Holopainen, Leiwo, Lyytinen, & Tolvanen, 2006 for more details).

Strengths in early language, such as receptive and expressive vocabulary skills, have also been found to predict PA development (Carroll et al., 2003; Cooper et al., 2002; Metsala, 1999; Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2004; Scarborough, 1989, 1990; Silvén, Niemi, & Voeten, 2002). The lexical restructuring account assumes a process through which a child acquires the ability to manipulate gradually smaller sublexical phonological units, and which is strongly driven by the children's language experience reflecting both quantitative and qualitative features related to vocabulary growth (Fowler, 1991; Metsala, 1999; Walley, Metsala, & Garlock, 2003). According to this account, at the early stage of language development when only a limited number of words or phrases are stored in memory, phonological representations are holistic (words, phrases), and with vocabulary growth the representations are gradually transformed to involve smaller segments (syllables and finally phonemes). However, children's ability to form segmental representations of words in memory varies, and vocabulary skills have also been found to be predicted by both PA (e.g. Bowey, 2001; McBride-Chang, Wagner, Muse, Chow, & Shu, 2005) and phonological memory (e.g. Gathercole et al., 1992).

Based on a series of hierarchical regression analyses, Sénéchal and LeFevre (2002) proposed a model representing the relations among home literacy experiences (shared reading, book exposure, parent teaching about reading and writing) and child outcomes in language, PA, emergent literacy (e.g. print concepts, letter knowledge), and reading. Their analyses (see also Sénéchal & LeFevre, 1998) suggested that language and literacy skills function as mediators between environmental effects and both reading and PA. To be more precise, shared book reading had an effect on vocabulary whereas parental teaching of reading and writing skills had on effect on emergent literacy. In their model both a composite of receptive language skills and emergent literacy skills were reciprocally related to PA. Children's book exposure at school age, PA, emergent literacy and language skills all predicted school-age reading level. Cooper et al. (2002) reported similar findings. The analyses by Sénéchal and LeFevre (2002) and Cooper et al. (2002) were conducted on a sample of children already receiving reading instruction (e.g. kindergarteners and 1st graders), thus the model, cannot address development before variance related to teachers, peers, or school-home interaction has had any effects on the associations between home factors and child outcomes.

In a shorter follow-up with an emphasis on the development of PA (without reading outcomes) Burgess (2002) has reported a series of regression analyses in which Time 2 PA (5- to 6-years of age) was predicted by composites of emergent literacy, oral language, and home literacy environmental factors assessed a year earlier (Time 1 at 4-to 5-years of age). Interestingly, he found that when a PA autoregressor from Time 1 was controlled, only a composite of environmental factors contributed significant variance to predicting PA at Time 2. Although the effect was rather small (4.3%), this finding is contrary to the suggestion (Sénéchal & LeFevre, 1998, 2002) that the influence of home literacy environment on PA development would be fully mediated by vocabulary development. This difference in results was most likely due to the differences in measures. For instance, in Sénéchal and LeFevre (2002) the amount of shared book reading was measured by giving lists of titles and authors of children’s books and asking parents to indicate which they recognized whereas in Burgess (2002) a broad questionnaire for parents was employed to provide a composite of both limiting and supportive HLE factors.

A large repertoire of measures has been employed in the literature to tap the aspects of the home literacy environment (HLE) contributing to children’s language and literacy development. Most of these aspects fall under the following three categories (Lundberg, 1991): 1) exposure to written language at home (e.g. shared reading experiences), 2) access to written language (e.g. books available at home, library visits), and 3) positive models (e.g. parent's own reading activities and attitudes). Lately children's reading interest has been emphasized as another important factor, one that has rarely been included in the models predicting language and literacy outcomes (e.g., Bus et al., 1995; Dunning, Mason, & Stewart, 1994; Laakso, Poikkeus, & Lyytinen, 1999; Metsala & Walley, 1998; Scarborough & Dobrich, 1994; Whitehurst & Lonigan, 2001). Of the HLE aspects, the context of shared reading is believed to be particularly beneficial as it draws the partners into reciprocal interaction, contains sophisticated linguistic models (e.g., Hoff-Ginsberg, 1991; Lewis & Gregory, 1987), and offers a clearly defined reference context that helps to maintain joint focus (Dunham, Dunham, & Curwin, 1993). In the light of empirical findings, parents' own reading activities and mere access to literacy materials tend to have a smaller impact on the children's literacy and language development than parent-child shared reading experiences (Payne et al., 1994; Scarborough et al., 1991; Scarborough & Dobrich, 1994). The overall effect of shared reading on literacy and language skills has been estimated to be about 8 % (Bus et al, 1995; Scarborough & Dobrich, 1994), but this amount of explained variance may, however, be an underestimation because of the methodological problems typical in many of the studies (Lonigan, 1994).

The present study aims to extend the previous findings (Burgess, 2002; Cooper et al., 2002; Sénéchal & LeFevre, 2002) in the following respects. First, we use several assessments of skills and HLE factors years before formal school entry (in Finland children enter the first grade in the fall of the year when they turn seven years and before that time they do not normally receive formal reading instruction). Second, our design included a group of children with at least one parent diagnosed with dyslexia, and as documented in a large body of literature the offspring of parents with reading problems are known to run a substantially higher risk for reading difficulties than children from families without such background (e.g., Elbro et al., 1998; Finucci, Guthrie, Childs, Abbey, & Childs, 1976;

Gilger, Pennigton, & DeFries, 1991; Hallgren, 1950; Lyytinen et al., 2004; Olson, Datta, Gayan, & DeFries, 1999; Pennigton & Lefly, 2001; Scarborough, 1990). Third, instead of the traditional regression analytic technique we employed a structural equation modeling (SEM) approach.

Because we were particularly interested in the growth patterns (e.g. linearity, stability, and individual variability) of children's PA development we employed latent growth curve (LGC) modeling. LGC is seen as an effective tool for analyzing change because it places individual growth trajectories at the center of focus, (Curran & Muthen, 1999; Francis, Fletcher, Stuebing, Davidson, & Thompson, 1991; Li, Duncan, & Acock, 2000; McArdle & Epstein, 1987; Meredith & Tisak, 1990; Willett, Ayoub, & Robinson, 1991; Willett & Sayer, 1994). With LGC we were also able to investigate whether the so-called Matthew effect (i.e. "the rich get richer and poor get poorer", Stanovich, 1996) can be found in PA development (c.f. the finding, for instance, by McBride-Chang et al. 1997 of a Matthew effect in a phoneme elision task among Kindergarten children).

Specifically, our research questions were the following: 1) What is the role of different aspects of home literacy environment and children's reading interest in the early skill development of PA, vocabulary, and literacy skills? 2) What pattern of associations exists between PA development, vocabulary, and literacy skills (i.e. letter knowledge and beginning reading) before school age? 3) Does familial risk for dyslexia risk have an effect on the development of skills, reading interest, HLE factors, or on the pattern of associations?

Phonological awareness development was expected to have strong reciprocal associations with vocabulary skills (e.g. Bowey, 2001; McBride-Chang, et al., 2005; Metsala, 1999), with letter knowledge (e.g. Burgess & Lonigan, 1998), and with beginning reading skill (e.g. Wagner, Torgesen, & Rashotte, 1994). Vocabulary development was expected to be associated with children's shared reading experiences with parents (e.g. Crain-Thoreson & Dale, 1992; Frijters, et al., 2000; Griffin & Morrison, 1997; Laakso, Poikkeus, Eklund & Lyytinen, 2004; Lyytinen et al., 1998; Payne et al., 1994; Scarborough & Dobrich, 1994; Sénéchal et al., 1998) and with children's reading interest (Crain-Thoreson & Dale 1992, Laakso et al, 1999; Lyytinen et al., 1998). Children's reading interest was also expected to be linked to letter knowledge (Frijters et al., 2000). Parents' own reading activities and mere access to literacy materials, on the other hand, were expected to have a smaller direct impact on the children's skill development than parent-child shared reading experiences (Payne et al., 1994; Scarborough et al., 1991; Scarborough & Dobrich, 1994). To examine their indirect influences on child outcomes through shared reading and child's reading interest, measures of parent's own reading activities and access to literacy materials were included into the analyses. Our design also enabled us to examine whether the association between phonological awareness development and supportive HLE (particularly the amount of parent-child shared reading) would be fully mediated by vocabulary development (e.g. Sénéchal & LeFevre, 2002) or if the association would emerge even after controlling for vocabulary skills (Burgess, 2002).

Based on earlier findings we expected children with a familial risk of dyslexia to perform poorer than children without such a risk in tasks of PA, vocabulary, letter knowledge, and beginning reading (e.g. Byrne, 1998; Elbro et al., 1998; Gallagher, et al., 2000; Lyon, et al., 2003; Pennington & Lefly, 2001; Puolakanaho et al., 2004; Scarborough, 2001; Stanovich & Siegel, 1994). In the few studies that have compared the literacy environments in families with and without reading difficulties, surprisingly few, if any differences have been found in the amount of parent-child shared reading (Elbro, et al., 1998; Gallagher et al., 2000; Laakso, et al., 1999; Scarborough et al., 1991; Snowling, 2000). However, parents with reading difficulties tend to read less and have less positive attitudes towards reading than parents without reading difficulties (Leinonen et al., 2001). Although robust differences between families with and without reading disabilities are, thus, generally not found in the mean level comparisons, it is possible that the links between home literacy experiences and literacy and language skills may still be different in groups with and without familial risk for reading problems due to gene-environment interplay mechanisms (see e.g. Rutter, Moffitt, and Caspi, 2006).

Method

Participants

For this study we drew data from the prospective Jyvaskyla Longitudinal Study of Dyslexia (JLD), which has been exploring early language development and precursors of reading skills (for a review of earlier results see Lyytinen, et al., 2001). Altogether 214 families joined the study before the birth of their children. We selected and assigned the participants to the study groups by assessing in a laboratory setting the parents' reading and reading-related language skills and cognitive level (for details see Leinonen, et al., 2001). Half of the participating families involve a parent who has been diagnosed with dyslexia, and who has also reported similar problems among immediate relatives. The children from these families are referred to as the at-risk group. The control group consists of children from families where parents have not had problems in learning to read or spell, nor do they have immediate relatives having reading deficits. The study reports selected data of 186 children (all the JLD participants from whom a full data set was available) from the assessment phases between ages 4 and 6.5 years. Altogether we analyzed assessments of 96 at-risk children (50 girls and 46 boys), and 90 control group children (40 girls and 50 boys). All the children and their parents came from the city of Jyväskylä and its surrounding communities in the Province of Central Finland. The parents' educational distribution was representative of the Finnish population. All the children are Caucasian, speak Finnish as their native language, and have not had mental, physical or sensory handicaps.

Measures

Children's phonological awareness was measured as a part of the JLD assessment phases at ages 4.5, 5.5, and 6.5 years. To represent the genuine growth of phonological awareness over time, at every measurement phase identical items were selected for every measure. The children participated individually in the assessments in a laboratory setting. A computer animation program called Heps-Kups Land administered the tasks of segment identification and synthesis. (The program was created especially for this purpose, for details see Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2003.) The child proceeded by pressing touch screen items or by answering questions orally. The program then automatically recorded the child's responses. The oral responses of the child were coded on line by the experimenter, as well as recorded in digital sound files in order to check the coding later.

Phonological awareness

Segment identification. The task of each child was to identify the object that contained the requested part of a word. The computer screen showed three pictures of tangible objects one after the other, and the name of each object was presented orally immediately after the object was seen on the screen. The child responded by touching one of the three pictures on the screen. For example, in Item 3 the set was: *koira* (dog) – *kissa* (cat) – *kukko* (cock), and the child was asked to identify the syllable *koi*. Each child received two practice items, and a third practice followed automatically if the child failed the first two. The size of the segment to be identified varied from one to four phonemes, and from two syllables to one phoneme. Segments came from the beginning, end, or middle part of the word. There were 14 items in this computer-aided task.

Synthesis of phonological units. This task required the child to blend separately pronounced segments into a whole word. The child heard segments of varying size (words, syllables, phonemes) with a 750 msec pause between each segment. The child then had to produce the targeted animal name. The words were three to nine phonemes long, and they were pronounced in three or four small pieces. Three items required synthesis at the level of syllables (e.g., *per-ho-nen* = butterfly), five items required synthesis at the level of syllables and phonemes (e.g., *tuo-l-i* = chair), and four items required synthesis at the level of phonemes (e.g., *m-u-n-a* = egg). Only a response containing the right assembled form was coded as correct. Two practice items reinforced the principle of assembly. This computer-aided task contained 12 items.

Segmentation. This task measured the children's ability to divide words and pseudowords into smaller segments. The child had to pronounce a specific word or pseudoword in smaller pieces (three or four segments). Picture cards helped the child to understand the instructions. The task contained pseudowords (two items), words (six items), and two phoneme long syllables with no meaning (two items). The total length of the items varied from two to eight phonemes.

Explorative factor analyses for each age indicated that the tasks represented one underlying factor. A composite variable of phonological awareness was constructed by calculating first the percent of correct answers in each variable and then the mean of these percentages.

Vocabulary

Measures of the children's word production skills were obtained at 3.5 and 5.5 years of age and language comprehension skills at 3.5 and 5.0 years of age with the tests described below. Two composite means were calculated (one for age 3.5 and another for age 5.0 / 5.5) from subtest scores which were standardized with respect to the non-risk group's mean and standard deviation.

Expressive vocabulary. 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 the 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).

Receptive vocabulary. 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 (166 in the Finnish version) ranges from easy for two-year-olds (e.g. bed) to difficult for adults (e.g. cornea, perpendicular). The starting point is based on the subject'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.

Literacy Skills

Letter knowledge. In this task, the child was asked to name letters that were written in large capitals and presented one at a time, each on their own page. At 4.5 and 5.5 years of age, the child was presented 23 letters that were organized in four sets (6 + 6 + 6 + 5 letters). At age 6.5 years the child was presented all 29 letters. However, to create identical measures for the growth curve analysis, only the child's responses to the first 23 letters were used at 6.5 years. The child received one point for each correct response (use of a phoneme or a letter name were both coded as correct responses) and thus, the maximum score for the task was 23. Testing was discontinued if the child did not correctly name any items in a set of letters. The testing always began by presenting the child the letter that was expected to be most familiar to him or her: the first letter of his or her own first name. After that the other letters were presented in a fixed order following the order in which letters are typically taught to Finnish first graders.

Beginning Reading. The non-word reading task was administered to the child individually in one session. It was a part of the child's assessments at the research laboratory which were scheduled within one week of the day the child turned 6.5 years of age. The list of non-words contained nine bisyllabic (vcv, cvcv, vcvc) targets (e.g. ame, hopa, olus). The participants were instructed to read the list as accurately and fluently as they could. Before each task the participants were presented with a practice list with three items. The non-word items were derived from a test battery compiled as part of a pan-European collaboration (COST A8 Action 'Learning Disorders as a Barrier to Human Development', for more details, see Aro & Wimmer, 2003 and Seymour, Aro, & Erskine, 2003). The score in each task was the number of items which the child read accurately. In the present analyses, a dichotomous variable indicating reader-nonreader was used because of the high number of floor values in this task at this age. A child was considered as a reader if he/she was able to decode at least two non-words.

Home literacy environment and children's reading interest

Before the birth of each child, we administered a Family Background Questionnaire to obtain demographic data, and data on parents' own reading models (parental models).

When the children were 2, 4, 5, and 6 years old, we asked the parents to complete a Reading Models Questionnaire, which included questions concerning various features of the home literacy environment (e.g. access to print materials and the amount of shared reading) and the children's focuses of interest. The questionnaire was shorter and the items were somewhat different at age 2 than at later ages, and therefore a measure on access to print materials was not available at that age.

Shared reading. To form a composite score of shared reading we employed parental reports both on the frequency and on the amount of time of the children's reading activities in the home. The following two items covered shared reading frequency at ages 4, 5, and 6 years: 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). Two items covered the amount of time spent with print materials at ages 4, 5, and 6 years: 1) the typical duration of reading episode when the child is reading with an adult, 2) the total amount of time in a day the child spends reading a book with an adult. Responses to these items were given using a three–point Likert scale (1 = less than 15 min/day, … , 3 = longer than 45 min/day). Shared reading composites were comprised by calculating a mean of the scores on these four items. At age 2 years, the shared reading measure consisted of somewhat different items. Three items covered shared reading frequency at age 2 years. In addition to shared reading with the mother and father, an item concerning picture book reading was added at this age since picture books are important reading materials at this early age. Parents responded to the items using a four-point scale (1 = not at all/seldom, … , 4 = daily).Only one item was available for the measurement of the amount of time spent with print materials at age 2 years: the typical duration of a reading episode when the child is reading with an adult. Responses to these items were given using a four–point Likert scale (1 = less than 5 min/day, … , 3 = longer than 15 min/day). Shared reading composite was arrived by calculating a mean of the scores on these four items.

Access to written language. The composite measure (a sum score) included the following six items: 1) How often the child and a parent go to library; 2) How often a parent borrows books from library for the child; 3) How often the child visits in the library (1= not at all, … , 5 = several times a week; for items 1 - 3); 4) Membership in a children's book club (1= no membership, 2 = was a member earlier, 3 = currently a member); 5) Subscription to children's magazines (1= no, 2 = subscription earlier but not now, 3 = yes, subscribing); 6) Number of books at home (1= less than 5 books, … , 5 = more than 100 books).

Children's reading interest. Parents were asked to estimate how interested in various activities their child was with a 5-point Likert scale (1 = not at all interested … 5 = very interested). Altogether 11 different activities were listed at ages 4, 5, and 6 years. Of these activities, two concerned reading: 1) picture books and children's magazines, and 2) listening to storytelling. At age 2 years, the items concerning activities other than reading related ones were somewhat different and included one additional activity: imitating adult behavior.

To estimate how interested in reading a child was 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. By contrasting reading activities to other type of activities, we got the parent's view on how much their child is interested in reading proportional to the amount of interest reported in general. In this way we reduced the error variance caused by the differing ways of understanding or answering these kinds of multiple-choice questions that have less precise choices, such as *interested* or *very interested*. The values were multiplied by 100 for technical reasons.

Parental models. Measures of the parents' literacy activities consisted of their report on: 1) how often they typically read newspapers (1 = seldom or never, …, 4 = 15 minutes or more per day); 2) how often they typically read magazines (1 = seldom or never, …, 4 = five or more magazines regularly); 3) the extent to which they liked book reading (1 = do not like reading, …, 4 = read with pleasure), and 4) how many books they generally read in a year (1 = none, …, 4 = more than 10 books per year). For the above items mothers and fathers received separate sums.

Parental education. Parental education (reported at the entry stage of the project) 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 = previous system comprehensive school education including only primary education grades,…, 3 = comprehensive school education comprised 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). These two scales were combined into one 7-point 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 from a polytechnic; 6 = upper secondary general school diploma combined with a lower university degree (Bachelor's) or a degree from a polytechnic; 7 = comprehensive school or upper secondary general school diploma combined with a higher university degree (Master's or a doctorate-level degree).

Results

Descriptives

Table 1 presents the at-risk and control groups' means and standard deviations with group comparisons for phonological awareness (PA), letter knowledge, receptive and expressive vocabulary, children's reading interest, parental education levels, and the three HLE facets (shared reading, parental reading models, and access to written language) at different time points. Before analyses, few outliers were relocated to the tails of the distributions. The few missing values were random in nature, and were imputed at the item level by using an EM algorithm.

The mean performance in PA, vocabulary and letter knowledge tasks increased steadily in both groups, but statistically significant change over time was not detected in the means of HLE factors or in children's reading interest. Children with familial risk of dyslexia performed on average poorer than control group children in PA tasks, letter knowledge, and in vocabulary skills (apart from receptive language at age 3.5 years). The children with familial risk of dyslexia also had on average less positive reading models provided by parents but neither the children's reading interest, nor the HLE factors differentiated the groups. There was, however, more variance in the parental reading model, letter knowledge at age 5.5 years, amount of shared reading at age 2.0 years, and in vocabulary skills at ages 5.0 and 5.5 years within the at-risk group. The group difference in the amount of children classified as readers at age 6.5 years did not quite reach the level of statistical significance (χ^2 (1) = 2.85, p = .06). Of the at-risk children, 21.9 % were readers, compared to 33.0 % of the controls. The sex of the dyslexic parent did not have an independent effect beyond the group membership on the HLE features or the skill measures.

Associations between variables

Table 2 presents the within-group correlations among variables. Within both study groups, PA correlated with vocabulary and letter knowledge. Vocabulary was associated with shared reading, and shared reading was associated with children's reading interest. In addition, among at-risk group children, there were fairly high correlations between the HLE factors and children's reading interest, between vocabulary skills, and children's reading interest, and between shared reading and PA.

Structural Equation Modeling

The next step in the analyses was the modeling of the associations between the measures in SEM framework. The modeling followed a three-step procedure. First, the factor and latent growth curve (LGC) models of each construct were fitted for the at-risk and control groups separately. The LGC models were estimated for measures with three identical repeats (PA, shared reading, access to print materials, and children's reading interest at ages 4, 5 and 6 years) (see Figure 1). Children's reading interest and shared reading at age 2 were treated as separate single indicator factors because of slight differences from the later occasions in the measurement. Second, the means and variances of the latent components were compared between at-risk and control group with multi-group models. Third, in order to examine the associations between variables, multivariate models were estimated separately within at-risk and control group. In these models, the measures with a single indicator were treated as factors with loading 1 and error variance 0. All models were analyzed using LISREL 8.50 (Jöreskog & Sörbom, 2001) and were based on the sample covariance matrices of the observed variables.

LGC Models for Phonological Awareness, Shared Reading, and Reading Interest

In an LGC model the variance is divided into two latent components: the Level component describes the level of the measure at a specified time point and the Trend component describes the slope of the change in time. In the present analyses loadings of the latent Level component were set to 1, 1, 1 and the loadings for the latent Trend component were set to 0, 1, and 2. With these specifications, the latent Level component defined the starting point (intercept) of the growth curve and the latent Trend component defined the rate of linear growth (slope) (see Figure 1).

Results for the within-group univariate LGC models for each construct are presented in Table 3. In the analysis of PA growth curves, a linear growth model was found to fit well for both groups. The error variances were estimated freely except for the error variance of PA at time point 3 (age 6.5) which was fixed to zero in both groups due to negative, close-to-zero estimates. The variances of the Level and Trend components were statistically significant in both groups, indicating substantial individual variability in the intercept and slope of the trajectories. The group means showed a steady linear growth in both groups. The covariance between the latent Level and Trend components was not statistically significant in either of the groups, indicating that children's PA at age 4.5 did not predict the growth rate of the skill later on.

The LGC models for shared reading, access to print materials, and children's reading interest consisted of only one latent component (Level), meaning these constructs did not change significantly within these two years (See Table 3). All error variances were estimated freely in these models. This kind of a latent component represents the general level of the repeated measures and is a more reliable measure than a single indicator factor.

Group Comparisons of the Latent Components

In the next step we compared the amount of individual variability and the means of the latent components between the groups. All previously mentioned model specifications were preserved during these multi-group models. Both the variances and the means of latent components were systematically constrained - one by one, starting from the variances - to be equal across the groups, and the fit of the consequent models was tested with a series of chi square difference tests. The equality of the factor structure (loadings and error variances) of vocabulary in the groups was confirmed before group comparisons of means, variances, and stability.

In the group comparisons of PA development, differences were found only in the Level component (See Table 3). The performance of at-risk group children at age 4.5 was on average at a lower level and the individual variability (variance) was larger in the at-risk group than in the control group. In the latent Trend component such statistically significant differences between the groups, either in the average growth, or in the individual variability in the growth, were not found. That is, the at-risk group children performed on average at a lower level at age 4.5 in phonological tasks, but they developed almost equally as fast as the control group.

The latent growth models for shared reading, access to print materials, and reading interest consisted only of the latent Level component, and the means and variances of the Level components were compared between the groups. The multi-group analysis of the constructs revealed no significant differences between these groups. Neither the means nor the individual variation differentiated the at-risk and control group.

Longitudinal Factor Analysis Model for Vocabulary Development

Two factors were estimated for vocabulary, one for age 3.5 years and another for 5.0-5.5 years of age (see Figure 2). The final model, which included both assessment waves as well as both groups and where the loadings were set equal across measurement times and groups, is presented in Table 4. In both groups there was significant change in the means of the factors from age 3.5 to 5.0-5.5 years and the at-risk group children were performing at a lower level than control group children at both time points (see also Table 1). In addition, the path from vocabulary at age 3.5 years to vocabulary at age 5 years was significantly stronger in the at-risk group compared to the control group (Regression coefficient was 1.28 for the at-risk and 0.81 for the control group). Squared multiple correlation (R^2_z) was .62 for the control group and .93 for the at-risk group.

Multivariate Models

The next step examined the interrelations of PA, vocabulary, letter knowledge, beginning reading, the HLE factors, and children's reading interest. In the multivariate modeling, we used a specific hierarchical estimation strategy to have stringent rules for obtaining unidirectional paths. That is, we first estimated the across-time paths between factors within each construct with repeated measurements (i.e. PA, vocabulary, letter knowledge, shared reading, and reading interest). For the second step we estimated the correlations between factors across the constructs within time (here the PA Level component was treated as an age 4.5 years measure and PA Trend component as an ages 5.5 and 6.5 years measure). Third, we estimated the across-time-across-factors paths. All statistically nonsignificant paths and covariances were removed within each step one by one, starting from the one with the closest to zero t-value. The standardized estimates of the final models are represented in Figures 3 and 4.

Multivariate model for the control group. Within the control group, vocabulary, letter knowledge, and reading skill development were strongly associated with PA development (see Figure 3). The association between PA Level and vocabulary skills was reciprocal. Similarly, letter knowledge at age 4.5 was strongly associated with the PA Level and the PA Level predicted letter knowledge one year later. The PA Trend component, on the other hand, was directly associated with reading skill emergence at age 6.5 years. Furthermore, letter knowledge predicted variance in the early reading skill and vocabulary at age 3.5 predicted letter knowledge at age 4.5. Direct paths between skill factors and the HLE factors were found only between shared reading and vocabulary development. Neither the HLE constructs nor the children's reading interest were directly associated with the development of PA, but a statistically significant indirect effect through vocabulary skills may be estimated (.24 x .41 = .10). The fit of this model was excellent (c^2 (277) = 257.75, p = .791).

Insert Figure 3 about here

Multivariate model for the at-risk group. The associations between vocabulary, letter knowledge, reading skill, and PA development were rather similar in the at-risk group as in the control group (See Figure 4). The path from PA Level to letter knowledge at age 5.5 years was, however, weaker than within the control group (.33 compared to .59). There was also significant correlation between PA Trend component and letter knowledge at age 5.5 in the at-risk group. The path coefficients and correlations were overall somewhat larger within the at-risk group than in the control group and there were several statistically significant associations between HLE factors in the at-risk group but not in the at-risk group. Additionally, an interesting path (.57) between vocabulary skill at age 3.5 and children’s reading interest level was identified only within at-risk children. The fit of the final model was adequate (c^2 (266) = 309.98, p = .033).

Discussion

The present study modeled phonological awareness (PA) development and its relations with home literacy environment (HLE), reading interest, vocabulary, letter knowledge, and beginning reading skill before school entry in a design involving a follow-up of children with and without familial risk for dyslexia. Instead of a traditional regression analysis approach, we employed longitudinal SEM modeling to simultaneously examine contributions of all the above factors to phonological awareness and literacy development. In many respects, the models of the present study replicated earlier findings from somewhat older children (e.g. Cooper et al., 2002; Sénéchal & LeFevre, 2002). The reciprocal associations between vocabulary and PA and between emerging literacy skills and PA were shown to hold true in our longitudinal model. Of the HLE factors, the amount of shared reading predicted vocabulary, but not letter knowledge, beginning reading, or PA. In addition, our models suggested that the relationships among HLE factors, reading interest, and children's skill development are reciprocal. Our findings add to the literature by showing that although the skill level of children at familial risk for reading difficulties is on average lower than that of the control children, a highly similar model describes the predictive relationships leading to school entry phonological awareness and beginning reading. The exceptions of this pattern were stronger associations among HLE factors in at-risk group than control group children and the predictive link from vocabulary to reading interest for the at-risk children.

By employing the latent growth curve modeling (LGC) technique we showed that PA development followed a linear learning curve in both study groups with no indications of a Matthew effect or a compensatory model. Evidence for a Matthew effect (see Stanovich et al., 1986), would have required a positive correlation between the Level and Trend components as well as an increase in variances across time. A compensatory model, on the other hand, would have required a negative correlation between the latent components (Level and Trend) and a simultaneous decrease in variances across time. The finding of no correlation between Level and Trend means that in these data the level of PA performance (at entry stage age 4.5) does not predict the rate of development during the following two years even though the PA scores correlate highly from year to year.

The rate of development in PA was almost identical in children with and without familial risk of dyslexia (as shown by group comparison of the latent slope component), but the at-risk group children performed on average at a lower PA level at each age. There was also a higher amount of individual variability in the at-risk group than in the control group, and the inspection of individual curves indicated that there were several at-risk children who were performing at a lower level than any of the controls. Our attempts to identify sub-groups within the data by inspection of the graphs or with mixture modeling showed, however, that there were no clear cut-points for sub-grouping but the PA development was best described as a continuum that involves all the children in the data (M-plus, Muthen, 2004).

As expected (e.g. Elbro, et al., 1998; Gallagher, et al., 2000; Pennington & Lefly, 2001) the performance of at-risk group children was also at a lower level in vocabulary and letter knowledge. In beginning reading at age 6.5 years, however, a trend for a group difference emerged which just failed to reach the level of statistical significance ($p = .06$). The latter finding of only slight advantage for the control children may be explained by the nature of the measure used, i.e. reading was assessed prior to formal reading instruction and thus, taps spontaneous reading acquisition. The percentage of spontaneous readers in the control group was 33 %, which corresponds to the percentage typically found in Finland at school entry. The slightly smaller percentage found in the at-risk group, 22 %, is in line with the expectation that about half of children with familial risk for dyslexia will face no problems in reading acquisition.

Some differences emerged between the at-risk and control groups in HLE. In line with earlier findings and suggestions (Bus et al., 1995; Elbro et al., 1998; Leinonen et al., 2000; Scarborough et al., 1991; Snowling, 2000), we found parents with reading problems to engage less in reading activities than parents with no such problems. This difference suggests that children with familial risk may experience less positive parental models of reading for pleasure. In the other HLE components, however, no group differences emerged. Our findings are, thus, consistent with the previous literature (Elbro, et al., 1998; Gallagher et al., 2000; Laakso et al., 1999; Scarborough 1991; Snowling, 2000) in that the extent of shared reading experiences and direct print exposure of children at familial risk of dyslexia appear to be similar to that of children without such risk. Moreover, there were no group differences in children's reading interest. However, the strong associations between different aspects of HLE and between reading interest and vocabulary suggest that in the at-risk group for some children there may be an accumulation of negative gene-environment correlation. That is, for some children inherited vulnerabilities may combine with less positive parental models, and possibly also with a lesser extent of shared reading, instigating slower than average vocabulary development and resulting in lower phonological awareness and letter knowledge at school entry. In contrast, for some children in the at-risk group an accumulation of a supportive home literacy environment and strengths in skills may hold true.

Even though there were rather robust group mean differences in most of the measured skills, the SEM model indicated that associations between PA, vocabulary, letter knowledge, and beginning reading development were highly similar in the two study groups. As expected (Carroll et al., 2003; Cooper et al., 2002; Metsala, 1999; Puolakanaho et al., 2004; Scarborough, 1989, 1990; Silvén et al., 2002), the associations between vocabulary and PA were rather strong. Support was found for a reciprocal relationship. The close relation between vocabulary and PA development is in line with the proposition of the lexical restructuring hypothesis that performance in phonological awareness varies as a function of the absolute size of children's vocabularies (e.g. Metsala, 1999). The present study did not, however, examine the so called *local* effects of children's vocabularies (neighborhood density and familiarity of items measured by frequency of age of acquisition, see e.g. Walley et al., 2003) and can by no means test the lexical restructuring account in detail.

As expected, letter knowledge showed high reciprocal correlations with PA development (e.g. Burgess & Lonigan, 1998; Carroll, et al., 2003; Johnston et al., 1996; Lonigan et al., 2000; Pennington & Lefly, 2001) in both study groups. An interesting group difference did, however, emerge in the relation between PA and letter knowledge: in the at-risk group but not in the control group the rate of growth in PA (Trend) was correlated with letter knowledge at age 5.5. We interpret this finding to reflect the slower development of PA and letter knowledge of the at-risk group children. It appears that in the control group the 4.5-year PA was already at a high enough level to provide a strong prediction of letter knowledge. In the at-risk group where both PA and letter knowledge were at a lower level than in the control group at all assessment waves, the variation among children in the *rate* of PA development had an additional association with letter knowledge above that predicted already by PA level at 4.5 years of age.

The rate of growth in PA was associated with beginning reading in both study groups. The children who were precocious readers at age 6.5 years were also developing more rapidly in PA between age 4.5 and 6.5 years than children who were non-readers. This finding is in line with previous literature on the close reciprocal relation between PA and reading skills (e.g. Wagner, Torgesen, & Rashotte, 1994). After learning to decode, children typically master any PA tasks because they can effectively capitalize on their knowledge of phoneme-grapheme correspondence. In addition, the strong letter knowledge supports the performance of PA tasks and this effect may be particularly strong in transparent languages such as Finnish

(Lyytinen et al., 2006). On the other hand, strong PA skills pave the way for accumulation of letter knowledge which in turn is the necessary but not only prerequisite for reading acquisition. In contrast to PA and letter knowledge, vocabulary skills were not directly associated with beginning reading in our model. These findings are consistent with the suggestion that oral language variables influence reading development indirectly by their connection with phonological awareness (Cooper et al., 2002). In addition, the findings of the present study also suggested a small indirect route from vocabulary to beginning reading skill through letter knowledge.

Although the correlation level analyses showed links between PA and shared reading and reading interest in the at-risk group, the SEM model that included vocabulary development showed that vocabulary size operated as a mediator between shared reading and PA (the indirect effect from shared reading towards PA through vocabulary was small but statistically significant. In the control group shared reading and PA were not correlated, but, as in the at-risk group, reciprocal associations were found between shared reading and vocabulary, and between vocabulary and PA. The findings of the present study concerning associations between PA, vocabulary and shared reading support the model of Sénéchal & LeFevre (2002) in that shared book reading at home supports language development which, in turn, associates with PA development. We would, however, like to stress that the reciprocal associations suggest that it is also likely that the child’s skills affect the literacy experiences that she or he receives, not only that the literacy environment fosters skill development. The results of the present study differed from the results of Burgess (2002), who found a direct unique, although small (4.3 %) effect from HLE towards PA even after taking account for the previous level of PA, early knowledge of print, speech perception, and oral language. One reason for this difference may lie in the measure used to tap oral language. In the present study as well as in that by Sénéchal and LeFevre (2002), oral language was assessed by vocabulary measures whereas in the analyses by Burgess et al., (2002) the oral language composite comprised a measure of grammatical knowledge.

Direct associations between HLE and letter knowledge or beginning reading development were not found. The lack of direct associations between HLE and PA and between HLE and literacy skills supports earlier findings in the literature that HLE, and shared reading in particular, has its strongest effects on vocabulary development (e.g., Crain-Thoreson & Dale, 1992; Frijters, et al., 2000; Griffin & Morrison, 1997; Payne et al., 1994; Scarborough & Dobrich, 1994; Sénéchal et al., 1998). It is also in line with observations (Sénéchal & LeFevre, 2002; Torppa, et al., in press) that emergent literacy skills tend to be more strongly associated with parental teaching behaviors (e.g. of letter names and sounds) than with mere exposure to print and story reading at home. It is notable that even though we used latent variable modeling and had a high risk sample, the associations between HLE and skill development were weak as in previous literature (e.g. Burgess, 2002; Bus et al., 1995; Lonigan, 1994; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002). It appears that the contribution of environmental factors to literacy development is extremely difficult to capture at least when questionnaire or checklist type measures of HLE are used.

Children’s reading interest did not predict directly any of the skills in our model although it was associated with the amount of shared reading which in turn was associated with vocabulary development. In the at-risk group, however, an interestingly strong path was discovered between 3.5-years vocabulary and reading interest level (at 4 to 6 years of age). Even though the strength of this association in the at-risk group is partly caused by a few children with very low vocabulary scores and also a very low reading interest level, removal of the data on these children did not erase the association. It can thus be speculated that in the at-risk group for some children the assumed core deficits in phonological processing, or underlying processes related to it, may interfere with or prevent the building of interest in shared reading activities and hinder the accumulation of vocabulary. This interpretation is in line with suggestions that variation in phonological awareness may be more strongly associated with genetic vulnerability/strengths than environmental variation (e.g. Bus, et al., 1995; Cunningham & Stanovich, 1993; Olson et al., 1989; Olson, 1991; Scarborough & Dobrich, 1994; Sénéchal & LeFevre, 2002).

Taken together, our model showed relatively little differences between children with and without familial risk for dyslexia in the overall pattern of language and literacy development, i.e. the effects of skills supporting the PA development and the rate of development in PA were close to identical. There were, however, very clear differences in the levels of PA, letter knowledge and vocabulary. In both groups development of phonological awareness was strongly related with vocabulary and literacy skills but not with HLE factors. In our model a direct supportive role of home environment on the children's skill development was found only for vocabulary. Our findings concerning HLE corroborate the previous literature in that parents' own reading activities and mere access to literacy materials have little (if any) impact on the children's literacy and language development, whereas variance that parent-child shared reading experiences explained vocabulary growth was in the same range as in previous studies (e.g. Payne et al., 1994; Scarborough & Dobrich, 1994). The finding of no group level differences between children with and without risk in the aspects of HLE directly involving children's participation (i.e. shared reading, access to print materials, child's reading interest) can be speculated to be due to the effects of the follow-up participation. It can be argued that a group difference might have emerged without the effect of an intensive 10-year follow-up which may have inspired the families with the dyslexia background into giving extra support for their children's language and literacy skills development. It should be noted, however, that the efforts of the at-risk group parents to help their children to prevent potential problems did not exceed that of the parents in the control group. Our recent analyses also indicated no group differences in the amount of letter name teaching in the home (Torppa et al., in press) which suggest that parents with dyslexia in our sample have not expended more pedagogical effort in the home than the control group parents.

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Table 1. Means, Standard Deviations, and Group Comparisons of Means (Independent Samples T-Test) and Variances (Levene Test Statistics)

	Control group		At-risk group			
	Mean	SD	Mean	SD	t-test [a]	Levene F [a]
Phon. awareness						
Age 4.5 years	52.37	13.34	46.21	13.76	-3.09 **	0.12
Age 5.5 years	67.21	12.40	60.52	15.03	-3.29 **	1.42
Age 6.5 years	78.48	10.79	73.16	13.03	-3.01 **	2.11
Letter knowledge						
Age 4.5 years	8.99	7.62	6.60	7.26	-2.17 *	1.84
Age 5.5 years	14.89	6.72	11.41	8.05	-3.20 **	8.94 **
Expressive Vocabulary						
Age 3.5 years	20.26	5.76	17.12	5.43	-3.81 ***	0.18
Age 5.5 years	36.10	5.30	33.49	6.67	-2.95 **	3.99 *
Receptive vocabulary						
Age 3.5 years	38.98	14.58	36.04	14.20	-1.39	0.34
Age 5 years	75.17	21.42	66.71	25.28	-2.46 *	5.05 *
Shared reading						
Age 2 years	3.14	0.53	3.09	0.66	-0.58	7.54 **
Age 4 years	2.43	0.54	2.34	0.58	-1.08	1.54
Age 5 years	2.30	0.49	2.35	0.56	0.58	1.85
Age 6 years	2.36	0.54	2.35	0.59	-0.14	0.30
Access to print						

Age 4 years	14.28	2.40	14.34	2.74	0.16	1.94
Age 5 years	14.77	2.17	14.95	2.38	0.53	0.78
Age 6 years	14.66	2.33	14.74	2.25	0.22	0.32
Parental models						
Father	7.23	1.85	6.30	2.34	-2.99 **	5.18 *
Mother	8.27	1.66	6.93	2.30	-4.58 ***	8.64 **
Parental education						
Father	3.79	1.41	3.70	1.28	-0.49	1.17
Mother	4.47	1.35	4.08	1.51	-1.84	0.69
Reading interest						
Age 2 years	95.37	20.56	99.58	18.68	1.43	1.16
Age 4 years	103.30	15.39	103.77	13.48	0.22	2.73
Age 5 years	103.42	13.50	104.69	15.66	0.59	1.47
Age 6 years	105.83	13.87	106.88	16.33	0.47	0.24

[a] Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 2. The Within-group Correlations (Pearson). At-Risk group (n = 96) below Diagonal, Control group (n = 90) above Diagonal

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
Phon. awareness																									
1. Age 4.5 years		.32	.27	.32	.29	.28	.27	.26	.29	.22	-.06	.08	.17	.02	.00	-.07	.00	-.06	-.10	.02	.12	.13	.23	.06	.05
2. Age 5.5 years	.49		.67	.40	.51	.54	.29	.35	.30	.41	.04	-.03	.10	.05	.03	.03	.02	.14	-.06	.09	.19	-.02	-.03	-.01	-.01
3. Age 6.5 years	.55	.64		.53	.57	.65	.26	.33	.26	.41	.05	-.08	.04	-.07	.07	-.01	-.04	.18	-.10	.08	.18	.13	.04	.04	-.02
Letter knowledge																									
4. Age 4.5 years	.34	.48	.58		.76	.67	.26	.33	.21	.29	.15	.10	.17	.06	-.04	-.10	-.14	.11	-.16	.11	.15	.13	.06	.12	.02
5. Age 5.5 years	.32	.54	.62	.80		.60	.26	.32	.24	.35	.10	.10	.24	.11	-.09	-.08	-.09	.12	-.11	.17	.25	.13	.09	.09	.07
Beginning reading																									
6. Age 6.5 years	.27	.54	.71	.65	.61		.22	.26	.17	.26	-.06	-.10	.02	.05	-.02	-.08	-.09	.00	.06	.15	.24	.13	.08	.02	.07
Expressive Vocabulary																									
7. Age 3.5 years	.33	.31	.37	.27	.31	.24		.58	.56	.41	.21	.23	.32	.30	.05	-.04	.00	.12	.06	.15	.08	.18	.18	-.01	.20
8. Age 5.5 years	.37	.43	.48	.37	.45	.35	.74		.41	.53	.12	.12	.30	.26	.10	.04	-.03	.04	.04	.11	.11	.11	.16	.16	.15
Receptive vocabulary																									
9. Age 3.5 years	.34	.21	.37	.33	.39	.15	.59	.48		.51	.10	.09	.22	.22	-.02	-.02	-.03	.07	.07	.08	.15	.09	.11	.07	.13
10. Age 5 years	.32	.37	.38	.26	.29	.22	.53	.57	.51		.18	.15	.25	.09	.13	.13	.01	.08	-.03	.19	.27	.11	.20	.12	.12
Shared reading																									
11. Age 2 years	-.07	-.01	.13	.10	.04	.02	.34	.30	.30	.35		.36	.46	.18	.04	.02	.04	.21	.18	-.03	.02	.49	.22	.29	.17
12. Age 4 years	.01	.00	.14	.15	.09	.06	.37	.41	.29	.26	.66		.62	.56	.13	.22	.19	.10	.14	-.04	-.03	-.05	.31	.12	.22
13. Age 5 years	.11	.22	.26	.16	.13	.19	.34	.43	.24	.37	.53	.68		.56	.07	.19	.13	.11	.10	.01	.02	.23	.28	.20	.23
14. Age 6 years	.10	.10	.26	.22	.17	.21	.34	.46	.30	.26	.50	.73	.74		.10	.18	.21	.10	.28	.12	.11	-.03	.00	.10	.36
Access to print																									
15. Age 4 years	.14	.04	.04	-.03	.06	-.03	.11	.16	.14	.26	.38	.41	.19	.28		.73	.61	.15	.11	.03	.17	-.03	-.14	-.02	.16
16. Age 5 years	.14	.13	.09	.03	.11	.03	.14	.33	.24	.34	.38	.38	.39	.47	.71		.76	.08	.03	-.01	.07	.00	.03	-.02	.17
17. Age 6 years	.08	.04	.09	.03	.09	.05	.16	.22	.20	.32	.37	.40	.37	.48	.68	.67		.07	.11	-.02	-.03	.00	.13	.07	.20
Parental reading models																									
18. Father	.01	.12	.16	.15	.18	.06	.10	.18	.17	.18	-.05	.06	.06	.19	.09	.21	.11		.19	.22	.02	-.04	.03	.10	.12
19. Mother	.05	.13	.16	.21	.26	.08	.19	.23	.12	.25	.27	.39	.26	.36	.45	.34	.48	.33		.05	.17	.00	.06	-.01	.14
Parental education																									
20. Father	-.05	.03	.12	.21	.09	.00	.18	.18	.24	.17	.15	.19	.20	.29	-.02	.07	.19	.41	.10		.39	-.03	-.06	-.12	.03
21. Mother	.02	.06	.11	.23	.18	.05	.14	.21	.10	.30	.06	.08	.12	.06	.01	.15	.14	.13	.20	.20		.11	-.08	-.07	.14
Reading interest																									
22. Age 2 years	.02	.00	.00	-.09	-.02	-.12	.16	.15	.09	.20	.52	.30	.23	.21	.34	.36	.25	.07	.21	-.09	.09		.21	.23	.17
23. Age 4 years	.08	.10	.25	.13	.14	.16	.18	.27	.33	.36	.30	.36	.36	.37	.14	.22	.22	.11	.18	.11	.07	.19		.32	.30
24. Age 5 years	.23	.35	.40	.34	.37	.35	.50	.49	.37	.44	.34	.42	.42	.36	.15	.24	.25	.17	.25	.13	.17	.24	.49		.45
25. Age 6 years	.23	.24	.33	.14	.15	.18	.25	.30	.23	.38	.16	.23	.27	.35	.18	.19	.23	.30	.18	.06	-.01	.22	.40	.38	

Note. All rs > .20, $p < .05$. All rs > 28, $p < .01$. All rs > .34, $p < .001$ within the at-risk group and all rs > .21, $p < .05$. All rs > .29, $p < .01$. All rs > .35, $p < .001$ within the control group

Table 3. Estimated Latent Growth Curve Models for Phonological Awareness, Shared Reading, Access to Print Materials, and Children's Reading Interest within Groups. The Unstandardized Solutions. Standard Errors in Parentheses.

Parameters	Phonological awareness		Shared reading		Access to print materials		Children's reading interest	
	Control	At-risk	Control	At-risk	Control	At-risk	Control	At-risk
Means								
Level (α_{1})	53.44 (1.26)	46.46 (1.33)	9.43 (0.19)	9.39 (0.21)	14.66 (0.22)	14.72 (0.22)	104.24 (1.14)	105.25 (1.11)
Trend (α_{2})	12.52 (0.68)	13.35 (0.62)	ns	ns	ns	ns	ns	ns
Variances								
Level (ψ_{11})	47.38 (14.44)	97.64 (20.07)	2.46 (0.47)	3.83 (0.63)	3.82 (0.64)	3.95 (0.67)	73.19 (17.94)	73.91 (17.45)
Trend (ψ_{22})	17.77 (4.16)	18.82 (4.44)	ns	ns	ns	ns	ns	ns
Error variances								
ε_1	135.78 (24.61)	86.34 (18.86)	2.06 (0.41)	1.73 (0.34)	2.45 (0.45)	2.82 (0.52)	176.09 (31.35)	178.30 (30.66)
ε_2	78.57 (12.69)	122.38 (18.71)	1.49 (0.34)	1.44 (0.31)	0.75 (0.25)	1.84 (0.40)	104.82 (21.61)	103.53 (20.77)

ε_3	0*	0*	2.19 (0.43)	1.35 (0.30)	1.76 (0.36)	1.54 (0.36)	118.62 (23.38)	118.22 (22.58)
	$\chi^2(3) = 3.92$	$\chi^2(3) = 1.18$	$\chi^2(4) = 6.93$	$\chi^2(4) = 1.43$	$\chi^2(4) = 7.78$	$\chi^2(4) = 11.07$	$\chi^2(4) = 3.76$	$\chi^2(4) = 4.61$
	p-value = .27	p-value = .76	p-value = .14	p-value = .83	p-value = .10	p-value = .03	p-value = .44	p-value = .33
	RMSEA = .06	RMSEA = .00	RMSEA = .09	RMSEA = .00	RMSEA = .10	RMSEA = .14	RMSEA = .00	RMSEA = .04
	GFI = .99	GFI = 1.00	GFI = 1.00	GFI = .99	GFI = .99	GFI = .98	GFI = .99	GFI = .99
	SRMR = .05	SRMR = .03	SRMR = .02	SRMR = .04	SRMR = .04	SRMR = .08	SRMR = .04	SRMR = .04

Table 4. The Longitudinal Factor Analysis Models for Vocabulary Development within At-risk and Control Groups. The Unstandardized Solutions. Standard Errors in Parentheses.

Parameters		Control group	At-risk group
Variances	ψ_{11}	21.76 (4.87)	21.79 (5.13)
	ψ_{22}	8.76 (4.75)	2.86 (5.23)
Regression coefficient	β_{21}	0.81 (0.14)	1.28 (0.14)
Loadings	λ_{11}	2.09 (0.09)	2.09 (0.09)
	λ_{21}	1.00 *	1.00 *
	λ_{32}	2.09 (0.09)	2.09 (0.09)
	λ_{42}	1.00 *	1.00 *
Error variances	θ_1	124.45 (22.74)	128.74 (6.25)
	θ_2	11.05 (3.38)	6.71 (2.22)
	θ_3	314.98 (50.64)	393.26 (59.98)
	θ_4	5.79 (4.12)	7.85 (4.38)
Factor means	α_1	0*	-2.73 (0.79)
	α_2	16.13 (0.52)	13.41 (0.62)
Model fit		$\chi^2(8) = 24.40$, p-value = .01	
		RMSEA = .14, GFI = .96, SRMR = .10	

*Note 1. * = Fixed*

Note 2. Factor loadings were invariant across times and groups

Figure Captions

Figure 1. A linear latent growth curve model for a three occasions covariance matrix (means included)

Figure 2. A longitudinal factor analysis model for vocabulary development

Figure 3. The control group (n = 90) multivariate SEM model with standardized estimates.

Figure 4. The at-risk group (n = 96) multivariate SEM model with standardized estimates.