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Effects of Bottom-Up and Top-Down Intervention Principles in Emergent Literacy in Children at Risk of Developmental Dyslexia: A Longitudinal Study

Turid Helland[1], Tomas Tjus[2], Marit Hovden[1], Sonja Ofte[3], and Mikael Heimann[1,4,5]

Abstract

This longitudinal study focused on the effects of two different principles of intervention in children at risk of developing dyslexia from 5 to 8 years old. The children were selected on the basis of a background questionnaire given to parents and preschool teachers, with cognitive and functional magnetic resonance imaging results substantiating group differences in neuropsychological processes associated with phonology, orthography, and phoneme–grapheme correspondence (i.e., alphabetic principle). The two principles of intervention were bottom-up (BU), "from sound to meaning", and top-down (TD), "from meaning to sound." Thus, four subgroups were established: risk/BU, risk/TD, control/BU, and control/TD. Computer-based training took place for 2 months every spring, and cognitive assessments were performed each fall of the project period. Measures of preliteracy skills for reading and spelling were phonological awareness, working memory, verbal learning, and letter knowledge. Literacy skills were assessed by word reading and spelling. At project end the control group scored significantly above age norm, whereas the risk group scored within the norm. In the at-risk group, training based on the BU principle had the strongest effects on phonological awareness and working memory scores, whereas training based on the TD principle had the strongest effects on verbal learning, letter knowledge, and literacy scores. It was concluded that appropriate, specific, data-based intervention starting in preschool can mitigate literacy impairment and that interventions should contain BU training for preliteracy skills and TD training for literacy training.

Keywords

dyslexia, at risk, intervention, bottom-up, top-down, longitudinal study

The aim of this longitudinal study was to assess the long-term effects of two different intervention principles for children 5 to 8 years old at risk of developmental dyslexia. The word *dyslexia* comes from the Greek language and means "difficulty with words." The British Dyslexia Association (BDA) defined dyslexia in this way:

> Dyslexia is a specific learning difficulty which is neurobiological in origin and persists across the lifespan. It is characterized by difficulties with phonological processing, rapid naming, working memory, processing speed and the automatic development of skills that are unexpected in relation to an individual's other cognitive abilities. These processing difficulties can undermine the acquisition of literacy and numeracy skills, as well as musical notation, and have an effect on verbal communication, organisation and adaptation to change. Their impact can be mitigated by correct teaching, strategy development and the use of information technology. (BDA, 2007, p. 15)

Literacy impairment can be caused by dyslexia as defined above, by reduced vocabulary and hence text comprehension, and by reduced motivation (Gabrieli, 2009). Prevalence rates range from 5% to 17% (Shaywitz, 1998), indicating

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that it may be difficult to differentiate between dyslexia and literacy impairment caused by other factors. A common view has been that the frequency of dyslexia is higher in boys than in girls, but epidemiological studies indicate no gender differences (Shaywitz & Shaywitz, 2001; Wadsworth, DeFries, Olson, & Willcutt, 2007). As to the brain basis of dyslexia, functional magnet resonance imaging (fMRI) in children and adults with dyslexia has revealed reduced or no activation in left temporo-parietal cortex (Berninger, Nagy, Richards, & Raskind, 2006; Goswami, 2010; Maisog, Einbinder, Flowers, Turkeltaub, & Eden, 2008; Shaywitz & Shaywitz, 2005; Temple et al., 2003), which is also seen in cross-linguistic studies (Paulesu et al., 2001). Tests of working memory showed extended neural networks in prefrontal cortex and superior parietal cortex in an fMRI study of dyslexic teenagers compared to controls (Beneventi, Tønnesen, & Ersland, 2009). The preliterate 6-year-old at-risk respondents in the present study showed diverging brain responses from matched controls similar to what is seen in formally diagnosed older children (Specht et al., 2009). Remediation studies have revealed that specific training is associated with normalization in left temporo-parietal and frontal regions of dyslexic children (Temple et al., 2003).

A common view is that dyslexia cannot be identified until the child has failed in learning to read and write, and usually not before fourth or fifth grade in school. Research shows that these children rarely catch up (Lyon et al., 2001). However, since dyslexia is a constitutional impairment, and since we know much about early risk signs of dyslexia, prevention starting in preschool should be possible. Although different intervention studies have shown positive effects of training, they are not easily comparable since they differ as to participant selection and methodology.

Intervention based on theories of auditory processing aims at developing the child's language processing skills. Intensive training with the computer-based program *Fast ForWord* showed effects on both phonological awareness and verbal language in preschool children with language impairment (Scientific Learning Corporation, 2004; Tallal, 2004). Another study of dyslexic adolescents yielded changes in brain functions toward typical activation and improved phonological awareness using the same program (Temple et al., 2003). A Finish study trained nonlinguistic audiovisual perception using the computer-based program *Audilex* (Karma, 1998), and this yielded improved reading skills in a group of children with reading problems (Kujala et al., 2001). Others have found no such effects and have therefore not supported computer-based training programs (Given, Wasserman, Chari, Beatti, & Eden, 2008; Hook, Macaruso, & Jones, 2001; McArthur, Ellis, Atkinson, & Coltheart, 2008; Troia & Whitney, 2003). However, it is widely recognized that training phoneme awareness and letter–sound knowledge facilitates emergent literacy (Elbro & Petersen, 2004; Hatcher et al., 2006; Johnston & Watson, 2004; Lundberg, Frost, & Petersen, 1988).

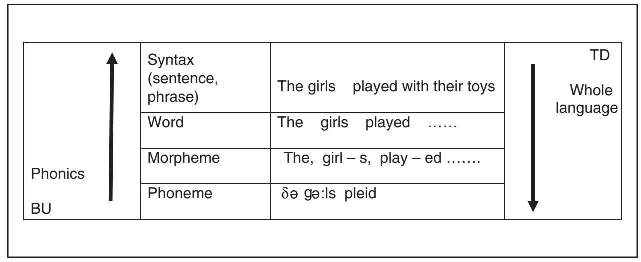

Figure 1. The hierarchy of linguistic units
Note: BU = bottom-up; TD = top-down.

There are comparatively few studies on early intervention based on holistic principles. A Dutch study concluded that semantic training improved reading compared to orthographic training, with the strongest effect in second grade (Berends & Reitsma, 2006). Children with autism improved their reading skills, phonological awareness, and interactive patterns when using a computer-based program focusing on semantics, orthographic decoding, and verbal communication between pupil and teacher (Basil & Reyes, 2003; Heimann, Nelson, Tjus, & Gillberg, 1995; Tjus, Heimann, & Nelson, 2001). Others have shown that letter processing is faster when the letters occur in context (e.g., words) than when they are processed in chains of nonword letters in isolation (Grainger, Bouttevin, Truc, Bastien, & Ziegler, 2003; Matlin, 2005). According to Rasinski and Stevenson (2005) a holistic training program aimed at parent–child interaction had its largest effect among children who were defined as at risk for developmental dyslexia. Thus, a holistic approach may be essential in reading not only to create meaning but also for the decoding process.

These examples mirror two philosophies of literacy teaching used in schools. Phonics-based methods of teaching reading and writing emphasize instruction for decoding and spelling. Whole-language methods emphasize focus on meaning and strategy instruction. The two methods start at different ends of the hierarchy of linguistic units, which is illustrated in Figure 1. The low-level processing starts at the bottom, building phonemes into words and words into the highest syntax level. High-level processing starts at the top, breaking sentences or utterances down into words, morphemes, and phonemes. Often teachers combine these two ways of teaching literacy, but strategies can also vary between cultures and orthographies. Norwegian has a semi-transparent orthography with about 40 phonemes served by 29 letters and approximately 40 graphemes. Norwegian teachers seem to combine a low-level, or phonic, approach with a high-level, or whole-language, approach (Hagtvet, Helland, & Lyster, 2006). In comparison, English has a deep orthography with about 40 phonemes, 26 letters, and more than 500 graphemes (Dewey, 1971), which represents a substantial challenge to learners of English. Presently, a phonic approach to literacy seems to be the dominant method

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both in Great Britain and the United States (Brooks, 2002; Garet et al., 2008).

In neuropsychological terms the information processing in emergent literacy can also be understood in accordance with theories of how the brain processes information. Two different concepts describe two different principles of information processing (Hugdahl, 1995, p. 43). *Bottom-up* (BU) processing refers to how a flow of information is analyzed from sensory integration to a higher, cognitive level. An example of BU processing in reading is the attention to and visual identification of a grapheme, the coding of a grapheme into a phoneme, and linking a chain of graphemes into a word. Thus, BU processes may be seen as basic in emergent literacy. In *top-down* (TD) processing, complex information is processed by the preexisting knowledge in long-term memory and other accessible information. For instance, the TD process is activated during text reading through stored knowledge, experience, and expectations as a basis for creating meaning (Fields, 2003; Matlin, 2005). The studies differ as to sample selection and methods of training. Thus, there is no single conclusion as to which method is most efficient, a BU approach or a TD approach.

The observation that dyslexia tends to run in families was made relatively early in the past century (Orton, 1937). Twin studies have confirmed that genetic factors underlie a large proportion (30%–70%) of population variability in reading measures (Francks, MacPhie, & Monaco, 2002), and longitudinal studies published to date have shown heredity as an early at-risk factor (H. Lyytinen et al., 2004; Wadsworth et al., 2007). Thus, the classic at-risk factor in dyslexia refers to familial occurrence (P. Lyytinen, Am, Puolakanaho, Richardson, & Viholainen, 2001; Pennington, 1999; van Alphen et al., 2004), but, as shown by Rejnö-Habte Selasse, Jennische, Kyllerman, Viggedal, and Hartelius (2005), only 39.3% of the participants in their sample actually had a history of biological heredity. Unpublished data from our own laboratory reveal a similar picture: Of children with a formal diagnosis of dyslexia, 35.5% did not have identified dyslexia in the immediate family (Helland, 2002). This points to sampling procedures in the genetic studies that do not cover all children at risk of dyslexia. Thus, available data show that exclusively relying on familiarity as the sole at-risk factor may underestimate the actual incidence of children with dyslexia; not all offspring of dyslexic parents develop dyslexia, and all dyslexic individuals do not have dyslexia in their nearest family members.

Finding at-risk participants based on phenotype rather than genotype means that one has to define other risk factors besides the genetic factor. The "grand" theories of dyslexia advocate a diversity of etiologies pointing to assessable risk factors: auditory, visual, audiovisual modalities (Boder, 1968; Gjessing, 1977, 1986); autoimmune deficits (Geschwind & Galaburda, 1985a, 1985b, 1985c; Richardson et al., 2000); deficits within the magno-cellular system (Stein & Walsh, 1997); genetics (Annett, 1985; McManus, 1991; Pennington, 1990); impaired phonological awareness (Vellutino, 1979; Vellutino, Fletcher, Snowling, & Scanlon, 2004); impaired motor control (Nicolson & Fawcett, 1999); and auditory processing impairment (Tallal, 1984, 2006). To our knowledge no longitudinal study of preschool children at risk has used phenotype criteria rather than genotype criteria for participant selection.

Learning to read and write demands that the child is able to segment, blend, and manipulate speech sounds and transform them into graphic symbols. Such preliteracy skills are skills of phonological awareness (Snowling, 2004), working memory (Baddeley, 1986) verbal learning, and letter knowledge (Gathercole & Baddeley, 1993; Pickering, 2006; Snowling, 2004). Typically, children with developmental dyslexia experience difficulties with these skills irrespective of orthographies (Helland, 2007; Helland & Asbjornsen, 2000, 2004; Smythe & Evarett, 2000).

The present longitudinal study compares the effects of computer-based training programs in a group of children at risk of developmental dyslexia during their period of emergent literacy. In the Norwegian school system this means the period from the last year of preschool, when the children are 5 years old, through the first 3 years of primary school. The group was split, to train one subgroup with a BU approach and one with a TD approach. The BU approach was defined as training "from sound to meaning," and the TD approach was defined as "from meaning to sound." This was done within the framework proposed by Goswami (2003), that the lowest level of impairment should be identified as early as possible and developmental effects of higher level impairment should be examined longitudinally. Typically, phonological processing and working memory are low-level impairments in dyslexia, whereas problems with literacy acquisition are high-level impairments. Thus, these functions were to be used as dependent measures of training effects. Based on the general consensus of a basic phonological processing deficit in dyslexia, we hypothesized that the BU training would strengthen low-level factors and consequently have a better effect on literacy skills compared to the TD training in at-risk children, whereas the TD training would strengthen high-level factors and hence literacy skills in typical children, that is, children with no phonological processing deficits.

Method

Participants

The study was approved by the Regional Committee for Medical Research Ethics in western Norway and the Norwegian Social Science Data Services. The participants were from Norwegian preschools selected on the criteria that all four counties in western Norway (Rogaland, Hordaland, Sogn og Fjordane, Møre og Romsdal) and both urban and rural districts be represented. The community authorities

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in each county selected nine preschools with a total of 120 children 5 years old. All parents, teachers, and clinicians from the preschools were orally informed about the project at local meetings. They were also informed that an at-risk group and a control group formed by fewer than half of the children would be selected to participate in the study. A screening questionnaire (see the description in the Instrumentation section below) was then sent to the parents and teachers of the 120 children. Questionnaires from both parents and teachers for 109 (90.8%) of the children, 55 boys and 54 girls, were filled out and returned (total of 218 questionnaires), together with formally signed parental acceptance of participation in the project.

Criteria of exclusion at project start were impaired sight or hearing, intellectual disability according to criteria from the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-IV*; American Psychiatric Association, 1994), and diagnosis of any other impairment included in *DSM-IV* (various syndromes, neurological impairments) as reported by parents. All participants had to have Norwegian as their first language. Five participants were excluded from taking part in the project because of these criteria. Based on the Risk Index calculated from the questionnaire (see the Instrumentation section), 26 children (13 boys and 13 girls) were defined as at risk for developmental dyslexia, constituting the risk group. From the remaining 78 children, 26 children matching the at-risk group based on age and gender constituted the control group. During the first year of the project, the parents of 3 children withdrew their children from further participation in the project. The two groups (25 at risk, 24 controls) were followed from when they were 5 years old until they were 8 years old through the project. When entering school at age 6, the children attended 10 different schools and 14 different classes.

Compared to many other countries, Norway has socioeconomic differences that are minor (Halvorsen & Stjernø, 2008). The municipalities participating in the project consist of small urban or rural communities with comparable living standards and with minor ethnic diversities. The educational level of the mothers was 4.4 years (SD = 2.5) of schooling after 9 or 10 years of compulsory school, with no statistical difference between the groups (for a further evaluation of parents' roles in the language development of their children, see Pancsofar & Vernon-Feagans, 2006). The Norwegian school system is public, unitary, and for everyone, with an overall educational ideology of active student inclusion and individually adjusted teaching (Hernes, 1996). In addition, the prevailing philosophy has been that literacy training should not be initiated until the second grade, when the children are 7 years old. This applies to the children in the present study. Children entering school from 2006 and onward started literacy training in first grade, that is, when they were 6 years old, because of national revisions to the school curriculum.

Instrumentation

The *Risk Index Questionnaire* was constructed especially for the project to select at-risk children (Helland, Ofte, & Hugdahl, 2006). One version was for the parents, with questions within six domains, and one version was for the teachers, with five identical domains leaving out familial dyslexia. Three criteria for construction of the list were set: First, it should be theory based; second, it should target the dyslexia phenotype; and third, it should be easy to fill out for those parents who may have dyslexia. The number of questions within each domain varied from three to eight, with response categories *yes* (1), *don't know* (0.5), and *no* (0). First, all of the six domain scores were averaged, and a score was calculated by the following formula: summed score / 12 × 100. Second, the Risk Index was calculated by adding the mean sum of all domain scores from the parents and the teachers, with Domain 6 (heredity) doubled to be weighted equally as the other five domains. Guttman split-half reliability for the parents' six domain scores and the teachers' five domain scores was .832, and Cronbach's alpha was .749 for the subscales. Besides the group differences seen in the present study, the Risk Index correlated with all preliteracy and literacy skills used in the present study (see Table 3 below). Also, the fMRI study of the same project showed positive correlation of occipito-parietal areas with the Risk Index (Specht et al., 2009). Nysæter and Helland (2008) found significant group differences and correlations with subtests of the *Cognitive Profiling System* (Singleton, Thomas, & Horne, 2000; Singleton, Thomas, & Leedale, 2001) used in the same longitudinal study as that reported here. A close to significant correlation (r = .271, p = .06) at age 7 was seen in the *Rapid Naming Test* (Lerøy & Helland, 2008). Appendix A shows the six domains and the mean domain scores for the parents and the teachers, specific regression outcomes, and results from discriminant analysis (Helland, Hugdahl, & Plante, 2008).

The *Wechsler Preschool and Primary Scale of Intelligence–Third Edition* (WPPSI-III; Wechsler, 2002) was used for background information of the children's cognitive functions.

Phonological awareness was assessed when the children were 5 and 6 years old (Fall I, II) by the *Ringerik Material* (Lyster, Tingleff, & Tingleff, 2002), which is a Norwegian test of phonological awareness for 6-year-old children comparable to, for example, the *Phonological Awareness Test 2* (Robertson & Salter, 2007). The Rhyme, Same Phoneme (words beginning with the same phoneme), and Phoneme Deletion (deletion of the first phoneme) subtests were used. Reliability coefficients (Spearman–Brown corrected) are .92, .79, and .70, respectively, for the three subtests according to the manual. No validity measures are given, but the test was constructed from tests used in the well-known Bornholm project (Lundberg et al., 1988). In this context only the

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summed raw scores were used. A correct response was scored with 1 point and incorrect with 0 points, yielding a maximum score of 31 points. Norm data are available for children 6 years 3 months old and 6 years 10 months old (see Appendix B).

Digit Span from the *Wechsler Intelligence Scale for Children–Third Edition* (Wechsler, 1974) was used to assess short-term and working memory when the children were 5, 7, and 8 years old (Fall I, III, IV). Since there are no norms for children younger than 6 years of age, the raw scores were used (see Appendix B). Each correct response was given 1 point; each incorrect response was given 0 points. Only the summed raw scores were reported.

Verbal learning was assessed when the children were 7 years old (Fall III). The *Vaale Test* (Andreassen & Øksenholt, 2002) is a standardized Norwegian equivalent to Luria's 10-word test (Christensen, 1985) and the *Children's Auditory Verbal Learning Test–2* measuring auditory verbal learning (Talley, 1993). The test contains 12 words within three categories: clothes, vehicles, and animals. All words are read out to the child 10 times, and the child repeats as many words as he or she remembers for each word chain. For a correct response 1 point was given, 0 for an incorrect response. Thus, 12 points was the maximum score for each trial. In accordance with learning phases reported by the test constructors (Andreassen & Øksenholt, 2002), 4 trial points were reported here. The first point is "immediate recall" after the first word list; the second is the "imprint phase" from Trial 1 to Trial 5, with a steep learning curve; and the third is the "consolidation phase" for the last five trials, with a rigid or only slightly increasing learning curve. The fourth phase reports long-term memory after 15 to 20 minutes without any repetition of the list. See Appendix B for descriptive data.

Letter knowledge was assessed by the *Word Reading Test* (Taube, Torneus, & Lundberg, 1984) when the children were 5, 6, and 7 years old (Falls I, II, III). The task consists of 24 upper and 24 lower case letters, omitting the low-frequency letters of the Norwegian alphabet (c, z, w, x, and æ). The children were shown the letters to be named one by one on a screen. For a correct response 1 point was given, 0 for an incorrect response, with a maximum score of 48 points. Correlations between the upper and lower case scores for each age were between .86 and .91, $p < .0001$.

Word reading was assessed with 34 words of increasing difficulty, that is, from shallow to semishallow orthography, from the *Word Reading Test* (Taube et al., 1984) when the children were 5, 6, and 7 years old (Falls I, II, III). The children were to read the words out loud without any time limit. A correct response was coded if the child communicated the word that was to be read. Thus, 1 point was given for a correct response, 0 for an incorrect response. No Norwegian norm data exist.

Word spelling. The spelling tests consisted of the 40 first words on *Word Dictation* from the Norwegian version of the *Aston Index* (Newton & Thomson, 1976; Sivertsen, 1992) administered when the children were 6 and 7 years old (Falls II, III). The test is not standardized, but mean scores and a range are given for each grade, 1 to 6. The maximum score was 40 points, and 1 point was given for correct spelling, 0.5 points if the spelling was incorrect but understandable, and 0 points for incorrect and incomprehensible spelling. Means and ranges for second grade fall and spring are shown in Appendix B.

The final test of reading and spelling was administered when the children attended third grade (Fall IV) using the single-word reading and spelling tests of the STAS (*Standardisert Test i Avkoding og Staving* [Standardized Test of Decoding and Spelling]; Klinkenberg & Skaar, 2001). The STAS reading test consists of four lists of 85 words to be read aloud, each within a time limit of 40 seconds. The test has norm scores and is standardized from 2nd to 10th grades. For a correct response 1 point was given, 0 for an incorrect response. The score was the number of words correctly read minus the number of words incorrectly read. The maximum score is 340 points, read within 160 seconds. Since preliminary analyses showed no statistical differences between the subgroups on any of the four lists of words, only the composite score was used. The spelling test of the STAS battery consists of 54 real words. Of the words, 11 are simple words with a shallow orthography, whereas the 43 other words are more complex in the sense that they differ in regard to phoneme–grapheme correspondence. For a correct response 1 point was given, 0 for an incorrect response, with a maximum score of 54 points. Norm scores for the STAS reading and spelling tests are given in Appendix B.

Training programs. The aim was to use only evidence-based computer programs. Since there is a limited choice of such programs in Norwegian, we also had to use programs that had been widely used clinically but with no research base.

BU training. The Spring I training used four language-independent tasks from the *Fast ForWord* program (Scientific Learning Corporation, 2002, 2004), Circus Sequence, Old MacDonald's Flying Farm, Phoneme Identification, and Phonic Match, exercising the ability to identify and remember sound sequences, discriminate among sounds, and match sounds to pictures. The Spring II training used tasks from the *Audilex* program (Karma, 1998), which is a computer game consisting of nonverbal sound patterns with 3 to 15 elements to be matched with graphically presented elements presented horizontally on the computer screen. The sound elements, which are visually represented by length, thickness, and position, respectively, of the rectangles on the screen, vary in duration, intensity, and pitch. Easy and difficult patterns are randomly presented during the training period (for a more detailed description and research findings, see Kujala et al., 2001). The Spring III training used

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Table 1. Design of the Study

School Age	Preschool, Ages 5–6		1st Grade, Ages 6–7		2nd Grade, Ages 7–8		3rd Grade, Age 8
	Fall I	Spring I	Fall II	Spring II	Fall III	Spring III	Fall IV
Assessments:							
Risk Index Questionnaire	1. WPPSI 2. Phon. Aw. 3. Digit Span 4. Letter knowledge 5. Word reading	None	1. Phon. Aw. 2. Letter knowledge 3. Word reading 4. Word spelling	None	1. Digit Span 2. Verbal learning 3. Word reading 4. Word spelling	None	1. Digit Span 2. Word reading 3. Word spelling
Training							
Bottom-up	None	FFW	None	*Audilex*	None	*AskiRaski*	None
Top-down	None	*Omega-Is*	None	*At the Farm*	None	*Talk, Write, Read*	None
Number of training sessions	None	40	None	32	None	32	None
Literacy training	No	No	No	No	Yes	Yes	Yes

Note: WPPSI = *Wechsler Preschool and Primary Scale of Intelligence*; Phon. Aw. = phonological awareness; FFW = *Fast ForWord*.

AskiRaski (Ask, 2002), a program training grapheme–phoneme correspondence and synthesizing of graphemes into short words. The main setting of the BU principle was the interaction between the child and the computer program. The role of the teacher was only to be present and to be ready to help the child if necessary.

TD training. The Spring I training used *Omega-Is* (Heimann, Lundälv, Tjus, & Nelson, 2004). The program allows the child to create sentences by clicking on text buttons. The child receives concrete and absolute feedback through print, by hearing the sentence, and through animations illustrating the sentence. The main setting for the *Omega-Is* training—and also for the TD training taking place during Years 2 and 3—was a three-way interaction among the child, the teacher, and the computer. The role of the teacher was to play an active, supportive role, recasting the child's utterances. Recasting means that the teacher repeats the semantic meaning of what the child is saying and adds something more; for example, the child says, "A banana," and the teacher says, "Yes, and it was a yellow banana." The Spring II training used *At the Farm* (NorMedia, n.d.). This program is a tool for working with language by building stories using pictures, text, and speech based on themes from which the child can choose. The Spring III training used *Talk, Write, Read* (Helland, n.d.), using four-card pictures to be assembled into stories to be told first orally (making a story line). Then the child dictates the story (usually one utterance for each picture) to the teacher, who writes it down on the computer. One utterance at a time is then presented to the child on the screen, and the child has to read and memorize the written utterance. When the child is ready, the utterance is removed from the screen and the child has to rewrite it from memory using a spell check program. The story is then printed out, in both picture and text, to be collected into a self-made story book. The last two programs are used extensively clinically but have no norms or standardized evaluations.

Design and Procedure

The design of the study is shown in Table 1. The training periods lasted 8 weeks every spring, and the cognitive assessments took place every fall. The final tests of reading and spelling took place when the children had received a little more than one school year of formal literacy training.

The spring training took place at the respective preschools and schools in individual sessions within the time frame of February to April. Appendix C has an overview of the training groups by regions, preschools, schools, training times, trainers, and testers. At least two teachers in each preschool or school shared the training between them. The teachers were especially selected for the task by their respective schools and received specific instruction for administration of the training programs. This training was given in the districts by two of the authors (Helland and Ofte) in sessions of approximately 4 hours and a month or less before the training of the children. The teachers noted in a protocol for each session how the actual child responded to the training. The clinicians and the teachers were not informed of which group each of the children belonged to.

Training sessions and periods. In Spring I (preschool) the children received 20 minutes of training sessions 5 days a week for 2 months, in sum 40 training sessions. In Spring II and III they received 20 minutes of training 4 days a week

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Table 2. Risk Index and Cognitive Measures for the Two Risk and the Two Control Groups Receiving Either Bottom-Up (BU) or Top-Down (TD) Training

	Risk				Control				One-way ANOVA			
	BU (n = 15)		TD (n = 10)		BU (n = 11)		TD (n = 13)					
Groups	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(45, 3)$	$p <$	Tukey's HSD Test[a]	Cohen's d
Age 5												
Risk Index	23.98	12.50	17.83	4.69	5.28	3.18	2.60	2.04	24.261	.0001	risk > con**	2.31
WPPSI												
FSIQ	103.00	15.59	99.90	15.39	106.91	12.13	105.15	9.63	*ns*			
VIQ	100.33	15.16	101.40	11.34	104.64	11.80	105.54	10.73	*ns*			
PIQ	105.80	13.98	98.00	17.89	107.36	19.17	104.62	10.96	*ns*			

Note: WPPSI = *Wechsler Preschool and Primary Scale of Intelligence*; FSIQ = full scale IQ; VIQ = verbal IQ; PIQ = performance IQ.
a. Tukey's honestly significant difference test for unequal numbers. There was no significant difference between two risk subgroups or the two control subgroups as to the Risk Index.
**$p < .01$

for 2 months, in sum 32 training sessions each year. Thus, each child got in total 104 sessions of training. As can be seen in Appendix C, there were 24 trainers for each training session, and each child trained with the same trainer or his or her substitute each year.

Fall assessments were administered by groups of licensed school speech and language therapists and psychologists who shared the testing between them. This took place within the months of October and November. The children were tested at the clinicians' offices or in separate rooms at the schools. Parents were present if wished for but were instructed not to interrupt the testing. Each session took between 3 and 5 hours and included other tests besides the ones used in the present study. The order of the tests was set so that there should be variability for the children not to tire them out. Thus, a cognitive task could be followed by a motor task or a drawing task, or a visual task could be followed by an auditory task. The clinicians administered breaks whenever needed.

Groups. The children were split into two training groups, one BU and one TD, yielding four subgroups: risk/BU (n = 15), risk/TD (n = 10), con/BU (n = 11), and con/TD (n = 13). For practical reasons the children within the same county received the same intervention package (BU or TD). As can be seen in Appendix C both rural and urban environments were represented in both training groups. It was decided by random which two communities would use the BU strategy and which two would use the TD strategy. Only the parents received information on which group their child belonged to. They were asked to keep this information to themselves, but no effort was made to check to which degree this information was shared.

Background data were the Risk Index and the WPPSI (Wechsler, 1974) administered when the children were 5 years old. All data from Fall I are preintervention data, and all data from Fall IV are postintervention data. There were missing data for phonological awareness and reading (n = 6, age 5; 4 in risk/TD, 2 in con/TD). Also, data from one child were missing for spelling age 6 and from another child for reading and spelling age 7. Data from these two children were in the project at age 8, both from the risk/BU group.

Data Analyses

All data are from the four fall assessments. Since the subgroups were small, the results should be looked on with care. Both nonparametric and parametric tests were used to explore within- and between-group differences. Separate analyses for gender were carried out, but no gender differences were seen. Also, the Risk Index was used as a covariate, but this did not yield any differences in the analyses. On the background of these tentative analyses, repeated measures analysis of variance (ANOVA) with a group (2: risk, con) by training group (2: BU, TD) by repeated measure design was used, followed by a one-way ANOVA with a group (2: risk, con) by training group (2: BU, TD) design. Tukey's honestly significant difference test for unequal numbers was used as a follow-up test. Also, the final word reading and spelling tests were compared with the STAS norm scores using a two-sided difference test (difference between two means). Cohen's d was reported where significant between-group differences were seen. Finally, the test scores were correlated with the Risk Index. The alpha level was set at $p < .05$.

Results

First background data are presented, then the results of the tests on preliteracy skills for reading (phonological awareness, memory, and letter knowledge), and finally the results for word reading and spelling.

Background Data

Results of a one-way ANOVA (Risk Index, WPPSI) are shown in Table 2. This yielded significant differences on the

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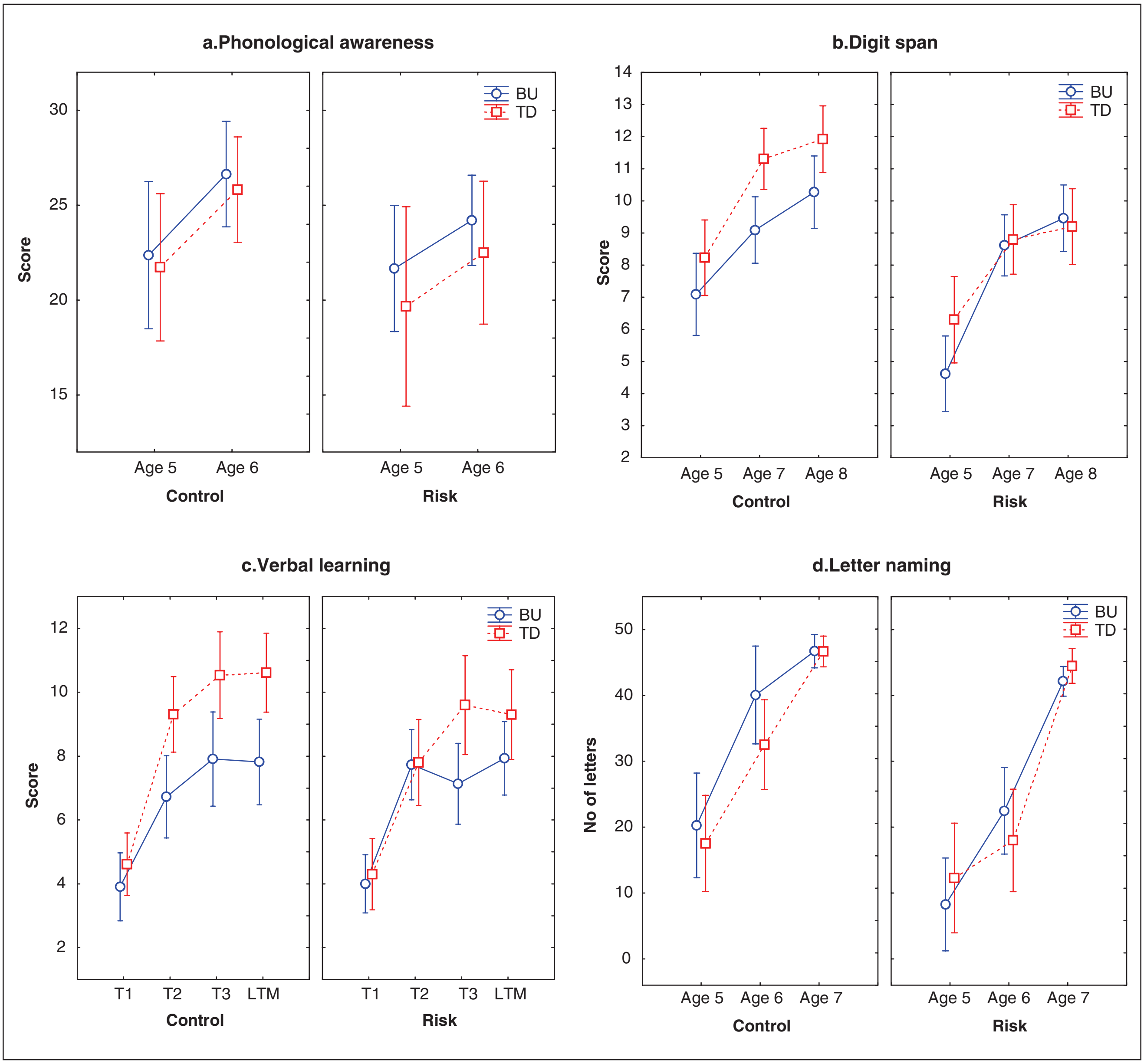

Figure 2. Preliteracy and literacy skills; repeated measures of the four training subgroups

Risk Index between the two risk groups on one hand and the control groups on the other. IQ scores at project start showed scores within the normal range. Repeated measures on the WPPSI scores for verbal IQ (VIQ) and performance IQ (PIQ) at age 5 yielded no significant differences.

Preliteracy and Early Literacy Skills

For all significant between-group differences reported below, Cohen's *d* ranged from 1.0 to 2.5.

Main effects of repeated measures (age and trials) were seen in all tests ($p < .001$). Main effects were also seen for group (control vs. risk) in Digit Span, letter naming, word reading, and word spelling because of higher scores in control versus risk ($p < .01$) and in the training group (BU vs. TD) in Digit Span, verbal learning, and word spelling because of higher scores in TD versus BU ($p < .01$).

As to phonological awareness (see Figure 2a), a one-way ANOVA showed a group difference, $F(3, 39) = 2.949$, $p < .04$, because of lower scores in risk/TD than con/BU at age 6 ($p < .05$), that is, after the first training period.

In Digit Span (see Figure 2b) an effect of interaction was seen for group by training group by age, $F(2, 86) = 4.67$, $p < .01$, because of the low scores in risk/BU age 5 versus

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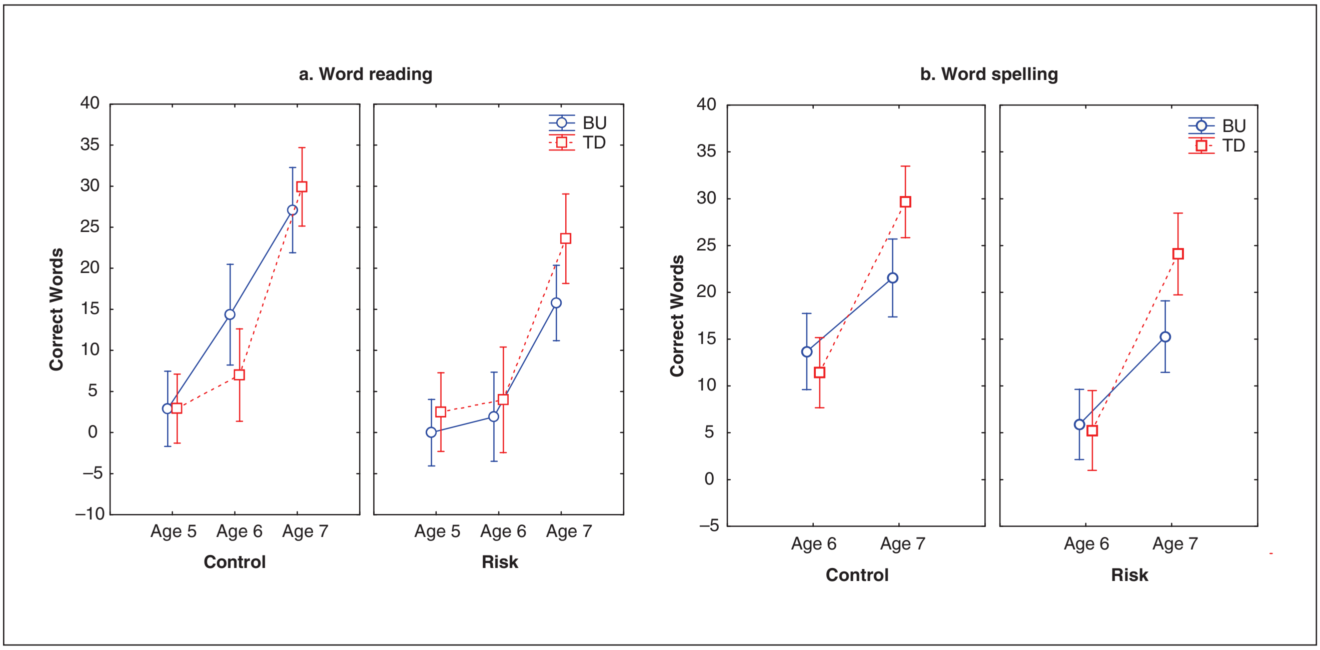

Figure 3. Posttraining results, third grade word reading and word spelling

all scores ($p < .001$) except for risk/TD age 5. The risk/BU leveled with the risk/TD at ages 7 and 8. However, the best scores were seen in con/TD, with significantly higher scores than con/BU at age 7 ($p < .05$) and the two risk subgroups at ages 7 and 8 ($p < .01$). Thus, the TD training seemed to have best effect for the control group, whereas the BU training seemed to have best effect for the children with the lowest scores, that is, the risk/BU subgroup, lifting their low scores at age 5 to the level of risk/TD at ages 7 and 8.

For verbal learning (see Figure 2c) an effect of interaction was seen in training group by trials, $F(3, 135) = 4.416$, $p < .01$, because of higher scores in TD versus all other scores at Trial 10 and long-term memory ($p < .03$). In addition, a one-way ANOVA showed a group difference at Trial 5, $F(3, 45) = 3.007$, $p < .04$, because of con/BU having a lower score than con/TD ($p < . 5$).

As to letter naming (see Figure 2d) an effect of interaction was seen in group by age, $F(2, 88) = 7.636$, $p < .001$, because of higher scores for control ages 6 and 7 versus all other scores ($p < .0001$) except for risk age 7, where there was a ceiling effect since the children by then had learned the letters of the alphabet. These findings were supported by the one-way ANOVA analyses.

In word reading (see Figure 3a) there was an effect of interaction group by age, $F(2, 88) = 3.53$, $p < .05$, because of the scores in control age 7 being higher than all other scores ($p < .01$). There was also an interaction of training group by age, $F(2, 88) = 3.78$, $p < .05$ because of higher scores in TD versus all other scores, except for BU at age 7 ($p < .0001$). One-way ANOVA showed that there was a group difference at age 6, $F(3, 45) = 3.616$, $p < .02$, because of a lower score in risk/BU versus con/BU ($p < .005$), and at age 7, $F(3, 45) = 6.880$, $p < .0007$, because of lower scores in risk/BU versus con ($p < .01$).

In word spelling (see Figure 3b) there was an effect of interaction training group by age, $F(1, 43) = 19.41$, $p < .001$, because of higher scores in TD versus BU ($p < .0001$) at age 7. Also, one-way ANOVA showed a group difference at age 6, $F(3, 45) = 4.093$, $p < .01$, because of a lower score in risk versus con ($p < . 05$), and at age 7, $F(3, 45) = 11.043$, $p < .001$, because of lower scores in risk/BU versus TD ($p < .01$) and higher scores in con/TD versus con/BU ($p < .05$).

Posttraining Results of Word Reading and Spelling, Age 8, Third Grade

Reading. A one-way ANOVA showed a group difference, $F(3, 45) = 3.199$, $p = .03$, because of a lower score in risk/BU versus con/TD ($p < .05$; Cohen's $d = 1.0$; see Figure 4a).

Spelling. A one-way ANOVA showed a group difference, $F(3, 45) = 6.475$, $p = .001$, because of a lower score in risk/BU versus con ($p < .01$; Cohen's $d = 1.4$; see Figure 4b).

Comparison With STAS Norms Data, Age 8, Third Grade (N = 118)

Word reading. A two-sided difference test (difference between two means) using the STAS norms ($M = 99$, $SD = 55$) versus risk and control summed mean score ($M = 111.9$, $SD = 47.1$) was not significant (see Figure 4a). However, STAS norm versus the control group ($M = 130.58$, $SD = 46.95$)

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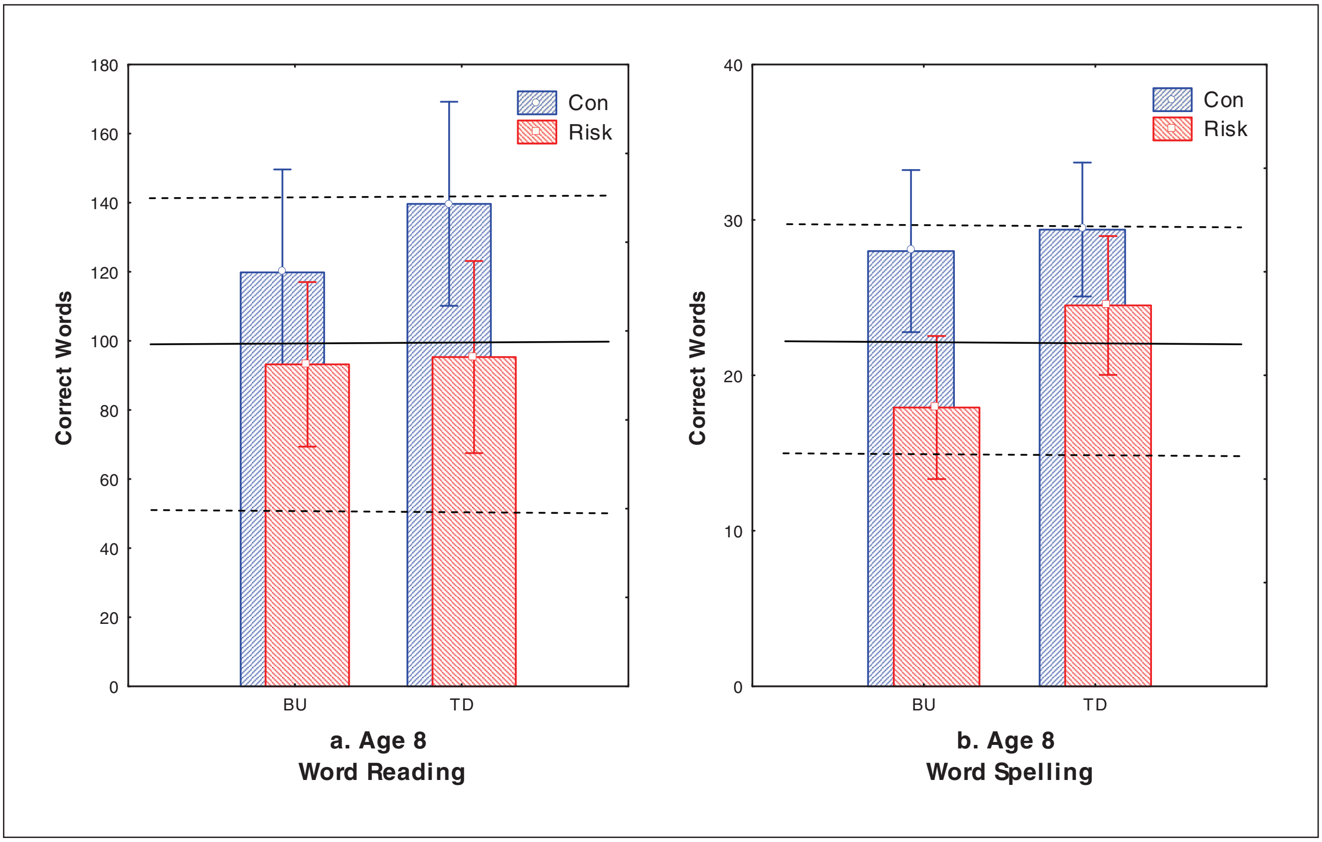

Figure 4. Overview of effects of bottom-up (BU) and top-down (TD) training in the at-risk group
"Note: Horizontal lines: solid = norm, mean; broken = norm, standard deviation."

Table 3. Correlations (Product–Moment) Between Risk Index and Preliteracy Skills, Reading, and Spelling

Age	5	6	7	7	8	8
Task	Digit Span	Phonological Awareness	Verbal Learning	Letter Knowledge	Word Reading	Word Spelling
5, Risk Index	–.5508	–.3077	–.3705	–.3507	–.3575	–.4238
p	.001	.031	.009	.015	.012	.002

showed that the control group scored significantly higher than the STAS norm score ($p = .01$). The risk group ($M = 94.04$, $SD = 40.57$) showed no significant difference to the STAS norm. Two participants, a boy from risk/BU and a girl from risk/TD, had scores slightly below 44 (1 *SD*; 42 and 38 points, respectively). Familial dyslexia was reported for the boy only.

Word spelling, age 8. A two-sided difference test (difference between two means) using the STAS norm scores ($M = 22$, $SD = 9$) versus the risk and control summed mean score ($M = 24.6$, $SD = 8.7$) showed no significant differences ($p = .09$; see Figure 4b). Split by groups, the control group ($M = 28.75$, $SD = 7.29$) scored significantly higher than the STAS norm score ($p = .0007$), whereas the risk group showed no significant difference from the STAS norm score. Two boys and two girls, all from the risk/BU subgroup, had scores slightly below 11 (<1 *SD*; scores = 8, 5, 10, and 9 points, respectively). Familial dyslexia was reported for the two boys but not for the two girls. Only one of these participants (girl) had scores 1 *SD* below the mean on both the reading and spelling tests.

Correlations. Table 3 shows the correlation between the Risk Index and a selection of the test scores distributed across age. All correlations revealed significant relationships between the Risk Index and the different test areas. The size of the correlations varied from .55 for Digit Span to .31 for phonological awareness.

Summary

Preliteracy skills. Overall, there was a stronger effect of BU for phonological awareness both in risk and control. As to Digit Span, the results were mixed in that TD had the

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strongest effect in the control group, whereas BU had the strongest effect in the risk group, in the sense that risk/BU had a steeper learning curve compared to risk/TD. As to verbal learning the TD subgroups scored in general highest. In letter naming all participants increased their scores from age 5. At age 6 the BU condition attained the highest scores, whereas at age 7 when formal training had started, risk/BU demonstrated unstable letter knowledge in spite of the ceiling effect.

Literacy. Although there was a significant increase in word reading and spelling in all groups by age, there were significant differences between risk and control at ages 6, 7, and 8. Tested for word reading when they were 5 years old, most of the children were not able to read. Despite increasing reading and spelling scores by age, the risk/BU subgroup got the lowest scores overall. However, risk/BU had a reading spurt from age 7 to age 8, leveling with risk/TD and con/BU. The highest reading scores were seen in con/TD at age 8. As to spelling, the risk/BU subgroup scored significantly lower than the control group. In sum the TD training principle seemed to have an advantage over the BU principle as to emergent word reading and spelling. The Risk Index correlated significantly with the scores of the tests used distributed over age.

Discussion

The main findings of this study can be summarized in three main points. First, as to the risk group, the BU training seemed to have the best effect on the lowest level processes, that is, phonological awareness and Digit Span, whereas the TD training had best effect on the higher level processes, that is, verbal learning, letter knowledge, word reading, and spelling. Second, as third-graders the sample as a whole had mean reading and spelling scores at the upper end of the norm score for the grade. This was surprising given that half of the children were defined as at risk for developmental dyslexia. The control group performed significantly better than the norm score on both the final reading and spelling tests, whereas the risk group scored at the norm. Third, a further exploration of the literacy scores showed that the three boys and the three girls, one from the TD and five from the BU, with scores below one *SD* on the reading and/or the spelling test all had scores showing that they were within the alphabet level of literacy acquisition (Ehri, 1991; Frith, 1986). There was no gender bias in this low scoring group, but there was a heredity bias as the familial occurrence was reported for the three boys and one of the girls. Thus, 6.4% of the original sample of 109 children showed relatively low reading or spelling skills, which is at the lower end of the prevalence rates ranging from 5% to 17% as reported by Shaywitz (1998). One girl from the control group scored slightly under norm on the reading test.

Both training approaches contributed to emergent literacy in significant but different ways. This is illustrated in Figure 4. The TD subgroups scored best on the final reading and spelling tests, which indicates that early print exposure might be highly beneficial to children susceptible of literacy impairment. However, it would be premature to conclude that TD is the single best approach. In particular access to phonological representations is basic to literacy development (Ramus & Szenkovits, 2008). The BU training seemed to have an effect on these representations rather than on letter knowledge, word reading, or spelling. The reading spurt seen in risk/BU from age 7 to age 8 may be attributed to the formal training that had started in school. But the BU training could also be an essential contributor to this spurt. In contrast to the risk/TD subgroup, the risk/BU subgroup received no training with letters or written words until they started formal training in second grade. A main contribution of the BU training may then be the processing skills that this training targeted. Since the reading task given to the children when they were 8 years old is time restricted, the reading score is an outcome of processing speed as well as reading skills. The spelling task, on the other hand, is not time limited and therefore does not put the same demand on processing skills.

The data showed an expected development with age. Ideally, to be able to answer the question of what is natural maturation and what is the effect of training, an age and gender matched control group receiving no training should have been established. This was not possible for ethical and practical reasons. However, age norms were available for most of the tests and, most importantly, for the third grade reading and spelling tests. With no intervention, we should have expected scores in the lower end of the norm for the whole sample, differentiated by the control group scoring at the norm and the risk group scoring below the norm. Since the results were better than this, it is reasonable to credit the positive results to the training that was given. However, a Hawthorn effect should always be taken into account in intervention studies and in the present study for both training approaches. This could explain some of the differences seen in relation to age norms, but not the differences between the BU and TD training groups.

As to the subgroup differences seen in most of the experimental data, our earlier reported data from the fMRI scanning when the children were 6 years old showed different brain activity in the risk group and the control group while doing reading-related activities. This indicates a slower maturation of the language areas of the brain in the risk group (Specht et al., 2009). This area is also activated in working memory tasks (Baddeley & Logie, 1999) and may thus explain the differences on the Digit Span task when the children were 5 years old. The BU training seemed to strengthen the risk/BU subgroup's working memory. However, in spite of higher score by age, the risk group did not catch up with the control group. This is in line with research on working memory, reporting that the memory span in itself is hard to expand by training but may be

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supported by acquired strategies and prior learning (Baddeley & Logie, 1999).

The score differences in the BU subgroups versus the TD subgroups on the two memory tasks, Digit Span and verbal learning, need commenting. The tasks assess two different memory systems. Digit Span forward and backward is a test of short-term and working memory, respectively, whereas verbal learning represents dynamic testing of learning skills and strategies and of long-term memory. Impaired working memory is a benchmark in dyslexia, whereas there is little evidence of impaired long-term memory in dyslexia (Kibby & Cohen, 2008). Since both TD subgroups scored higher than the BU subgroups on this test, we suggest that the use of functional language, as in the TD training, contributed to the development of semantic information rather than to attention to linguistic sounds, which was focused in the BU training. Also, the use of strategies may be the reason why the TD training gave better results on the verbal learning test. Probably the most efficient way to recall the 12 words in this task is to categorize them into the three groups: clothes, vehicles, and animals. Undoubtedly, stimulation of verbal communication, which was typical of the TD training, would also stimulate conceptualization based on acquired strategies and semantic information. Thus, it should not be surprising that the children trained by the TD approach surpassed the BU group on this task.

Furthermore, we know from much research on aphasic patients that although the left hemisphere plays a crucial role in fine processing of linguistic information, the right hemisphere maintains activation for figurative and pragmatic aspects of language, coarse processing, double meanings, and ambiguities (Beeman & Chiarello, 1998; Luria, 1973). Also, patients with either left or right hemisphere cerebrovascular diseases yielded different results on language tests (Bryan & Hale, 2001). In the present study the TD approach targeted higher-level linguistic skills, as the starting point was utterances and sentences. Thus, it might be possible that this approach activated the linguistic interaction between the two hemispheres to a larger degree than did the BU approach and that the activation of both hemispheres is mutually more stimulating also in emergent literacy. If so, this is a very important aspect because of the plasticity of the young brain and may be used as an argument for using the TD approach.

Methodological considerations are crucial for how the data should be interpreted. A study like the present one has a complex design that may easily be seen as confounding factors. According to Goswami (2003) it is important that developmental designs in dyslexia research use a neuroconstructivistic framework. As described earlier, the lowest level of impairment should be identified early, and developmental effects of higher-level cognition should be examined longitudinally. Also, she holds that only a phonological processing deficit arising from low-level auditory processing problems meets the criteria for a neuroconstructivistic approach across orthographies. We started with assessing 5-year-olds with tests of phonological awareness and working memory, which could both be defined as low-level processes, and gradually examined their development into literacy, which is a higher-level cognitive activity.

Participant selection criteria set by Goswami (2003) are (a) careful matching of experimental and control groups for IQ, using verbal as well as nonverbal IQ with minimal differences; (b) chronological age controls matched also for IQ; and (c) (younger) reading level controls. The present study meets these criteria. The risk group and the control group were matched not only on age and IQ but also on reading level at project start. The questions posed to parents and preschool teachers targeted dyslexia as a disorder with multiple overlapping risk factors and not as a single-domain disorder (see Pennington & Bishop, 2009). This is in line with the definition of dyslexia we referred to in the introduction (BDA, 2007). Significant group differences were seen on tests of both preliteracy skills and literacy skills, and the experimental scores correlated significantly with the Risk Index. The questions set forth in the questionnaire should be labeled as low level, in the sense that they addressed developmental issues targeting dyslexia in a preliterate population.

Dyslexia is a dynamic developmental disorder that changes over time. This study addressed the effects of two different training approaches for children at-risk of developing dyslexia during a period of time when they typically undergo dramatic changes. The expected developmental spurt from illiteracy into literacy represents an extra challenge when children are at risk of failure. Our choices of tests and data-based training programs were based on adjusting to the children's development, as to both their low-level preliteracy skills and their higher-level literacy skills. In consequence, multiple sets of tests and training programs were used. This may seem confounding from a scientific point of view, but if a demanding research project involving children is to be implemented in a pedagogical setting, it must have a face value to the participants. This means that the research project has to be meaningful to the involved schools, teachers, children, and parents. In Norway, and in many other countries, teaching literacy is often done with a mixture of phonics and whole-language approaches, often in an unsystematic way. The parallel to a BU and TD training was immediately drawn, and thus the training principles met the professional interests of the teachers. Besides, the programs and the methods used could provide new insight into their teaching in general and the special educational programs in particular.

An essential question in all intervention studies is how to control for environmental factors. In this study environmental bias was minimized because of the many different trainers and schools involved and the equal socioeconomic

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opportunities typical of Norway. Therefore, we conclude that the early, appropriate, and specific computer-based intervention starting in preschool benefitted the children at risk of dyslexia in this study. Also, the lowest scoring children acquired literacy skills in a manner that should not exclude them from later academic school activities. Intervention was provided earlier than is common in Norway and in many other countries, and, as a result, the at-risk participants were performing at a level equal to their non-at-risk peers. Even though the TD training principle seemed to foster reading and spelling skills more efficiently than the BU principle, both principles should be applied. The early BU effects on the low-level impairments are important because of the general consensus that these are benchmarks of dyslexia and that they are basal skills in emergent literacy. Thus, the BU training may be the underlying cause for the reading spurt seen in the risk/BU subgroup from age 7 to age 8.

That the TD approach so far yielded better spelling results than the BU approach may seem surprising. Many studies from England and the United States indicate that using teaching methods comparable to a BU approach gives better results compared to methods comparable to a TD approach. The differences in orthographies may be one factor explaining this finding. Norwegian has a closer phoneme–grapheme correspondence than English, and thus the TD training also trains phonological awareness to a large degree. Moreover, since literacy training did not start until second grade in Norway, there was no interference with classroom literacy training during the first 2 years of the project. In England and the United States literacy training starts earlier, and the officially recommended phonic method might bias the BU approach.

Our follow-up study of the same children as sixth graders will add more knowledge of how the children progress. Meanwhile, the promising results of the present intervention study give us reason to believe that children at risk of dyslexia can and should be identified early and that their literacy training should start playfully in preschool. The training should combine a BU and a TD approach with systematic pre- and posttesting. This would satisfy the criteria of being appropriate and specific, using information technology as stated in the definition of dyslexia by the BDA (2007). We suggest that this method of intervention would prevent educational failure in children at risk for dyslexia and help schools prepare them for a life dependent on literacy skills.

Appendix A. The six domains in the Risk Index questionnaire

		No of questions	Parents	Teachers
1. Domain	Soma	6	6.0 (10.4)	4.0 (8.3)
2. Domain	Autoimmune	3	13.1 (20.5)	7.8 (16.1)
3. Domain	Language dev.	4	7.8 (18.0)	9.3 (23.0)
4. Domain	Motor skills	8 (parents) 6 teachers)	6.3 (10.0)	15.0 (17)
5. Domain	Special edu.	3	6.7 (22.3)	7.2 (23.2)
6. Domain	Heredity	4 (parents)	18.1 (24.2) x 2	

1. Domain: somatics (6 questions): born within term, hearing, sight, ear infections, chronic illness, physical handicap
2. Domain: the GBG-hypothesis (3 questions): asthma, allergies, left-handedness
3. Domain: language development (4 questions): typical, comprehension, vocabulary, pronunciation
4. Domain: motor skills (parents 8 questions, 1-8; pre-school teachers 6 questions, 3-8:): crawling: walking, drawing, building blocks, puzzling, playground, go for walks, find the way
5. Domain: special needs education (3 questions): receives, referred, is considering
6. Domain: heredity (parents only, 4 questions): dyslexia, language impairment, mathematics impairment, visuo-spatial impairment

Specific regression outcomes, preliminary analyses.

Age 6. The sum of the Preschool teachers' scores plus Parent report of genetic risk predicts word reading. Preschool teachers' report in the areas of language and special-education predicts word reading. The sum of the Preschool scores plus Parent report of genetic risk predicts word reading.

Age 7. The mean Preschool teachers' score predicts word reading

The Preschool teachers' report in any of the 6 areas entered individually predicts STAS scores

Age 8. The sum of the Preschool teachers' scores plus Parent report of genetic risk predicts STAS scores. Each component contributes significantly to the regression.

Discriminant analysis. Small letters, capital letters, word reading (sum) and spelling scores will classify children in the risk/no risk groups with 75% sensitivity and 87.5% specificity at age 6 and 62.5 and 87.5% at age 7. No one variable is a statistically significant contributor to the discrimination, but the combination yields a statistically significant result. This is true at age 6 and age 7.

From Helland, T., Hugdahl, K. & Plante, E. (in preparation). Finding early at-risk factors of dyslexia by a simple questionnaire. The questionnaire can be attained from the first author.

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Appendix B. Available descriptive statistics from the tests used

Test	Mean	SD	Range	Scaled scores	N
	Descriptive statistics				
Risk Index	9.96	10.07			109
Phon. aw. (age – months)					
6 - 3	23.6	2.2			273
6 - 10	24.4	2.2			200
DS, raw scores (age - months)					
7 - 6	8			10	
8 - 6	8			10	
Verbal learning (2nd grade)					
Immediate recall (R1)	4.51	3.14			103
"imprint phase" (R 5)	8.82	1.73			103
"consolidation phase" (R 10)	10.13	1.58			103
LTM (R 11)	—	—			—
Spelling, A.I. (2nd grade*)					
October	7.88		3-20		100
April	17.69		14-20		
STAS reading (3rd grade)	99	55			119
STAS spelling (3rd grade)	22	9			119

Appendix C. Overview of training

Sessions	Preschool (P) n (Con-risk)	No of trainers	School (S) n (Con-risk)	No of trainers	No of testers
	Spring I		Spring II Spring III		Fall I, II, III
	20 min 5 days a week for 8 weeks		20 min 4 days a week for 2 x 8 weeks		
BU County I	P I (1-2)	2	S I (0-1)	2	
Urban	P II (1-2)	2	S II (1-2)	2	2
			S III (1-1)	2	
TD County II	P III (5-3)	4	S IV (0-1)	2	
Rural	P IV (1-0)	2	S V (6-1)	2	4 to 6
			S VI (0-1)	2	
TD County III	P V (3-3)	3	S VII (0-1)	2	
Urban	P VI (4-4)	3	S VIII (7-6)	4	4 to 6
BU County VI	P VII (6-5)	4	S IX (0-1)	2	
Rural					4 to 7
	P VIII (2-3)	2	S X (11-8)	4	
	P IX (1-3)	2			

Notes: The children in S V attended two different classes, and in S X three different classes.

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The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

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