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Effects of Three Interventions on the Reading Skills of Children With Reading Disabilities in Grade 2

Stefan Gustafson[1], Linda Fälth[2], Idor Svensson[2], Tomas Tjus[3], and Mikael Heimann[4]

Abstract

In a longitudinal intervention study, the effects of three intervention strategies on the reading skills of children with reading disabilities in Grade 2 were analyzed. The interventions consisted of computerized training programs: One bottom-up intervention aimed at improving word decoding skills and phonological abilities, the second intervention focused on top-down processing on the word and sentence levels, and the third was a combination of these two training programs ($n = 25$ in each group). In addition, there were two comparison groups, 25 children with reading disabilities who received ordinary special instruction and 30 age-matched typical readers. All reading disabled participants completed 25 training sessions with special education teachers. All groups improved their reading skills. The group who received combined training showed higher improvements than the ordinary special instruction group and the typical readers. Different cognitive variables were related to treatment gains for different groups. Thus, a treatment combining bottom-up and top-down aspects of reading was the most effective in general, but individual differences among children need to be considered.

Keywords

intervention, reading disability, individual differences, response to intervention

The process of reading is a very complex cognitive activity involving many subprocesses and systems. It is therefore not surprising that a group of children with reading disabilities tends to be quite heterogeneous, exhibiting different types of reading problems and therefore also different challenges for remediation. According to “the simple view of reading” (Hoover & Gough, 1990), three basic groups of poor readers can be identified: those with decoding problems (cf. developmental dyslexia), those with language comprehension problems, and those with both decoding and comprehension problems. It should be noted that in special education settings, these three groups often tend to be mixed together and that all children who receive special education in reading do not have developmental dyslexia. Cognitive and neuropsychological assessment can be used here both for problem identification and to assist in the development of appropriate interventions (Hale, Kaufman, Naglieri, & Kavale, 2006).

There is firm evidence that educational interventions focusing on developing phonological skills and linking phonological units of language (phonemes, word segments, and words) to the corresponding written units can improve the word decoding and reading skills of children with reading disabilities (Ehri et al., 2001; Elbro & Petersen, 2004; Hatcher, Hulme, & Ellis, 1994; Tijms & Hoeks, 2005; Torgesen et al., 2001; Wise, Ring, & Olson, 1999). Of course, word decoding strategies and word decoding skills are only two examples of variables that might predict response to phonological training (see also Torgesen & Davis, 1996), and in the present study a wide range of cognitive variables was examined (see Method section).

Average improvements of groups in response to phonological training might hide substantial individual differences in improvements, and while some children are easily remediated, other children are difficult to remediate (Gustafson, Ferreira, & Rönnberg, 2007; Gustafson, Samuelsson, & Rönnberg, 2000; Poskiparta, Niemi, & Vauras, 1999; Torgesen & Davis, 1996; Vellutino et al., 1996). For example, in a previous study (Gustafson et al., 2000) some children did benefit from a phonological intervention while other children seemed resistant to the same intervention. Results indicated that to benefit from the phonological training, children

[1]Linköping University, Sweden
[2]Växjö University, Sweden
[3]University of Gothenburg, Sweden
[4]Linköping University, Sweden and Swedish Institute for Disability Research (SIDR), Linköping, Sweden

Corresponding Author:
Stefan Gustafson, Linköping University, Department of Behavioural Sciences and Learning, 581 83 Linköping, Sweden
Email: stefan.gustafson@liu.se

had to use a phonological word decoding strategy at least to some extent. It should be noted that participants in this study were in Grade 4 and therefore had more firmly established word decoding strategies than children who just started learning to read. Another study demonstrated a double dissociation among children with reading disabilities in Grades 2 and 3: Children with pronounced phonological problems increased their reading skill more from phonological training than from orthographic training, while children with pronounced orthographic problems did benefit more from orthographic than from phonological training (Gustafson et al., 2007).

Most intervention studies have focused on phonological bottom-up training since problems with reading have long been known to be related to deficits in phonological awareness (Elbro, 1996). However, the observations that some children do not improve as expected from a strict bottom-up strategy have lent support for the use of alternative strategies for children who are behind in their reading development. Some recent early intervention studies implementing a top-down strategy have reported positive findings. One example is a study by Berends and Reitsma (2006) where the effects of orthographic and semantic training were compared in a group of reading impaired children in first and second grades. It was found that semantic training outperformed orthographic training with the largest effect in second grade. In two studies by Hatcher, Goetz, et al. (2006) and Hatcher, Hulme, et al. (2006) it was observed that children at risk of developing dyslexia made significant gains in reading and spelling after training semantics and grammar.

The comprehension training used in this study is based on the rare event transactional model (Nelson, Welsh, Camarata, Tjus, & Heimann, 2001), which states that several learning conditions must act in concert to maximize the scaffolding effect and thus increase the likelihood for learning to take place. These learning conditions are often difficult to bring together so that significant learning can take place, and according to the theory, it is rare for all relevant and enhancing factors to be present simultaneously in any specific teaching or learning situation. The instructional aim is to facilitate learning in an as optimal way as possible for each student. This is especially true when teaching children with learning problems who often display high individual variation of needs, capabilities, and motivation. By making use of multimedia material where text is illustrated by enjoying animations combined with verbal and emotional interaction with the teacher, this strategy has proven to be an effective additional route to reading skills in both typically developing preschool children and children with various communicative impairments (Basil & Reyes, 2003; Heimann, Nelson, Tjus, & Gillberg, 1995; Tjus, Heimann, & Nelson, 1998, 2004). Significant progress in letter knowledge and word and sentence reading but also in phonological awareness has been found even if the multimedia program focused on orthographic and semantic training. When comparing one group of children with reading problems using this multimedia-based rare event strategy and a group using a Reading Recovery–inspired strategy, both groups made progress but no between-group difference could be documented (Fälth, Svensson, & Tjus, 2009).

Strategy instruction, that is, to encourage critical thinking and consideration of alternatives when making decisions, seems to be a successful method to enhance reading comprehension (Fletcher, Lyon, Fuchs, & Barnes, 2007), and some strategy instruction was included in the comprehension training of the present study. By receiving immediate feedback from the computer and by their teachers' support and comments, the children had the opportunity to reflect upon their decisions.

In addition to obtaining reading improvement, it is important to promote the children's motivation to engage in literacy and language learning. This has also been evidenced since positive changes in motivation and communication expressed by an increase of enjoyment and speech production have been noted (Tjus et al., 2001). See also Mayer (2008) and Moreno (2006) for a more detailed discussion on how to use multimedia to promote learning.

In the present study, participants were selected to represent the whole population of children with reading disabilities (see Participants section). Given the heterogeneous sample, including children who had problems with either decoding or comprehension or both components, it was by no means evident that all would benefit from the same intervention. It is possible that the two aspects of reading have different cognitive origins that imply distinct forms of interventions to remediate these two types of reading difficulties (for an overview, see Fletcher et al., 2007). The present study compared three different interventions, one focused on bottom-up processing, that is, phonological abilities and word decoding skills, and another on top-down processing and comprehension. We also examined the effects of an intervention that combines phonological training and comprehension training. A study by Lovett et al. (2000) showed that a combination of phonological training and strategy-based instruction proved superior to either program alone for children with severe reading disability. It should also be noted that many previous phonological intervention studies have contained a mix of different activities related to phonological skills and reading skills rather than focusing on one particular skill (e.g., Torgesen et al., 2001). Furthermore, since our participants have decoding problems, comprehension problems, or both problems, an intervention covering both components might provide an appropriate content.

The present study attempted to answer the following research questions. What are the general effects of the three interventions, phonological training, comprehension training, and combined training (phonological and comprehension training), on the reading skills of children with reading

Table 1. Cognitive Abilities Preintervention for Each Group (*M*, *SD*; *N* = 130)

Cognitive Tests Preintervention	Phonological Training		Comprehension Training		Combined Training		Ordinary Special Instruction		Typical Readers	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Nonverbal intelligence	24.04	4.58	23.44	4.17	26.28	3.93	23.00	4.73	26.17	5.32
Short-term memory	5.60	1.35	5.48	1.33	5.83	1.66	5.76	1.62	7.47	2.54
Working memory	4.92	1.15	4.48	1.83	4.38	1.44	4.56	1.29	5.50	1.33
Phonological short-term memory	7.92	2.10	5.79	2.34	6.60	2.77	6.29	2.79	9.43	1.50
Segment subtraction	5.38	2.53	4.64	2.04	4.96	2.64	4.80	2.33	8.57	2.54
Rapid automatic naming	128.5	31.7	128.9	40.9	130.0	42.4	132.8	52.0	91.3	12.1
Processing speed	25.36	3.55	24.58	5.88	27.67	7.30	25.17	4.98	30.60	4.06
Verbal fluency	11.76	5.09	8.04	4.03	11.36	4.57	9.36	5.08	17.03	5.60
Spelling	8.30	3.50	6.25	2.00	6.74	3.65	7.43	4.26	14.93	6.33
Pseudoword spelling	6.14	2.71	5.20	2.84	4.23	2.81	6.04	3.17	9.63	2.43
Arithmetic	15.52	3.72	13.96	2.76	15.17	3.42	14.56	2.89	17.87	3.32

disabilities in Grade 2 compared to comparison groups? What cognitive variables are correlated with reading improvement for each intervention?

Method

Participants

A total of 130 participants in Grade 2 were included in the study. They had received regular reading instruction in school for almost 1.5 years before the first test session was conducted. This previous instruction focused on knowledge about the letters of the alphabet and their corresponding sounds as well as spelling and text reading. They were randomly assigned to five groups: phonological training (25 children), comprehension training (25 children), phonological/comprehension training (25 children), ordinary special instruction (25 children), and typical instruction (30 children). Children with reading disabilities in the first four groups were approximately matched on sex, initial cognitive abilities, and initial reading skills (see Tables 1 and 2). Matched groups were obtained by monitoring group differences resulting from the random assignments and successively limiting the number of groups a child could be randomly assigned to, given his or her results at the first test session.

There were two main criteria for inclusion as a child with reading disability: (a) The child had been assigned to receive special instruction in reading in Grade 2. Since the interventions took place in general educational settings, this was a necessary requirement for practical reasons. (b) In the present study the child had to perform at least .75 standard deviations below the mean of the typical readers on the reading test sight word reading (see Materials) at the first test session (T1). Children who were recent immigrants and therefore did not master Swedish and children who had gross neurological disturbances or sensory deficits were not included in the study. Attrition rate was low. One school representing five children dropped out of the study after the first test session but before children were assigned to groups, so the design was not affected.

The ordinary special instruction group was not a traditional control group since these children also received their regular special instruction in reading (i.e., treatment as usual). Ordinary special instruction consisted of a variety of activities related to reading and writing, such as reading aloud or silently, discussing stories, spelling instruction, phonological awareness training, and some memory training. Compared to the three interventions (see Training Programs), ordinary special instruction was more heterogeneous, less focused, and less systematic. A nontreatment control group consisting of children with reading disabilities was not possible for ethical reasons.

Test Procedure

One of the authors (Linda Fälth) and 13 trained psychology students administered all tests to all participants. The psychology students had received training in test administration during their regular university courses and participated in several workshops and training sessions designed specifically

Table 2. Results on the Reading Tests (*M*, *SD*) Preintervention ((T1 + T2)/2) and Postintervention (T3) and Effect Sizes (Cohen's *d*[a]) for All Five Groups of Participants (*N* = 129)

	Preintervention		Postintervention		
	M	*SD*	*M*	*SD*	Cohen's *d*
Reading comprehension					
Phonological training (*n* = 22)	6.75	4.82	12.23	7.24	0.89
Comprehension training (*n* = 19)	3.63	4.19	7.11	6.62	0.65
Combined training (*n* = 21)	6.69	5.24	12.19	6.82	0.91
Ordinary special instruction (*n* = 22)	5.89	3.96	8.64	5.09	0.59
Typical readers (*n* = 30)	22.15	8.87	25.93	7.20	0.51
Passage comprehension[b]					
Phonological training (*n* = 23)	11.00	5.88	15.48	6.57	0.72
Comprehension training (*n* = 25)	6.24	4.21	10.60	5.18	0.92
Combined training (*n* = 25)	7.76	5.40	12.92	6.38	0.87
Ordinary special instruction (*n* = 25)	8.04	5.92	11.68	6.93	0.56
Typical readers (*n* = 30)	20.03	6.74	22.33	4.91	0.39
Word decoding					
Phonological training (*n* = 24)	6.72	3.25	10.92	3.54	1.25
Comprehension training (*n* = 24)	6.12	2.81	8.33	3.56	0.69
Combined training (*n* = 24)	6.52	2.45	10.79	4.46	1.25
Ordinary special instruction (*n* = 23)	6.72	2.46	8.78	3.40	0.70
Typical readers (*n* = 30)	15.30	5.84	18.93	6.49	0.59
Sight word reading					
Phonological training (*n* = 24)	33.08	14.00	49.38	17.74	1.06
Comprehension training (*n* = 23)	29.85	15.72	47.43	18.01	1.06
Combined training (*n* = 25)	29.40	12.01	47.68	15.94	1.34
Ordinary special instruction (*n* = 24)	30.48	13.22	45.08	20.05	0.91
Typical readers (*n* = 30)	87.77	22.15	100.90	24.19	0.57
Pseudoword reading					
Phonological training (*n* = 23)	5.98	4.28	8.30	5.41	0.45
Comprehension training (*n* = 20)	4.62	4.02	8.10	5.96	0.70
Combined training (*n* = 21)	6.19	4.38	11.57	6.94	0.95
Ordinary special instruction (*n* = 22)	4.93	4.85	7.41	5.25	0.48
Typical readers (*n* = 30)	16.02	6.47	18.73	8.59	0.35

[a]Cohen's *d* = (*M* at T3 – (*M* at T1 + *M* at T2)/2)/pooled *SD* for T1, T2, and T3.
[b]Data only from T2. Cohen's *d* = (*M* at T3 – *M* at T2)/pooled *SD* for T2 and T3.

for the present study. The test leaders were carefully instructed to follow the same test procedure and had written instructions for each test. They were also continuously supervised by two members of the research team.

There were two test sessions preintervention, the first (T1) in November 2008 and the second (T2) 5 weeks later. Between those test sessions children were assigned to groups but the intervention did not start until T2 had been completed. Data from T1 were used to ensure that groups were approximately matched (see previous). The purpose of T1 and T2 was to provide a solid and reliable documentation of preintervention status, and in the main analysis of variance (ANOVA), they were merged into a single preintervention variable. The third test session (T3) took place directly after the intervention, as soon as 25 training sessions had been completed for each child with reading disabilities. The duration between T2 and T3 varied between 5 and 9 effective school weeks. Test administrators visited the schools in approximately the same order on each test session to keep the duration more constant. Most tests were individually administered to increase the reliability, but group testing was allowed for the *Wordchains* test and the tests measuring spelling and pseudoword spelling. Most tests were administered on several occasions, but the relatively long interval between test sessions and the inclusion of comparison groups greatly reduced the potential problem of test-retest training effects. A few children failed to complete one or two tests, explaining why the reported number of participants varied slightly.

The reading tests were administered at T1, T2, and T3 except for *Woodcock Passage Comprehension*, which was only administered at T2 and T3 (given time restraints at T1).

Design

The main design was a factorial 5 × 2 split-plot design with the independent variable group (phonological training, comprehension training, combined training, ordinary special instruction, and typical readers) as a between-subjects variable and test session (preintervention and postintervention) as a within-subjects variable. The most important dependent variables were five different measures of reading comprehension and word decoding skills, which were also used to form a composite score of reading skill. In addition, 11 different cognitive variables—nonverbal intelligence, short-term memory, working memory, phonological short-term memory, segment subtraction, rapid automatic naming (RAN), processing speed, verbal fluency, spelling, pseudoword spelling, and arithmetic—were included preintervention to be able to analyze correlations with reading improvement (change scores) for each group.

Materials

Five different measures of reading skills were administered: reading comprehension, passage comprehension, word decoding, sight word reading, and pseudoword reading.

Reading comprehension. A reading comprehension test, *Vilken bild är rätt?* (Which Picture Is the Correct One?), developed by Lundberg (2001), was used comprising national norms for Grades 2 and 3 and with a test–retest reliability of .88. The child's task was to read two or three sentences and then mark the correct picture out of four where only one picture exactly fit the meaning of the sentences. The score was the total number of correct pictures subtracted by errors within 10 minutes.

Passage comprehension. A Swedish translation of a subtest from *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987) was used. Children read a short passage of text with a blank line. The first passages had a corresponding picture. Children were instructed to fill in the blank verbally with a word that fit the passage. The level of difficulty increased within the test and it was ended when the participant failed on six consecutive passages.

Word decoding. Word decoding was assessed by the *Wordchains* test (Jacobson, 1993; Miller Guron, 1999). The participant silently read chains of Swedish words where the blank space between words had been removed. Each chain consisted of three semantically unrelated words and the child was instructed to mark each word boundary with a pencil. The chains were constructed to have no ambiguities regarding boundary locations and had a large proportion of high frequency words. The number of correctly marked word chains in 2 minutes was used as a measure of general word decoding skill. It was impossible to complete all 80 word chains in 2 minutes. The *Wordchains* test had test–retest correlations with an interval of 12 months between measurements of r = .80 to .90 in different groups of children in Grades 1 through 6 (Jacobson, 1993). Test–retest correlations between T1 and T2 in the present study was r = .88.

Sight word reading. A Swedish translation of the word subtest from the *Test of Word Reading Efficiency* (TOWRE; Torgesen, Wagner, & Rashotte, 1999) was used. Participants were asked to read simple words out loud as quickly as possible. Children were allowed to read for 45 seconds on each of two test versions (A and B), and the results were summed to increase reliability (test–retest reliability for children aged 6–9 years was .97).

Pseudoword reading. A list of pseudowords was presented to the participants. The participants' task was to correctly read aloud as many pseudowords (80 items) as possible in 1 minute. The pseudowords presented consisted of one up to four syllables. Data for comparison were available from previous studies (Svensson, 2009; Svensson & Jacobson, 2006). Test–retest correlations between T1 and T2 in the present study was r = .90.

In addition, 11 other tests were used to examine cognitive variables that could potentially predict the responsiveness to training.

Nonverbal intelligence. To get a measure of nonverbal intelligence at T1, a Swedish edition of *Raven's Coloured Progressive Matrices* was administered (Psykologiförlaget AB, 1995). Maximum score was 36.

Short-term memory (STM). Short-term memory was assessed by *Digit Span*, a subtest from *Wechsler Intelligence Scale for Children–Fourth Edition* (WISC-IV; Wechsler, 2003). The task was to repeat digits (a span from two to nine) forward in correct order. Each correctly repeated digit span was scored.

Working memory. Working memory was also assessed by *Digit Span* from WISC-IV (Wechsler, 2003). The task was to repeat digits (a span from two to eight) backward in correct order. Each correctly repeated digit span was scored.

Phonological short-term memory. Phonological STM was assessed by a nonword repetition test (Gathercole, Tiffany, Briscoe, Thorn, & The ALSPAC Team, 2005; Radeborg, Barthelom, Sjöberg, & Sahlén, 2006). The task for the pupil was to repeat nonwords that the test leader had just pronounced as exactly as possible. The test included 12 nonwords, consisting of two up to four syllables. Each correctly pronounced nonword was scored. Comparison data from an earlier study were available (Svensson, 2009). Test–retest correlations between T1 and T2 in the present study was r = .78.

Segment subtraction. A subtest from a Swedish standard test of phonological awareness, *UMESOL: Segment Subtraction* (Taube, Tornéus, & Lundberg, 1984), was used. Participants should decide and verbally report which segment of a word had been removed from a Swedish word (i.e., "What has been removed from the word *krokodil* [*crocodile* in English] if only *kroko* remains?"). Maximum score was 15. Test–retest correlations between T1 and T2 in the present study was $r = .83$.

RAN. Rapid automatized naming for letters and for numbers was assessed (see Wolf & Denckla, 2005). The total time in seconds for naming both numbers and letters was used as a measure of RAN. There were two lists of numbers, and correlation between them at T2 was $r = .90$. There were two lists of letters, and the correlation between them at T2 was $r = .87$.

Processing speed. In the *Letterchain* test the task was to mark a pencil line between the two adjacent letters that were the same. Two such pairs in each letter chain occurred, for example, LIOOPKTTUR, where the marks should be as follows: LIO/OPKT/TUR. The performance was expressed as the number of correctly marked chains within a period of 2 minutes (Jacobson, 2001). Test–retest correlations between T1 and T2 in the present study was $r = .78$.

Verbal fluency. The *Initial Letter Verbal Fluency Test* (FAS) was administered. It has been used as an assessment of executive function and semantic memory store (Parker & Crawfoord, 1992). It is a timed test where the participant is asked to generate words beginning with the letters F, A, and S, respectively. The total number of real Swedish words was used as a measure of verbal fluency.

Spelling. Participants were asked to spell 34 Swedish words, 2 to 11 letters long. The test leader first said the word, then a sentence containing the target word, and then the word was repeated and the child were instructed to write it and spell it correctly on a response sheet. There was a time limit of 15 seconds for each response and the test was terminated if the child made four consecutive errors.

Pseuoword spelling. In this test, 12 pictures of "monsters" were presented on a sheet of paper. Each monster had a Swedish pseudoword as their name (e.g., *Liplo*, *Gadrö*). The name was spoken out loud to the children and they were asked to write the monster's name next to its picture. Names were chosen so that one specific spelling should be most appropriate, but all phonetically correct Swedish spellings were regarded as correct answers.

Arithmetic. Participants received a mix of 60 simple addition and subtraction tasks (i.e., $5 + 1 = \_\_$ and $9 - 2 = \_\_$) on a sheet of paper and were asked to complete as many as possible in 1 minute. The large number of items made it impossible to complete them all in 1 minute. The number of correct answers was used as a measure of arithmetic skill.

Training Programs

The phonological training program, named COMPHOT (Ferreira, Gustafson, & Rönnberg, 2003), had four sections: *Rhyme* (four exercises), *Position* (eight exercises), *Addition* (five exercises), and *Segmentation* (three exercises). Exercises were mainly phonological and sound based. Pictures were included in the exercises and when participants clicked on them the corresponding words were sounded out by a natural, recorded voice. The task for the child was, for instance, to decide which pictures depicted words that rhymed or had the same initial phoneme. In other exercises the task was to combine or remove phonemes or segments of words. There were also some links to written letters and words. The units of language that were focused in COMPHOT were phonemes, word segments, and words. No sentences or passages were presented to participants. To make the exercises entertaining and motivating, game-like elements were included. The program supplied direct feedback to the participant. After correct choices the computer responded with a "happy" sound and when the child made a mistake the computer produced a "sad" sound. There were also personal high score lists where children could check their performances on the different exercises.

The comprehension training program, named Omega-IS (Omega-Interactive Sentences) (Heimann, Lundälv, Tjus, & Nelson, 2004), used a top-down strategy including both word- and sentence-level processing of written language. By clicking on text buttons with words or phrases, the child "wrote a sentence" such as "The lion chases the swan," then the child heard the sentence being read by prerecorded human speech, and then the meaning of sentence was illustrated by an animation. Thus, the program offered close to one-to-one correspondence between text, speech, and animations, providing semantic comprehension and training of text material. The lessons included in the program went from two- (noun + verb) and three-word sentences (noun + verb + noun) up to stories in which the child could construct stories and choose different actors and scenarios to increase the children's motivation to explore literacy. In total, more than 1,900 different sentences were possible to construct with feedback in speech and animations as described previously.

Both training programs were computerized and had been developed with the assistance of professional programmers.

A third intervention group, combined training, used both COMPHOT and Omega-IS. During the first 20 training sessions of combined training, COMPHOT and Omega-IS were used alternately, that is, each program was used every other session. During the last 5 training sessions the children were allowed to choose which program to use. Thus, 10 to 15 of the 25 sessions (40%–60%) were spent on each program.

Training Procedure and Training Times

A total of 52 special education teachers representing 41 Swedish schools participated in the interventions. To reduce potentially confounding teacher effects, children belonging to two of the four groups phonological training, comprehension training, combined training, or ordinary special instruction were assigned to each special education teacher.

These children received the intervention or ordinary special instruction as part of their scheduled special education sessions in their regular schools. Before the actual intervention started, special education teachers had been instructed on how to use the training programs, and information and educational suggestions were also included in a written manual for each program. Special education teachers could adapt the intervention to the appropriate level of difficulty for individual children by selecting difficulty level for exercises and by focusing the training on particular exercises. However, they were instructed to include all types of exercises for each and every child at least once. Special education teachers were encouraged to have an active role in all three interventions. Authors monitored treatment integrity by personal meetings, e-mail correspondence, and phone calls.

Each reading disabled participant received a total of 25 training sessions. Special education teachers were instructed that the minimal time for a session was 10 minutes but that longer times were preferred, and most sessions lasted 15 to 25 minutes. Children who received phonological training had an average total training time of 422.2 minutes (SD = 102.9, n = 23), for the group comprehension training it was 443.5 minutes (SD = 111.7, n = 19), for combined training 480.9 minutes (SD = 117.7, n = 21), and for ordinary special instruction 502.7 minutes (SD = 117.1, n = 23). A one-way ANOVA showed that there was no significant main effect of group on training times. The observed differences would tend to favor the comparison condition ordinary special instruction rather than the intervention groups.

Results

Characteristics of Participants

In the group phonological training there were 17 boys and 8 girls, in the group comprehension training 18 boys and 7 girls, in the group combined training 17 boys and 8 girls, in ordinary special instruction 18 boys and 7 girls, and in the group typical readers 19 boys and 11 girls. A chi-square test showed that there were no significant differences between the proportions of boys/girls between the five groups, $\chi^2(4, 129) = .69$, $p > .05$.

The test battery included 11 cognitive test and the results for each group preintervention can be seen in Table 1.

The 11 one-way ANOVAs comparing the means of the five groups all revealed significant main effects of group (all ps < .05). Tukey's honestly significant difference (HSD) post hoc tests showed that on short-term memory, segment subtraction, RAN, verbal fluency, spelling, and pseudoword spelling typical readers outperformed all other groups (all ps < .05). On nonverbal intelligence, Tukey HSD revealed no significant differences. On working memory, typical readers performed significantly better than combined training (p < .05). On phonological STM, typical readers outperformed comprehension training, combined training, and ordinary special instruction, and phonological training outperformed comprehension training (all ps < .05). On processing speed, typical readers performed significantly better than phonological training, comprehension training, and ordinary special instruction (all ps < .05). On arithmetic, typical readers outperformed comprehension training, combined training, and ordinary special instruction (all ps < .05).

Thus, typical readers tended to outperform the other groups in many cognitive areas whereas only one significant difference was found between groups of children with reading disabilities.

The four groups of children with reading disabilities were also approximately matched on initial reading skills (see Table 2 and the following analyses).

General Effects of the Intervention

General effects of the intervention are presented in Table 2. There were two test sessions preintervention and one after the intervention. To firmly establish a baseline status, results from T1 and T2 were combined into a single preintervention variable. Only participants who completed all three test sessions were included in Table 2 and in the corresponding statistical analyses.

Five separate one-way ANOVAs on preintervention scores of reading skills (see Table 2) all revealed statistically significant main effects of group (all ps < .01). Tukey HSD post hoc tests revealed that typical readers performed significantly better than the other four groups in all five analyses (all ps < .01). No other differences between groups were statistically significant. Thus, the four groups of children with reading disabilities were approximately matched on the five measures of reading skills preintervention and performed significantly below typical readers.

General effects of the interventions were analyzed by five separate split-plot ANOVAs with group (five levels) as a between-subjects variable and test session (two levels) as a within-subjects variable (see Table 2). Results showed statistically significant main effects of test session (i.e., improvements) for all five measures of reading skills (all ps < .01).

There was a statistically significant interaction between group and test session for word decoding, $F(4, 120) = 2.71$, $p < .05$, $MSE = 5.00$. Combined training and phonological training showed larger improvements than the other groups (see Table 2). For reading comprehension, passage comprehension, sight word reading, and pseudoword reading, there were no significant interactions.

The design included two different comparison groups measured on several occasions, and one of these (typical readers) performed better than the other groups preintervention. Therefore, when calculating effect sizes (Cohen's d), posttest scores were compared with pretest scores within each group instead of comparisons between groups. Original standard deviations (instead of paired t test values) were used in the calculations in order not to overestimate effect sizes (see Dunlop, Cortina, Vaslow, & Burke, 1996). According to Cohen (1988), d = .20 can be considered a small effect, d = .50 a moderate effect, and d = .80 or above a large effect.

The phonological training group showed large effects on reading comprehension, word decoding, and sight word reading; a large to moderate effect on passage comprehension; and a moderate to small effect on pseudoword reading. Comprehension training resulted in large effects on passage comprehension and sight word reading, large to moderate effects on word decoding and pseudoword reading, and moderate to large effects on reading comprehension. Combined training resulted in large effects on all five measures. Ordinary special instruction obtained a large effect on sight word reading, a large to moderate effect on word decoding, moderate to large effects on reading comprehension and passage comprehension, and a moderate to small effect on pseudoword reading. Typical readers showed a moderate effect on reading comprehension, moderate to large effects on word decoding and sight word reading, and moderate to small effects on passage comprehension and pseudoword reading.

Analysis of General Effects Using a Composite Change Score

To obtain a more general and more reliable measure of improvements in reading skills, a composite score was calculated. First, change scores were calculated for the five reading tests shown in Table 2 by subtracting the scores at T2 from the scores at T3. Test session 1 was not included because data were missing for passage comprehension. Also, T2 could be regarded as the most crucial test session since it was completed closer to the intervention. Change scores were then transformed into standardized z values, and a mean z value was calculated representing a composite measure of improvement in reading skills between T2 and T3.

Mean standardized composite change scores were for phonological training .12 (SD = .59), comprehension training .02 (SD = .56), combined training .38 (SD = .68), ordinary special instruction –.09 (SD = .47), and typical readers –.17 (SD = .48). These scores represent general improvements in reading. Thus, the group combined training enhanced their reading skills the most between T2 and T3. A one-way ANOVA revealed a significant main effect of group, $F(4, 111) = 3.54$, $p < .01$. Tukey HSD post hoc test revealed two statistically significant differences: Combined training showed significantly higher improvements in reading skills than the two groups ordinary special instruction and typical readers (both ps < .05).

What Cognitive Variables Are Correlated With Reading Improvement for Each Intervention?

To examine individual differences in reading improvements, bivariate correlations were calculated between the composite change score of reading skills (see previous discussion) and the 11 cognitive variables measured preintervention (see Table 3).

Within the group phonological training, there were significant negative correlations between reading improvement and two of the cognitive variables: RAN and pseudoword spelling (both ps < .05). Note that a low score on RAN represents rapid naming measured in seconds, so a high gain from phonological training was associated with good initial performance on RAN and a poor performance on pseudoword spelling. The group comprehension training revealed no significant correlations. The group combined training showed a significant positive correlation between reading improvement and working memory ($p < .05$). Within the ordinary special instruction group there were significant negative correlations with short-term memory ($p < .05$) and phonological short-term memory ($p < .01$) and a significant positive correlation with spelling ($p < .05$). Typical readers only showed a significant positive correlation between reading improvement and verbal fluency ($p < .05$).

For some of the cognitive variables, phonological STM, segment subtraction, processing speed, spelling, and pseudoword spelling, data were available also postintervention at T3. Correlations between change scores for these variables (T3 scores minus T2 scores) and the composite change score of reading improvement were calculated for each group. For the group phonological training there was a significant correlation between improvement in pseudoword spelling and reading improvement (r = .58, $p < .01$). For combined training there was a significant correlation between improvement in segment subtraction and reading improvement (r = .67, $p < .01$). The other three groups revealed no significant correlations between improvements in cognitive abilities and reading improvement.

Discussion

General Effects of the Interventions

The first aim of this study was to measure the effects of three intervention programs with the purpose to improve reading ability. The general effects of the interventions can be regarded as satisfactory for all three interventions and the most positive effects were obtained for the group who received combined training (see the following). Results showed that the three intervention groups improved their reading skills at least as much as the comparison groups ordinary special instruction and typical readers (see Table 2). It can be argued that the group receiving the ordinary special instruction had an advantage compared to the three interventions in that special education teachers were free to choose the reading instruction they thought would best meet the particular needs of individual children and that they could choose from various existing exercises and training programs

Table 3. Correlations (Pearson's r) Between the Composite Score of Reading Improvement and Cognitive Abilities Preintervention

Cognitive Variables Preintervention	Phonological Training (n = 22)	Comprehension Training (n = 20)	Combined Training (n = 22)	Ordinary Special Instruction (n = 23)	Typical Readers (n = 29)
Nonverbal intelligence	.16	–.07	.33	.16	.06
Short-term memory	.00	.18	.16	–.43*	.04
Working memory	–.04	.06	.48*	.30	.16
Phonological short-term memory	.05	.11	.18	–.58**	.03
Segment subtraction	.00	.15	.13	–.32	.17
Rapid automatic naming	–.44*	–.08	–.32	.11	.09
Processing speed	.18	–.10	.34	.37	–.04
Verbal fluency	.39	–.09	.18	.24	.43*
Spelling	.08	–.15	.28	.46*	–.05
Pseudoword spelling	–.52*	.27	.39	.09	–.21
Arithmetic	.40	.14	.43	–.07	.14

Note. *p < .05, **p < .01.

they were already familiar with. Thus, the ordinary special instruction group represents a comparison group that is difficult to surpass (see Gustafson et al., 2000, 2007). Keeping this in mind, it is notable that a statistically significant interaction was found on word decoding where the intervention groups combined training and phonological training showed higher improvements than the ordinary special instruction group and the other groups (see Table 2).

One might have expected comparatively better effects for comprehension training on reading comprehension, but reading comprehension is a product of both decoding and comprehension and it seems that for children with reading disabilities in Grade 2 who were still in an early stage of reading development, basic phonological training was just as effective. On passage comprehension, however, comprehension training had the highest observed effects.

Surprisingly, phonological training only produced a moderate to small effect on pseudoword reading. One explanation is that the phonological training program COMPHOT contained basic phonological awareness training and was not directly targeted at phonological word decoding. Also, another phonological variable, pseudoword spelling, was important for reading improvement for this group (see Table 3 and the following discussion). Maybe pseudoword spelling was a more pure and sensitive phonological test than pseudoword reading because no letters or written words were presented to the child.

As stated earlier, the most positive effects on reading skills were obtained for the group who received combined training. When a composite change score representing general reading improvement was calculated, the results demonstrated that children who received combined training made statistically significantly more progress in reading than ordinary special instruction and typical readers. This is in line with the findings by Lovett et al. (2000), which demonstrated that a combination of phonological training and strategy-based instruction was more effective than either program alone. A study by Frost, Madsbjerg, Niedersøe, Olofsson, and Sørensen (2005) also demonstrated that both phonological skills and semantic skills are important in early reading development. Since reading involves both bottom-up processes and higher level semantic processes, it is not surprising that training containing both these components was effective.

The effectiveness of any intervention also depends on the characteristics of the participants. Some of the children with reading disabilities in the present study had comprehension difficulties, and they might benefit from reading instruction targeting those problems. Furthermore, targeting reading comprehension seems to benefit reading ability regardless of the source of difficulty, that is, positive effects are observed also for those children with reading disabilities with decoding problems (for an overview, see Fletcher et al., 2007).

The intensity of the three interventions was only moderate. It is quite possible that at least for the phonological training program more intense training would yield even better results (Lundberg, 2009; Torgesen et al., 2001). Motivational aspects then also need to be considered to ensure that training will not become repetitive, tiring, or boring for the participants.

What Cognitive Variables Are Correlated With Reading Improvement for Each Intervention?

Within the group phonological training, large reading improvement was correlated with poor performance on pseudoword spelling preintervention (see Table 3). Pseudoword spelling can be regarded as a pure phonological test requiring distinct phonological representations. Thus, this finding is in line with previous findings that children with pronounced phonological problems benefit a lot from a phonological intervention (Gustafson et al., 2007). There are at least two possible explanations of this result. One possibility is that children with congenital phonological deficits (possibly developmental dyslexia) benefit from interventions targeted at their specific deficit. Another explanation is more developmental; for children to benefit from phonological training they should be in an early stage of their reading development and rely on phonological word decoding when reading at least to some extent (Ehri et al., 2001; Gustafson et al., 2000; see also Frost et al., 2005). Treatment gains in reading from phonological training were also significantly correlated with improvement in pseudoword spelling. This indicates that a specific effect of the phonological training (improvement in a phonological ability) was associated with general reading improvement.

For the group who received phonological training, large improvement in reading was also correlated with good initial performance on RAN. Maybe RAN was a complementary ability that enhanced the experience of the training program and the treatment gains on reading. Reading is a complex cognitive activity, and if the intervention is specific and focused on one aspect, then other cognitive abilities preintervention might help boost treatment gains.

For the group who received comprehension training, there were no significant correlations between reading improvement and initial cognitive abilities. Given that comprehension training revealed positive effects on reading and was rather focused in nature, we expected to find at least some significant results differentiating between responders and nonresponders. In the present study, only effects on reading were analyzed, and it is possible that comprehension training had differentiating effects on other abilities. This group also suffered from the lowest statistical power.

Combined training was effective in general, and for this group a positive correlation was found between reading improvement and initial working memory (see Table 3). Working memory is important for reading skills (Gathercole, Alloway, Willis, & Adams, 2006; Swanson & Jerman, 2007) but was not explicitly targeted in any of the interventions. A well-functioning working memory might have worked as a good complement to phonological training and comprehension training. Also, a good working memory might have led to more rewarding learning experiences when using some of the exercises in the training programs.

Also, note that even though only 1 of the 11 correlations between cognitive variables and reading improvement was statistically significant, all the other 10 correlations pointed in the same direction. The general pattern of results indicates that higher reading improvement might be associated with good initial cognitive abilities for this group (see Table 3). One explanation of this pattern of results would be that combined training put higher demands on cognitive abilities since children had to integrate knowledge from two different training programs. Phonological skills also seemed important for combined training since there was a significant correlation between improvement in segment subtraction and reading improvement.

The ordinary special instruction group revealed significant negative correlations between reading improvement and two measures of memory: short-term memory and phonological short-term memory. Reports from special education teachers reveal that some children in this group received memory training. Maybe some aspect of this training resulted in reading improvements for children with poor initial memory skills. For the ordinary special instruction group, there was also a significant correlation between reading improvement and initial spelling. Good initial spelling might have worked as an important complementary ability and/or a skill that was utilized during the reading instruction and enhanced the experience of ordinary special instruction.

Typical readers showed a significant positive correlation between reading improvement and verbal fluency. Verbal fluency includes a phonological component. Even if these children are typical readers, they are still in an early stage of their reading development when phonological abilities are important (Høien & Lundberg, 1988; Lundberg, 2009; Samuelsson, Gustafson, & Rönnberg, 1996).

Finally, we want to emphasize that educational interventions should be regarded from a dynamic rather than static perspective. Recent studies in the fields of dynamic testing and assessment and response to intervention demonstrate the need to think of educational interventions as ongoing processes where assessment can assist intervention and vice versa (see Grigorenko, 2009). In the present intervention study, we have identified cognitive variables that are associated with treatment gains in reading for different groups of children. This can be regarded as an assessment and might provide suggestions for future interventions for individual children at their respective schools. Intervention studies can contribute with general theoretical knowledge as well as have direct educational implications.

Limitations

Two of the interventions used in the present study were quite specific, but the combined training was broader and contained two very different components. In the present study it is not possible to assess how the two different components interacted and led to the positive effects obtained for the combined training program.

It should also be noted that some individual variation was allowed within each intervention. Teachers were asked to use all exercises at least once but were free to spend more time on certain exercises than others to facilitate children's learning and keep them motivated. Thus, children belonging to the same group had somewhat different experiences during the intervention.

Teachers are important mediators of knowledge and skills and it is possible that some special education teachers approached the interventions more enthusiastically and had more positive effects on the children's learning than other teachers. We tried to control for this teacher effect by having each special education teacher meet children belonging to two different groups. Ideally each teacher should have met children belonging to all four groups of children with reading disabilities to further reduce teacher effects. However, this would have put too high demands on the special education teachers since they would have needed to master and administer three different interventions as well as ordinary special instruction.

Ideally, the number of participants should have been higher to increase statistical power, obtain more reliable results, and allow more sophisticated statistical methods to be used. Given the promising results of the interventions, especially for combined training, follow-up testing will take place during 2009.

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About the Authors

Stefan Gustafson, PhD, is an assistant professor of developmental psychology in the Department of Behavioural Sciences and Learning at Linköping University, Sweden. His research is mainly focused on individual differences among children with reading difficulties and developmental dyslexia and intervention studies examining individual differences in response to intervention.

Linda Fälth is a special education teacher and PhD student in the Department of Pedagogic, Psychology and Sports Science at Linnaeus University, Sweden. Her thesis will be about children with reading and writing disabilities and educational interventions for these children.

Idor Svensson, PhD, is an assistant professor and authorized psychologist in the Department of Pedagogic, Psychology and Sports Science at Linnaeus University, Sweden. His research is mainly focused on individual differences among children in compulsory school, university students, young offenders, substance abusers and forensic patients with reading and writing difficulties and dyslexia and intervention studies examining individual differences in response to intervention.

Tomas Tjus, PhD, is an associate professor at Department of Psychology, University of Gothenburg, Sweden. He conducts intervention research on the development of language and reading on children with language and communication disorders and studies of children with dyslexia in different countries and their processing of cognitive skills related to divergent orthographic structures. He also pursues interest in early memory development, communicative skills and social interaction in both children with typical development and children with atypical development.

Mikael Heimann (PhD 1988, Pennsylvania State University, USA) is a professor of Psychology at the Department of Behavioural Sciences and Learning, Linköping University, Sweden and deputy director of the Swedish Institute for Disability Research, Linköping. His research interest includes areas such as infant cognition and social development as well as intervention studies aimed at increasing reading skills among children with various disabilities.