


Separating the Different Domains of Reading Intervention Programs: A Review

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Abstract

Providing a child with reading difficulties with the appropriate reading intervention as early as possible is critical to prevent future academic failure. As reading is composed of several sub-components (phonology, orthography, fluency, comprehension), choosing the appropriate intervention may be confusing. Here, we attempt to provide an up-to-date review of different reading intervention programs and their outcomes that currently are available for children 4 to 16 years of age. We also introduce the possible beneficial effect of including a component of executive-functions training to reading curricula to enhance the effects of reading intervention programs. These programs are separated by the sub-components of reading that each is designed to address, with discussion based on several leading models for reading acquisition. Our aim is to direct educators, professionals, and researchers to the most appropriate intervention according to either their domain of interest or the child's needs.

Keywords

language studies, language, curriculum, education, literacy, education theory and practice, special education, learning disabilities, reading, learning difficulties, reading difficulties

Introduction

Reading difficulties are defined as the inability to decode accurately and fluently, as well as to comprehend written material. These difficulties are observed in individuals with dyslexia (Breznitz, 2006) and those with attention difficulties (Greven, Rijdsdijk, Asherson, & Plomin, 2012), psychiatric disorders (Pavuluri, O'Connor, Harral, & Sweeney, 2006), emotional difficulties (Arnold et al., 2005), illiteracy (Ardila et al., 2010), temporal lobe epilepsy (Noppeney, Price, Duncan, & Koepp, 2005), autism (Newman et al., 1999), and others. Reading difficulty can stem from a variety of reasons, including the following: (a) a basic difficulty in executive functions (attention, working memory, inhibition; Altemeier, Abbott, & Berninger, 2008; Brosnan et al., 2002; Gooch, Snowling, & Hulme, 2011; Helland & Asbjørnsen, 2000; Horowitz-Kraus, 2012; Menghini et al., 2010; Reiter, Tucha, & Lange, 2004; Tiffin-Richards, Hasselhorn, Woerner, Rothenberger, & Banaschewski, 2008), (b) phonological deficit (Lieberman, Shankweiler, Fischer, & Carter, 1974; Morris et al., 1998; Stanovich & Siegel, 1994), (c) impaired orthography (Badian, 2005), (d) impaired reading fluency (Bowers, 1993; Bowers & Wolf, 1993; Breznitz, 1987a, 1987b, 2006), and (e) reading comprehension difficulties (Fisher & Frey, 2014; Harvey, 2015; Solis, Miciak, Vaughn, & Fletcher, 2014).

The *phonological processor* is specialized for perceiving, remembering, interpreting, and producing the speech-sound

system of a person's language (Moats, 2009), which enables the appropriate matching of the grapheme to the corresponding phoneme. A deficit in the phonological processor can result in an inability to correctly identify, recall, manipulate, and/or remember phonemes (Moats, 2009). The *orthographic processor* recalls the letters and letter sequences in the words to be written, and forms word templates in the reader's mental lexicon (see also "self-teaching" theory; Share 1995). A deficit in this domain will result in slower reading as well as poorer spelling and is tightly related to fluency difficulties (Breznitz, 2006). *Fluent reading* is defined as the overall timing and smoothness in reading, which is attributed to speed-of-processing abilities (Bowers & Wolf, 1993; Breznitz, 2006) and/or the level of proficiency with the phonological/orthographical routes (Seidenberg & McClelland, 1989). Impaired reading fluency may occur due to deficits in working memory (Swanson & Siegel, 2001), rapid automatic naming (RAN; Wolf, Bowers, & Biddle,

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2000; Wolf & Katzir-Cohen, 2001), or timing (Bowers & Wolf, 1993) and/or an asynchrony between the auditory-phonologic and the visual-orthographic processing speeds (Breznitz, 2006; Breznitz & Misra, 2003). *Reading comprehension* is defined as the ability to extract and construct meaning through interaction with the written language (Snow, 2002). Impairment in this domain will harm reading comprehension on several levels: verbatim, gist, metacognitive questions, and conclusions (Nation, 2008). In 1974, LaBerge and Samuels pointed out the importance of automated technical reading (i.e., without investing attention resources), which involves fluent word recognition to enable the allocation of attention resources toward comprehension. The authors described the involvement of several key memory components in technical reading: visual, phonological, episodic, and semantic memory. Due to the characteristics of the attention system and based on the model for attention by LaBerge and Samuels, attention cannot be fully allocated both for decoding (visual memory, phonological memory, and episodic memory) and to comprehend the meaning (semantic memory), and therefore, to improve comprehension, technical reading should be automatic (LaBerge & Samuels, 1974). It is important to note that a major portion of the “technical” reading phase also relies on basic executive functions, including memory, attention, and speed of processing (i.e., automaticity).

The integration of the phonological, orthographical, and semantic components of reading is well described in the parallel-distributed processing (PDP) model (Seidenberg & McClelland, 1989). Word reading requires decoding that involves perception of the word in the visual modality and recoding of its sounds in the auditory-phonological system, and then, the semantic representation of the word from the mental lexicon is evoked (Breznitz, 2006; Seidenberg & McClelland, 1989). As a skilled reader acquires word reading skills, their decoding process becomes automatic and accurate (Van der Leij & Van Daal, 1999), resulting in few decoding errors. Support for this model has been provided from the neuroimaging field, illustrating simultaneous activation of brain regions related to phonology, orthography, and semantics (Lyon, Shaywitz, & Shaywitz, 2003). In the “Construction–Integration” model, contextual reading is organized into construction and integration phases. The construction phase focuses on decoding a single word, during which its semantic meaning is elaborated in a bottom-up process. The integration phase entails the integration of words into sentences, paragraphs, and stories, and is based on previous knowledge and context. It is conceivable that the integration phase processes information in a top-down manner, which relies on the skilled reader’s ability to identify words that are variable in font/handwriting and words with different meanings in different contexts (Rayner & Pollatsek, 1989). Based on Kintsch’s (1988) model, it can be concluded that readers with reading difficulties are more susceptible to errors in the construction phase than are skilled readers

because of their phonological deficit (see also Snowling & Nation, 1997), whereas skilled readers are more prone to errors in the integration phase because of the more complex processes involved in top-down processing and the lack of deficits in the underlying reading mechanisms in these readers. For skilled readers, when reading becomes automatic, it also becomes effortless, and a trade-off occurs with higher-control processes (Walczyk, 2000).

Chall describes reading as a multi-level process, where each component is integral to the development of the next (Chall, 1983). The first level of the Chall model is “learning to read,” whereas the second level is “reading to learn.” The first level is divided into several stages: (a) pre-reading stage (0-6 years old), (b) predecoding stage (first and second grades), and (c) fluent-reading stage (second and third grades). The second level is composed of reading to learn (extracting knowledge from the text; fourth-sixth grades), reading for different perspectives (high school grades), and building new knowledge (high school and college). The Chall model emphasizes that phonology is the most basic component, followed by orthography (or holistic word reading), and then an automatic mastery of both of them resulting in fluent reading. Only when the child reads fluently can he or she move to the comprehension level.

For this review, we attempt to provide researchers, clinicians, teachers, and parents with an up-to-date overview of the research-based reading intervention programs currently available for children ages 4 to 16 years. Using a PubMed search (U.S. National Library of Medicine, 2015), we have included only research-based articles describing reading intervention programs for this age range (key words were “reading intervention” and “children”). The biomedical perspective of the programs reviewed broadens the scope of existing reading program reviews created by the U.S. Department of Education’s Institute of Education Sciences (IES). Founded in 2002 to promote informed educational decision making, the IES *What Works Clearinghouse* website provides educators, legislators, and community members with a central source for research-based educational programs, including reading intervention programs, from an educational perspective (U.S. Department of Education, 2005). Additional reviews of reading intervention programs are also available through national and state Response to Intervention (RTI) search engines, such as the American Institutes for Research (2015) *Center for Response to Intervention*. However, these reviews do not provide a review on only research-based interventions and the actual quantitative information reflecting the level of improvement, and they do not separate the interventions according to the different aspect of reading they are treating (i.e., phonology, fluency, comprehension, multi-component). Our review aims to direct educators, professionals, and researchers to the most appropriate intervention according to either their domain of interest or the child’s needs.

An attempt was made to divide the presented intervention programs into one of the three main reading sub-components (Table 1—phonology, Table 2—fluency, Table 3—comprehension). As intervention programs that train orthography use context to train this domain, we included these programs under “fluency.” We also included programs that involve several components (Table 4—multiple components) and the outcomes that are available for each of these programs in the following domains: phonology, orthography, fluency, comprehension, and other general domains if reported (spelling, motivation, knowledge, and others). Results in the tables report the effect measured immediately after intervention. We then attempted to conclude as to a preferable trained reading domain that results in many improved reading domains.

Phonological processing interventions, such as Lindamood-Bell, code-based classroom instruction, and Phono-Graphix, result in improvements in phonology, orthography, and comprehension, whereas reading fluency (contextual accuracy and speed) was not affected (Table 1). The lack of the “timing” component (i.e., the encouragement of faster contextual reading) that is absent in the listed interventions may contribute to the lack of changes in the fluency domain. However, the ages of the participants listed in some of the phonology-based interventions that did not show an improvement in fluency were less than 7 years (i.e., Graphogame and the classroom instructions). Also, in the intervention program that did have an effect on reading fluency (i.e., Lindamood-Bell), the intervention lasted 2.5 years as opposed to 12 to 16 weeks for the other two interventions, which may have had an effect on the development of fluency skills.

Interestingly, the number of research-based intervention programs is limited. To date, we found that only the Reading Acceleration Program (RAP), which is a computer-based intervention, has a published effect on orthography, fluency, and comprehension (Table 2). The effect was found in a variety of orthographies (i.e., German, Hebrew, and English) and different age groups (6-12 years), with reports in adults as well (Breznitz et al., 2013). The effect of this intervention was found after 3.5 to 8 weeks of training.

A variety of intervention programs are focused on comprehension (Table 3). These programs vary from listening comprehension programs that are computer-based (van Kleeck, Vander Woude, & Hammett, 2006) to a teacher-based setting (Garner & Bochna, 2004). Some programs, such as Concept-Oriented Reading Instruction (CORI), improved comprehension and other domains not related to reading (e.g., reading motivation, strategies, knowledge, searching, and more). Only the Guided Reading (GR) intervention had an effect on the phonology, orthography, and comprehension domains related to reading, but without a direct effect on fluency. Interestingly, GR was the shortest intervention compared with the other interventions listed in the table (i.e., only 6 weeks), but the participants were the oldest (9-14 years of age)

Multi-component interventions are both computer based as well as teacher based, with a major difference in the training time frame (4 weeks to 3 school years; Table 4). The only intervention that showed an improved reading on all four examined domains of reading (phonology, orthography, fluency, and comprehension) was the Multi-component Tier 2 intervention for 9-to-12-year-old children, which lasts from a couple of weeks to a couple of years. Another program for this age group is computer based for 6 weeks (i.e., video instructions; Xin & Rieth, 2001), which only showed an effect on orthography and comprehension.

Discussion

The purpose of this current-literature review was to provide an overview of research-based phonological, fluency (includes orthography), comprehension, and multi-component reading intervention programs. The intervention programs we have reviewed include those for children aged 4 to 16 years, both computer-based and teacher-based in each of the following reading domains: phonemic awareness, phonology/decoding, orthography, fluency, and comprehension. Other outcome measures, if given in the original studies, are also provided. Due to the different measures in each study, we are unable to provide a meta-analysis that compares the main effects of the intervention programs to identify the most effective intervention. However, based on the literature review, greater gains in all levels of reading measures and comprehension are achieved when using techniques that specifically address reading fluency (such as the RAP; Horowitz-Kraus & Breznitz, 2013). We base our conclusions on the reports of increase in orthography, fluency, and comprehension abilities (i.e., all components involved in contextual reading; see Horowitz-Kraus & Breznitz, 2013; Horowitz-Kraus, Cicchino, Amiel, Holland, & Breznitz, 2014) following a fluency training.

Reading fluency recently has been acknowledged as a composite of key cognitive processes (phonological, orthographical, and semantic processes, as well as more basic higher-order abilities such as executive functions [attention, working memory, and speed of processing]; Benjamin & Gaab, 2012; Berninger, Abbott, Billingsley, & Nagy, 2001; Wolf & Katzir-Cohen, 2001). Only a synergy in the activation of all of these components results in fluent reading (Breznitz, 2006). Recent neuroimaging studies also support this concept; fluent-reading training resulted in increased activation in phonological, orthographical, and semantic regions, as well as executive functions-related brain regions (Horowitz-Kraus & Breznitz, 2013; Horowitz-Kraus et al., 2014; Horowitz-Kraus & Holland, 2015). We suggest that by encouraging fluent reading, more information units can be processed in a given time, and reading fluency training “releases” the speed of the cognitive bottleneck resulting from the slow speed of processing and deficits in working memory demonstrated by children with reading difficulties

Table 1. Reading Intervention Programs According to the Sub-components of Reading: Phonology.

Program	Type of program	Level of training	Age (years)	Language	Duration			Outcomes
					Weeks	Times per week	Length of sessions	
Lindamood-Bell PASP Auditory Discrimination in Depth Program (Torgesen et al., 1999)	Teacher		5-8	English	2½ school years K-2	4	20 min	Phonology: Non-words (WJ-RMT Word Attack): Increased from 0 to 24 non-words, with SS increasing from 0.76 to 21.3 Non-words (non-word list): Increased from zero to 50 non-words, with SS increasing from 1.8 to 43.2 Orthography: Words (WJ-RMT WI): Increased from 0 to 55 words, with SS increasing from 1.2 to 47.9. Words (real word list): Increased from 1 to 154 words, with SS increasing from 5.1 to 137.9 Words (TOWRE Sight Word Efficiency): Increased from 22 to 43 words. Non-words (TOWRE Phonemic Decoding Efficiency): Increased from 12 to 25 non-words Comprehension: WJ-RMT Passage Comprehension: Raw scores increased from 13 to 26, with SS increasing from 10.7 to 23.2 GORT-II Comprehension: Raw scores increased from 5 to 13, standard increasing from 3.8 to 10.9
Computer-assisted reading program (CARIs) GG Rime and GG Phoneme (Kyle, Kujala, Richardson, Lyytinen, & Goswami, 2013)	Computer	GG Phoneme phoneme-level connections between letters and sounds GG Rime introduced and reinforced grapheme-phoneme connections via rhyming word families, explicit focus on orthographic rime units, and demonstrating how rime units and GPCs are related in English spelling	6-7	Finnish (also exists in English)	12	5	10-15 min	Note. Due to small sample size, results are given in raw scores and effect sizes (calculated by computing gain scores for each group for each measure and then subtracting the mean gain score for the control group from the mean gain for the experimental group of interest). However, none of the ESs reported had a <i>p</i> value < .05 Phonological awareness: GG Rime group mean raw score increased from 10.2 at T1 to 15.9 at T2 on phoneme deletion task, GG Phoneme group increased from 12.1 to 18.5, and control group increased from 9.7 to 12.2

(continued)

Table 1. (continued)

Program	Type of program	Level of training	Age (years)	Language	Duration			Outcomes
					Weeks	Times per week	Length of sessions	
Code-based classroom instruction and a supplemental maintenance intervention. Comparison group: Only code-based classroom instruction	Teacher	Phonological awareness Alphabetic skills Decoding strategies Text reading Spelling Writing	5-6	NA	~16	5	Classroom: 60-90 min Supplemental: 30 min	<p>GG Rime mean raw score increased from 6.8 at T1 to 10.0 at T2 for Rhyme Oddity task, GG Phoneme increased from 10.0 to 11.2, and control group increased from 8.9 to 9.5</p> <p>Phonology:</p> <p>GG Rime group read seven more non-words on the TOWRE Phonemic Decoding Efficiency test, GG Phoneme group read five more non-words, and control group read four more non-words at T2 than at T1</p> <p>Orthography:</p> <p>GG Rime group read 14 more words on the BAS II, GG Phoneme read 11 more words, and control group read 10 more words at T2 than at T1</p> <p>GG Rime group read 10 more words on the TOWRE Sight Word Efficiency sub-test, GG Phoneme read nine more words, and control group read seven more words at T2 than at T1</p> <p>Spelling:</p> <p>GG Rime group correctly spelled seven more words on the BAS II, GG Phoneme spelled five more words, and control group spelled four more words at T2 than at T1</p> <p>Post-test performance did not differ between the experimental and comparison groups.</p> <p>Combined group performance (experimental + comparison) made more growth than normative sample</p> <p>Phonology (Word Attack): SS gain of 3</p> <p>Orthography (Word ID): SS gain of 5</p> <p>Comprehension: SS gain of 5</p>
Classroom instruction emphasized phonological awareness, letter-sound correspondences, decoding strategies, and text reading. Supplemental: Write Well—Enhancing phonological awareness and alphabetic skills through spelling, writing, and practice. (Coyne, Kame'enui, & Simmons, 2004)								

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Table 1. (continued)

Program	Type of program	Level of training	Age (years)	Language	Duration			Outcomes
					Weeks	Times per week	Length of sessions	
ERI (replication study) (Coyne et al. 2013)	Tutor/ interventionist	Letters and sounds, segmenting and blending phonemes, reading words, decoding	5-6	English	126 lessons	5	Supplemental: 30 min	No significant differences in phonology, decoding, and orthography fluency between the intervention and control groups
Stepping Stones to Literacy Intensive preventive pre-reading intervention program (Nelson, Benner, & Gonzalez, 2005)	Trained paraprofessional-level tutors.	Exclusive focus on improving kindergarten children's phonological awareness, letter ID, and rapid naming. Does not include word reading or letter-sound correspondence. 1:1 tutoring	5-6	English	25 lessons		Treatment group only 10-20 min daily supplemental	Phonological awareness: CTOPP; SSs increase from 91.3 to 100.6 An overall effect of intervention compared with the comparison group is $F(1, 34) = 10.96, p < .01$ Orthography: Word reading (DIBELS NWF) SSs increase from 2.1 to 12.1 An overall effect of intervention compared with the comparison group is $F(1, 34) = 17.22, p < .01$
Phono-Graphix (Denton, Fletcher, Anthony, & Francis, 2006)	Tutor	Explicit phonics instruction using picture cards. Four stages of progressive sound-symbol relationships Decoding practice through reading decodable texts	5-8 identified with reader deficits	English	8	2	Supplemental: 50 min	Decoding: WJ-III Word Attack increased raw scores from 459.5 to 482.8; $F(1, 25) = 72.64, p < .0001$ TOWRE Phonemic Decoding Fluency increased raw scores from 9.7 to 16.4; $F(1, 25) = 53.86, p < .0001$ Orthography: WJ-III Letter-Word ID increased raw scores from 430.5 to 448.8; $F(1, 25) = 46.63, p < .0001$ TOWRE Sight Word Fluency increased raw scores from 38.8 to 45.6; $F(1, 25) = 19.16, p < .0001$ Fluency: GORT increased raw scores from 6.1 to 8.6; $F(1, 25) = 33, p < .0001$ Comprehension: WJ-III Passage Comprehension increased raw scores from 451.7 to 460.4; $F(1, 25) = 25.98, p < .0001$

Note. PASP = Phonological Awareness Skills Program; K = kindergarten; SS = standard score; WJ-RMT = Woodcock-Johnson Reading Mastery Test; WI = Word Identification; TOWRE = Test of Word Reading Efficiency; GORT-II = Gray Oral Reading Tests-Second Edition; CARI = computer-assisted reading intervention; GG = Graphogame; GPC = grapheme-phoneme correspondence; ERI = early reading intervention; CTOPP = Comprehensive Test of Phonological Processing; DIBELS = Dynamic Indicators of Basic Early Literacy Skills; NWF = non-word fluency; ID = identification; WJ-III = Woodcock Johnson-Third Edition; ES = effect size; T1 = Treatment Group 1; T2 = Treatment Group 2.

Table 2. Reading Intervention Programs According to the Sub-components of Reading: Fluency.

Program	Type of program	Age (years)	Language	Duration			Outcomes
				Weeks	Times per week	Length of sessions	
A computerized training of repeated reading of a limited set of 32 training words, with special emphasis on the onset segment. Active and passive conditions were set, and children were asked to pronounce (or listen to) the words appearing on the screen. This was done in stages (Thaler, Ebner, Wimmer, & Landerl, 2004)	Computer	8-11	German	~3.5 (25 days)	5	15 min; six sessions	Orthography: Reading accuracy: No change Reading times (per word): Trained words: Decreased by 1,300 ms Transfer words: Decreased by 550 ms Control words: Decreased by 420 ms
RAP (Horowitz-Kraus, Cicchino, Amiel, Holland, & Breznitz, 2014)	Computer	8-12 (readers with dyslexia)	English and Hebrew	4	5	20 min	In the Hebrew-speakers group: Reading fluency: Reading speed decreased by 89 ms/letter Comprehension increased by 23% In the English-speakers group: Reading fluency: Reading speed decreased by 40 ms/letter Comprehension increased by 24%
RAP (Horowitz-Kraus, & Breznitz, 2013)	Computer	8-12 (typical readers and readers with dyslexia)	Hebrew	8	3	15-20 min	Orthography (number of words per minute): From 56.46 to 79.36 in children with dyslexia; from 61.87 to 84.91 in typical readers Fluency decreased time in the parsing test from 7.85 s per sentence to 6.57 s per sentence in children with dyslexia; from 6.18 to 5.01 s in typical readers Comprehension: Increased SS from -0.71 to -0.15 in children with dyslexia and from -0.33 to 0.12 in typical readers.
RAP: A computer-controlled reading situation in which reading rate was accelerated and decelerated according to the highest and lowest rates demonstrated by each participant in a preliminary test. Auditory masking: Music of a well-known song was played by the computer during all three reading rate condition (Breznitz, 1997a, 1997b)	Computer	6-7 (typical readers) 8-9 (readers with dyslexia)	Hebrew	NA	NA	NA	Without auditory masking: Comprehension: average raw score increased from 3.11 to 3.90 Orthography: Reading accuracy (errors): Average number of errors increased from 27.01 to 29.30. Fluency: Reading time: Average time decreased from 34.13 to 22.50 s With auditory masking: Comprehension: average raw score increased from 3.01 to 4.3 Orthography: Reading accuracy (errors): Average number of errors decreased from 23.09 to 17.78 Fluency: Reading time: Average time decreased from 27.20 to 18.77 s
RAP (Horowitz-Kraus, et al., 2014)	Computer	8-12 (readers with dyslexia)	English and Hebrew	4	5	20 min	In the Hebrew-speakers group: Reading fluency: Reading speed decreased by 89 ms/letter Comprehension increased by 23% In the English-speakers group: Reading fluency: Reading speed decreased by 40 ms/letter Comprehension increased by 24%

Note. RAP = Reading Acceleration Program; SS = standard score.

Table 3. Reading Intervention Programs According to the Sub-components of Reading: Comprehension.

Program	Type of program	Age (years)	Language	Duration			Outcomes
				Weeks	Times per week	Length of sessions	
Dialogic reading: Adults read two books and were asked both literal (~70%) and inferential (~30%) questions. For each book, three sets of 25 questions were developed, allowing repeated readings of the same stories while varying the questions asked. For some of the questions, subsequent prompts were scripted to aid the child in responding if he could not. (van Kleeck, Vander Woude, & Hammett, 2006)	Computer	4	English	8	2	15 min	Literal language: Mean SS for the PPVT-III increased from 80.07 at pre-test to 90.93 at post-test. Scores remained relatively unchanged for untreated control group, with a mean SS of 74.53 at pre-test and 74.07 at post-test. Inferential language: Mean raw score on PLAI increased significantly from 21.6 to 31.47 in the treatment group. Mean raw score in the untreated control group increased from 14.47 at pre-test to 19.27 at post-test, an insignificant change.
Listening comprehension Direct explanation and guided practice were employed to teach main character, setting (time and location), problem, attempted solution (plot episodes), and solution. Half the students in each group read silently. Half of oral and silent readers in each group were questioned about story structure knowledge prior to reading. (Garner & Bochna, 2004)	Teacher	6-7	Not stated	16	8 (twice daily)	15-20 min	Listening comprehension: Free recall: Not influenced by instruction Prompted recall: Intervention group mean raw score (10.1) significantly higher than that of comparison group (6.73) Reading comprehension: Reading ability: No group differences Identification of story structure: 75% of intervention group could correctly identify and define story elements (when questioned) prior to reading, compared with 25% in comparison group. Free recall: No significant differences Prompted recall: Mean scores for intervention group were 0.68 higher for character elements, 0.8 higher for setting elements, 1.06 higher for problem elements, and 0.55 higher for solution elements than for comparison group
GR Tutors merely modeled specific comprehension strategies. EC Explicit instruction of strategies and self-regulatory procedures, along with collaborative interaction between teacher and student. Unlike the GR condition, the strategies were introduced sequentially (Manset-Williamson & Nelson, 2005)	Teacher	5-12		6 (1 week spent on pre- and post-testing)	4 days	1 hr	PDF + GR: Phonology: significant SS gain of 3.3 on WJ-III Word Attack Orthography: Significant SS gain of 3.9 on WJ-III Letter-Word ID Fluency: Significant SS gain of 4.9 on WJ-III Reading Fluency sub-test Comprehension: Significant SS gains of 1.4 on Retell Quality and 0.5 on Main Idea PDF + EC: Phonology: Insignificant SS gain of 4.6 on WJ-III Word Attack Orthography: Insignificant SS gain of 0.3 on WJ-III Letter-Word ID

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Table 3. (continued)

Program	Type of program	Age (years)	Language	Duration			Outcomes
				Weeks	Times per week	Length of sessions	
Three treatment conditions: Explicit reading strategies instruction followed by (a) practicing topics during teacher-led whole-class activities (A), (b) practicing in reciprocal same-age dyads (A + B), (c) practicing in cross-age (fifth + second graders) dyads (A + C) (Van Keer, 2004)	Teacher	9-12		; 5 weeks spent on tutoring)	All school years	1-2 hr	<p>Fluency: Significant SS gain of 4.6 on WJ-III Reading Fluency sub-test</p> <p>Comprehension: Significant SS gain of 2.6 on Retell Quality and insignificant SS gain of 0.9 on Main Idea</p> <p>A multivariate analysis was conducted using the results from the three treatment conditions and revealed that the A and A + C conditions showed greater effect on reading measures than the control group (traditional reading comprehension group; actual scores were not given).</p>
CORI	Teacher	8-9	12 (CORI) 13 (SI)		CORI NA SI NA	CORI: 90 min SI: 90 min	<p>Reading comprehension</p> <p>Multiple text comprehension: CORI ($M = 3.65$) was significantly higher than SI ($M = 2.87$); $ES = 1.32$</p> <p>Passage comprehension: CORI ($M = 0.56$) was significantly higher than SI ($M = 0.31$); $ES = 1.32$</p> <p>Reading motivation</p> <p>CORI ($M = 14.50$) was significantly higher than SI ($M = 13.71$); $ES = 0.98$</p>
SI (Guthrie et al., 2004)							
CORI SI TI (Guthrie et al., 2004)	Teacher	8-9	12 (CORI, SI, and TI)		NA	90 min Struggling readers received an additional 30 min of SI instruction	<p>Reading strategies</p> <p>CORI ($M = 7.72$) was significantly higher than SI ($M = 1.80$); $ES = 1.23$</p> <p>Activating background knowledge</p> <p>No significant difference</p> <p>No significant differences</p> <p>Questioning</p> <p>No significant differences</p> <p>Searching</p> <p>No significant difference</p> <p>Comprehension</p> <p>CORI ($M = 0.46$) was significantly higher than TI ($M = 0.8$) but not SI ($M = 0.35$). TI and SI did not differ significantly</p> <p>Gates-MacGinitie Reading Comprehension Test</p> <p>Intrinsic motivation</p> <p>Self-efficacy</p> <p>Extrinsic motivation</p> <p>Combined motivations</p>

Note. SS = standard score; PPVT-III = Peabody Picture Vocabulary Test-Third Edition; PLAI = Preschool Language Assessment Instrument; GR = guided reading; EC = explicit comprehension; PDF = Phonemic Awareness/Analysis, Decoding, and Fluency Instruction; WJ-III = Woodcock Johnson-Third Edition; ID = Identification; CORI = Concept-Oriented Reading Instruction; SI = Strategy Instruction; ES = effect size; TI = Traditional Instruction; SA = same age; CA = cross age.

Table 4. Reading Intervention Programs According to the Sub-components of Reading: Multiple Components.

Program name	Type of program	Emphasis on			Age (years)	Language	Weeks	Duration		Outcomes
		Decoding	Fluency	Comprehension				Times per week	Length of sessions	
Project Read Trains phonemic awareness, decoding, reading comprehension, and expressive oral language (Stoner, 1991)	Teacher	✓	✓	✓	6-8 First to third grades	English	1 school year over 3 years	5 days	Not indicated in the study	Orthography: Results from the Stanford Achievement Tests, 1982 Grade 1: Word Reading: Mean scaled score for control group was 545, whereas the mean scaled score for T1 was 441 and T2 was 493 Reading Comprehension: Mean scaled score for control group was 450, whereas the mean scaled score for T1 was 435 and T2 was 487 Grade 2: Word Reading: Mean scaled score for control group was 533, whereas the mean scaled score for T1 was 526 Reading Comprehension: Mean scaled score for control group was 541, whereas the mean scaled score for T1 was 524 Grade 3: Word Reading: Mean scaled score for control group was 577, whereas the mean scaled score for T1 was 587 Reading Comprehension: Mean scaled score for control group was 586, whereas the mean scaled score for T1 was 587 The ES of Total Reading scores in Grade 1 was significantly different, with an ES of 1.35. The total reading scores in Grades 2 and 3 were not significantly different Academic gains within the experimental group School-related achievement was assessed using the Metropolitan Reading Test and the Gates-MacGinitie Reading Test: Primary A, Form I The experimental group showed significant gains when compared with the control group, with significance levels ranging from .05 to .005.
OG instruction Trains phonology, phonological awareness, sound-symbol correspondence, syllables, morphology, syntax, semantics, and fluency	Tutor	✓	✓	✓	First-grade students	English	3 school years	5 days	3 hr	
OG Trains phonology, phonological awareness, sound-symbol correspondence, syllables, morphology, syntax, and semantics (Simpson, Swanson, & Kunkel, 1992)	Tutor	✓	✓	✓	13-18	English	Information not given	5 days	90 min	Orthography: Treatment group ($n = 32$) mean reading growth in grade units was 0.93, significantly greater than the comparison group ($p < .01$). The comparison group ($n = 31$) mean reading growth in grade units was 0.07.

(continued)

Table 4. (continued)

Program name	Type of program	Emphasis on				Age (years)	Language	Duration		Outcomes
		Decoding	Fluency	Comprehension	Level of training			Weeks	Times per week	
Language basics: Elementary curriculum Trains phonemic awareness, phonics, fluency, reading comprehension, handwriting, and constructing text (Joshi, Dahlgren, & Boulware-Gooden, 2002)	Teacher	✓	✓	✓	Phonemic awareness Decoding Syllables Morphemes Irregular words Spelling Words Phrases Connected text Vocabulary Text comprehension Narrative text Expository text Manuscript Cursive Sentence level Punctuation Narrative composition Expository composition	First grade (general education)	English	1 school year	5	50 min Phonological awareness: SS increased from 91.46 to 100.75— $F(1, 53) = 5.02, p < .03; \eta^2 = 0.26$ —on TOPA for treatment group. This is compared with controls whose SS increased from 91.65 to 94.61— $F(1, 63) = 0.838, p < .36$ Phonology: SS increased from 93.80 to 107.36— $F(1, 55) = 8.94, p < .02; \eta^2 = 0.14$ —on WA sub-test of WI-RMT-R. This is compared with controls whose SS increased from 88.34 to 92.59— $F(1, 59) = 2.87, p < .10$ Comprehension: SS increased from 39.83 to 55.96— $F(1, 52) = 6.35, p < .02; \eta^2 = 0.11$ —on GMRT. This is compared with controls whose SS increased from 35.97 to 44.03— $F(1, 61) = 5.36, p < .02$
DTP Trains phonemic awareness, phonics, fluency, vocabulary, reading and listening comprehension, handwriting, and spelling (Oakland, Black, Stanford, Nussbaum, & Balise, 1998)	Teacher- or video-directed	✓	✓	✓		11	English	2 years	5 days	1 hr DTP group made significant progress after 2 years of training, compared with controls who did not— $F(2, 46) = 4.80, p < .05$ Orthography: DTP group made significant improvement after 2 years. They performed lower than controls at pre-test and performed better than controls at the post-test— $F(2, 46) = 6.18, p < .005$. The control group had minimal improvement. Spelling: Both groups performed comparably, however, neither the DTP nor the control group improved after 2 years— $F(2, 46) = 0.67, p > .05$ Phonemic awareness: Both groups had similar gains. FFW had a gain of 9.7 and OG had a gain of 7.8 on LAC Orthography: No significant gains for either group on WI WI-RMT; FFW had no significant gain and OG had significant gain of 5.8 on WA. Comprehension: No significant gains for either group on PC. Oral language competency: Mean SS on OWLS Oral Expression sub-test increased from 90.36 at pre-test to 96.52 at post-test, a significant time by group interaction, $F(1, 35) = 6.52, p < .05$ No significant changes observed in the following domains: 1. Phonological processing 2. Basic reading skills 3. Classroom behavior
FFW (Hook, Macaruso, & Jones, 2001)	FFW: Computer OG: Teacher	✓ FFW OG		✓ FFW		7-12	English	FFW 8 weeks OG 5 weeks	FFW 5 days OG 5 days	100 min; two 10-min breaks OG: 1 hr a day
FFW language—A computer-assisted intervention program (Tallal, Miller, Jenkins, & Merzenich, 1997) Trains memory, attention, processing rate, sequencing, phonological awareness, phonemic awareness, fluency, vocabulary, comprehension, decoding, working memory, syntax, and grammar (Troia & Whitney, 2003)	Computer	✓	✓	✓		5-13	NA	4-8 weeks	5 days	20 min

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Table 4. (continued)

Program name	Type of program	Emphasis on			Age (years)	Language	Duration			Outcomes
		Decoding	Fluency	Comprehension			Weeks	Times per week	Length of sessions	
FFW language—A computer-assisted intervention program (Temple et al., 2003)	Computer	✓	✓	✓	8-12	NA	8	NA	NA	Phonology (WA) ^a : Mean SS increased from 85.5 to 93.7; t stat = 6.8, $p < .0001$ Orthography (Word ID) ^b : Mean SS increased from 78.2 at pre-training to 86.0 at post-training; t stat = 3.9, $p < .0005$ Comprehension ^c : Mean SS increased from 83.3 to 88.9; t stat = 2.9, $p < .005$ *Measures from the WJ-RMT Language: CELF-3 Receptive: Mean SS increased from 92.5 to 101.3; t stat = 3.6, $p < .001$ Expressive: Mean SS increased from 95.0 to 102.2; t stat = 2.8, $p < .006$ Rapid naming: Mean SS increased from 79.1 to 86.5; t stat = 2.8, $p < .006$ Note. These results indicate significant differences between pre- and post-training on the behavioral measures listed. These scores were not compared with a control group of untrained dyslexic children, as this group was not included in the study.
FFW Trains memory, attention, processing rate, sequencing phonological awareness, phonemic awareness, fluency, vocabulary, comprehension, decoding, working memory, syntax, and grammar (Hook et al., 2001)	Computer	✓	✓	✓	Children aged 7-12 years with reading difficulties	English	12 weeks (summer)	5 days	100 min	Phonemic awareness: Children with reading impairments assigned to the OG group started with a weighted score of 68.2 on the LAC and, 4 months after interventions, resulted in a weighted score of 76.0 Children with reading impairments assigned to the FFW group started with a weighted score of 65.0 on the LAC and, 4 months after interventions, resulted in a weighted score of 74.5. At the end of Academic Year 1, the score was 76.5 and, at Year 2, 85.2 The longitudinal control group started with a weighted score of 70.4 on the LAC. At the end of Academic Year 1, the score was 78.5 and, at Year 2, 82.4 Phonology: Children with reading impairments assigned to the OG group started with an SS of 82.4 on the WA sub-test of the WJ-RMT-R and, 4 months after interventions, resulted in an SS of 88.2 Children with reading impairments assigned to the FFW group started with an SS of 83.3 on the WA sub-test of the WJ-RMT-R and, 4 months after interventions, resulted in an SS of 81.7. At the end of Academic Year 1, the score was 86.9 and, at Year 2, 89.8 The longitudinal control group started with an SS of 81.6 on the WA sub-test of the WJ-RMT-R. At the end of Academic Year 1, the score was 89.9 and, at Year 2, 90.5 Orthography: Children with reading impairments assigned to the OG group started with an SS of 74.3 on the WI sub-test of the WJ-RMT-R and, 4 months after interventions, resulted in an SS of 75.3 Children with reading impairments assigned to the FFW group started with an SS of 76.5 on the WI sub-test of the WJ-RMT-R and, 4 months after interventions, resulted in an SS of 74.4. At the end of Academic Year 1, the score was 77.8 and, at Year 2, 83.7 The longitudinal control group started with an SS of 73.3 on the WI sub-test of the WJ-RMT-R. At the end of Academic Year 1, the score was 78.6 and, at Year 2, 78.1 Reading comprehension: Children in the OG group were not given the PC portion of the WJ-RMT-R Children with reading impairments assigned to the FFW group started with an SS of 74.9 on the PC sub-test of the WJ-RMT-R and, 4 months after interventions, resulted in an SS of 75.6. At the end of Academic Year 1, the score was 80.9 and, at Year 2, 85.1 The longitudinal control group started with an SS of 73.7 on the PC sub-test of the WJ-RMT-R. At the end of Academic Year 1, the score was 76.4 and, at Year 2, 81.7

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Table 4. (continued)

Program name	Type of program	Emphasis on				Duration			Outcomes
		Decoding	Fluency	Comprehension	Level of training	Age (years)	Language	Weeks	
LEXY Trains phonology, morphology, reading accuracy, fluency, and spelling (Tijms & Hoeks, 2005)	Computer	✓	✓	✓		10-14	Dutch	NA	Orthography: Word Reading Rate (1-min test): T1 correctly read 15 more words after training, having read 52.34 words pre-test and 66.77 words post-test. SSs increased from 77.37 to 88.15 ($Z = -9.67$, $p < .001$). T2 correctly read 16 more words after training, having read 50.64 words pre-test and 66.59 words post-test. Mean SS increased from 75.78 to 87.85 ($Z = -9.97$, $p < .001$) Fluency: Text Reading Accuracy ("Livingstone" text): T1 made on average 24 fewer errors after training, having made 42.98 errors pre-test and 18.54 errors post-test. Mean SS increased from 84.35 to 105.98 ($Z = -9.47$, $p < .001$). T2 made on average 26 fewer errors after training, having made 44.88 errors pre-test and 19.29 errors post-test Text Reading Rate ("Livingstone" text): Reading time for T1 decreased on average by 146 s after training. Mean SS increased from 61.38 to 84.58 ($Z = -8.87$, $p < .001$). Reading time for T2 decreased on average by 159 s. Mean SS increased from 60.56 to 86.23 ($Z = -9.70$, $p < .001$) Spelling (IWAL Standard Dictation): T1 made on average 32 fewer spelling errors after training, having made 39.84 pre-test and 8.41 post-test. Mean SS increased from 54.37 to 101.09 ($Z = -9.86$, $p < .001$). T2 made on average 37 fewer spelling errors after training, having made 47.10 pre-test and 9.50 post-test. Mean SS increased from 58.86 to 99.31 ($Z = -10.01$, $p < .01$) Note. Both the two treatment groups consist of dyslexic children who underwent the same training program. There were no statistically significant differences in the characteristics of the two groups ($p > .1$). Scores were compared with norm-referenced scores
ADD (now called the Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech) vs. EP Trains phonology, phonics, fluency, and expressive and receptive language (Torgesen et al., 2001)	Teacher	✓	✓	✓		8-10	NA	8	Phonology based on the WJ-RMT-R: For the ADD group, the WA SS before intervention was 68.5 and after intervention 96.4. At the 2-year mark, the SS was 91.8 For the EP group, the WA SS before intervention was 70.1 and after intervention 90.3. At the 2-year mark, the SS was 89.9 For the ADD group, the phoneme decoding efficiency SS before intervention was 74.3 and after intervention 83.3. At the 2-year mark, the SS was 84.3 For the EP group, the phoneme decoding efficiency SS before intervention was 75.7 and after intervention 83.7. At the 2-year mark, the SS was 82.7 Orthography based on the WJ-RMT-R: On WJ, before intervention, the ADD group had an SS of 68.9 and after intervention 82.4. At the 2-year mark, the SS was 87.0 On WJ, before intervention, the EP group had an SS of 66.4 and after intervention 80.5. At the 2-year mark, the SS was 83.9 Fluency based on the GORT-III: On Gray Accuracy, before intervention, the ADD group had an SS of 73.8 and after intervention 89.4. At the 2-year mark, the SS was 91.3 Gray Rate SS before intervention was 71.3 and after intervention 75.4. At the 2-year mark, rate was 72.7 On Gray Accuracy, before intervention, the EP group had an SS of 77.5 and after intervention 87.5. At the 2-year mark, the SS was 90.4 Gray Rate SS before intervention was 71.5 and after intervention 72.1. At the 2-year mark, rate was 70.7

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Table 4. (continued)

Program name	Type of program	Emphasis on				Age (years)	Level of training	Duration				Outcomes
		Decoding	Fluency	Comprehension				Language	Weeks	Times per week	Length of sessions	
PHAB/DI WIST (metacognition) Letter-cluster-sound	Teacher	✓	✓	✓		6-13		English	70 hr	5	1 hr	Both the PHAB/DI and the WIST approaches resulted in gains but were most effective when paired together
Trains: Phonology analysis, phonological blending, letter sounds, word ID, and decoding (Lovett et al., 2000)	Computer	✓	✓	✓		7-11			6 months 27-29 hr	NA	NA	Phonology: Gains noted in phonological skills and remained 2 years post-training In the 1- and 2-year follow-up, there were no significant effects on word reading at any age/grade Additional research is suggested to look at interventions that will provide a carryover from phonological skills to word reading
Word building: The intervention directs attention to each grapheme position within a word through a procedure of progressive minimal pairing of words that differed by one grapheme. The program integrates decoding with text reading. Scaffolding tutorial instruction was used. (McCandliss, Beck, Sandak, & Perfetti, 2003)	Teacher-trained undergraduate students	✓		✓		7-10 years old; $M_{age} = 7.3$ years			4 months; 20 tutorial sessions + four additional sessions	3 times	50 min each	Phonemic awareness: (Elision sub-test, raw score): A gain of 3.3 Phonology: (WA, raw score): A gain of 0.9 Orthography: (Letter-Word, raw score): A gain of 3.3 Comprehension: (PC raw score): A gain of 7.7 Gains were identified in the areas of decoding, phonemic awareness, and PC
RAVE-O Trains: Automaticity, fluency, word ID, WA, reading rate, reading accuracy, letter recognition, orthographic patterns, auditory processes, and vocabulary comprehension (Wolf & Kazir-Cohen, 2001; Wolf, Miller, & Donnelly, 2000)	Computer combined with other program		✓	✓		Second to third grade		English	10 weeks 70 hr overall	Daily	30 min phonological program (PHAB) 30 min RAVE-O	Numerical information is not provided. However, improvements in phonology, orthography, and comprehension are reported.

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Table 4. (continued)

Program name	Type of program	Emphasis on			Age (years)	Language	Duration			Outcomes
		Decoding	Fluency	Comprehension			Weeks	Times per week	Length of sessions	
RAAC Trains fluency and comprehension (Therrien, Wickstrom, & Jones, 2006)	Teacher		✓	✓	9-14		4 months	NA	10-15 min	Overall reading measure: WJ-III Broad Reading Scale: Intervention group SSs increased an average of 6.2, with an average of 80.4 pre-test and 86.6 post-test. The control group SSs increased an average of 3.0, with an average of 83.0 pre-test and 86.0 post-test, $F(1, 27) = 3.47, p = .073$ Phonology (nonsense word): DIBELS non-word fluency: Mean SS for decodable text group remained unchanged at 40.5 ($p > .05$), whereas the mean SS for the less decodable text group increased from 61.3 pre-test to 72.0 post-test ($p > .05$) Fluency: DIBELS: Intervention group increased an average of 13.0 CWPM, having read 68.40 pre-test and 81.40 post-test. The control group increased an average of 2.28 CWPM, $F(1, 27) = 5.70, p = .024$ Fluency: DIBELS 6th Edition Oral Reading Fluency: Mean SS for the decodable text group increased from 58.8 pre-test to 60.2 post-test ($p > .05$), whereas mean SS for the less decodable text group decreased from 71.0 pre-test to 68.5 post-test ($p > .05$) Note. Scores reported are of those participants identified as "poor readers" by the investigator
Repeated reading intervention groups (each with good, average, and poor readers) employed four types of repeated reading: Echo reading, choral reading, paired reading, and paired "popcorn" style reading. Each classroom used one of the text types and repeatedly read each text in the four different ways. Trains fluency, and comprehension (Chrisman, 2005)	Teacher		✓	✓	7-8		3 weeks	4 days	20-30 min	
Multi-component HOSTS (Burns, Senesac, & Symington, 2004)	Computer	✓		✓ Vocabulary	5-6 and 9-10		5 months (or 20 weeks)	4 days	30 min	Phonological awareness: DIBELS ISE: Mean SS increased from 12.79 pre-test to 34.00 post-test, $F = 12.01, d = 1.70, p < .007$ DIBELS PSF: Mean SS increased from 5.63 to 16.33, $F = 0.03, d = 0.27$ Alphabetic principle: DIBELS NWF: Mean SS increased from 9.15 pre-test to 19.85 post-test, $F = 0.01, d = 0.25$ Fluency: DIBELS: Mean SS increased from 41.40 pre-test to 66.92 post-test, a gain of 25.52, $F = 10.37, d = 0.64, p < .007$ GORT-IV: Mean SS increased from 6.00 pre-test to 6.75 post-test, $F = 4.24, d = 0.24$ Comprehension: GORT-IV: Mean SS increased from 8.06 pre-test to 8.62 post-test, $F = 9.49, d = 0.18, p < .007$
Treatment group was exposed to 60 novel words in context: 10 books read 4 times. Elaborated condition: Adult reader provides the meaning of the word followed by an example of its use in a sentence. Comparison group received the regular kindergarten curriculum. (Justice, Meier, & Walpole, 2005)	Computer			✓ Vocabulary	5-6.5	NA	10	1-3; About 20 sessions	20 min	Orthography: Elaborated words: Treatment group read on average five more words at post-test than at pre-test. Univariate analysis of interaction was significant, $F(1, 55) = 11.77, p = .001$ Non-elaborated words: Treatment group read on average 0.75 fewer words at post-test than at pre-test. Univariate analysis of interaction was not significant, $F(1, 55) = 1.321, p = .255$

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Table 4. (continued)

Emphasis on						Duration					
Program name	Type of program	Decoding	Fluency	Comprehension	Level of training	Age (years)	Language	Weeks	Times per week	Length of sessions	Outcomes
Treatment group were given computer games (the child listens to a story, answers questions, arranges pictures, and plays vocabulary games). Control group spent less time working on computers, using entertainment software with stories and games concerning shapes and colors.	Computer			Vocabulary		5	NA	15	2	15 min	Vocabulary Curriculum-Dependent Vocabulary Test: There was a significant interaction between time and intervention, $F(2, 155) = 3.678, p = .028, \eta^2 = 0.045$. Experimental native group increased on average the number of correctly identified words by 5.07 words during the first year of the study. During the second year, they increased on average by 2.81 words. At the end of Year 2, they correctly identified on average 29.06 words (max score = 37). Experimental immigrant group increased on average by 4.18 words in the first year and by 4.27 words in the second year. At the end of Year 2, they correctly identified on average 23.27 words (max score = 37). Curriculum-Independent Vocabulary Test (the Passive Vocabulary Test from Taaltoets Alle Kinderen): No effects of intervention found. Experimental native group identified on average 9.71 more words after Year 1 and 7.12 more words after Year 2. At the end of Year 2, they correctly identified 55.50 words (max score = 96). Experimental immigrant group identified on average 7.09 words after Year 1 and 11.74 words after Year 2.
Three components of book reading module were trained: (a) asking questions, (b) building vocabulary, and (c) making connections. Oral language training was designed to teach teachers how to use conversational strategies that promoted multiple opportunities to speak, to actively listen, and to use varying vocabulary.	Teacher	✓		Vocabulary		2-4	NA	36 (9 months)	NA	NA	Receptive vocabulary PPVT-III: Mean SS increased from 82.02 pre-test to 92.73 post-test. There was a significant main effect for condition, with student as the unit of analysis— $F(1, 189) = 33.28, p < .001$ —as well as with classroom as the unit of analysis, $F(1, 13) = 27.13, p < .01$ Expressive vocabulary EOWPVT-III: Mean SS increased from 79.76 pre-test to 86.08 post-test. There was a significant main effect for condition, with student as the unit of analysis— $F(1, 97) = 18.08, p < .001$ —as well as with classroom as unit of analysis, $F(1, 13) = 15.24, p < .01$
Trains: Vocabulary and comprehension (Wasik, Bond, & Hindman, 2006)	Teacher	✓		Vocabulary		4	English	15	Modeling the shared book reading for teachers for 4 weeks, teachers working by themselves for 11 weeks.	Information not provided in article Information provided in article	Receptive vocabulary 1. PPVT-III: • No significant difference in scores at pre-test but significant difference at post-test. With students as the unit of analysis, $F(1, 120) = 13.69, p < .001$ • Experimental and Teacher A: Mean SS increased from 74.37 at pre-test to 81.58 at post-test, a mean gain of 7.21 • Experimental and Teacher B: Mean SS increased from 74.52 to 81.67, a mean gain of 7.15 • Control and Teacher C: Mean SS decreased from 72.51 at pre-test to 72.43 at post-test, a mean loss of 0.42 • Control and Teacher D: Mean standard decreased from 74.23 to 73.62, a mean loss of 0.61 2. Experimental Receptive Vocabulary Test (44 words total): • Main effect of condition was significant, $F(1, 120) = 76.61, p < .001$ • Experimental and Teacher A: identified an average of 37.88 words at post-test (test not done at pre-test for any group) • Experimental and Teacher B: average of 38.02 words • Control and Teacher C: average of 27.09 words • Control and Teacher D: average of 27.05 words Expressive vocabulary: 1. Experimental Expressive Vocabulary Test (44 words total) • Main effect of condition was significant, $F(1, 120) = 76.6, p < .001$ 2. Experimental Expressive Vocabulary Test: • Experimental and Teacher A: Average of 7.59 words at post-test (test not done at pre-test for any group)

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Table 4. (continued)

Program name	Type of program	Emphasis on			Level of training	Age (years)	Language	Duration			Outcomes
		Decoding	Fluency	Comprehension				Weeks	Times per week	Length of sessions	
Revisions involved (a) teaching more meanings on each reading and using four readings. (b) using vocabulary reviews of word meanings taught during each reading of a story. (c) using an additional review with new context sentences in a final review, and (d) using only teacher explanations of word meanings. Seven to 10 word meanings were explained at each reading. Examines more intensive word instruction and transfer of word meanings to new contexts.	Computer			✓ Vocabulary		5-7		2	5	30 min	<ul style="list-style-type: none"> • Experimental and Teacher B: Average of 7.29 words • Control and Teacher C: Average of 2.47 words • Control and Teacher D: Average of 2.97 words <p>Note. Experimental vocabulary tests contained words introduced during the 15-week program. Of the possible 100 words on the list, 44 were chosen randomly and used in the experimental assessments. Experimental assessments were only administered at the post-test.</p> <p>Average gain of 22% when repeated reading (12%) was used along with word explanations (10%). $F(1, 109) = 19715, p < .001$</p> <p>Average learning of 41% of words taught during instruction. $F(2, 192) = 528.597, p < .001$</p>
Trains vocabulary and comprehension (Biemiller & Boote, 2006) Two books were read twice, and another was read 4 times. Twelve word meanings were taught from books read twice in 1 week. Twelve more word meanings were taught from a third book read 4 times during the second week of instruction. Four to six words were taught each day. Examines the effect of pre-testing, number of times books were read, and word explanations on word acquisition.				✓ Vocabulary		5-7		2 weeks	4	NA	<p>Orthography (word identification):</p> <p>Children who read twice showed an increase of 22% of instructed words and 12% of non-instructed words after intervention.</p> <p>Children who read 4 times showed an increase of 24% of instructed words and 15% of non-instructed words after intervention.</p>
Trains vocabulary and comprehension (Biemiller & Boote, 2006)											

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Table 4. (continued)

Program name	Type of program	Emphasis on			Level of training	Age (years)	Language	Duration		Outcomes	
		Decoding	Fluency	Comprehension				Weeks	Times per week		Length of sessions
Video instruction group learned word meanings and concepts in videodisc-based contexts (multi-sensory context). Non-video group learned word definitions and concepts using dictionary and printed texts Trains vocabulary and comprehension (Xin & Rieth, 2001)	Computer		✓	Vocabulary		9-12		6	3	30 min	Orthography: Treatment group correctly defined 8.76 more words post-test than pre-test. They defined on average 13.07 words post-test (max score = 30). There was a significant interaction between time of testing and condition of instruction, $F(1, 148) = 3.35, p = .038$ Comprehension: Treatment group correctly answered 3.59 more questions post-test than pre-test. They correctly answered on average 8.03 questions post-test (max score = 15). There was no interaction between instructional condition and testing time. Sentence Cloze: Treatment group correctly completed 9.43 more sentences post-test than pre-test. They completed on average 14.46 sentences post-test (max score = 30). There was no interaction between instructional condition and testing time. Note. All three measures were teacher-made tests. Test–retest inter-related correlation coefficients were all within the coefficient of stability acceptable for a teacher-made test.
The definition method: Learning novel words by being told their meanings. The context method: Teaching of a strategy for deriving meanings from written context (clue words). Trains vocabulary and comprehension (Nash & Snowling, 2006)	Teacher		✓	Vocabulary		7-8		6	2	30 min	Experimental Vocabulary Knowledge Test, receptive vocabulary: Definitions group correctly defined on average 10.67 words (max score = 24) pre-test. They defined 19.17 and 17.42 words at Post-test 1 and Post-test 2, respectively. Context group correctly defined on average 11.50 words pre-test. They defined 18.92 and 17.67 words at Post-test 1 and Post-test 2, respectively. No significant group by time interaction, $F(1, 19) < 1$ Experimental Vocabulary Knowledge Test, expressive vocabulary: Definitions group correctly defined on average 2.17 words (max score = 48) pre-test. They defined 11.08 and 8.41 words at Post-test 1 and Post-test 2, respectively. Context group correctly defined 1.25 words pre-test. They defined 7.75 and 8.25 words at Post-test 1 and Post-test 2, respectively. There was a significant group by time interaction, with the context group able to express significantly more meanings at Post-test 2, $F(1, 19) = 7.05, \eta^2 = 0.27, p < .05$
Responsive Trains vocabulary and comprehension (Mathes et al., 2005)	Teacher	✓				First grade	English	October to May	5 days	40 min	Orthography: Increase of ~30 words per minute and an increase of ~1.7 in z-score for untimed word reading within 6 months Phonology: An increase of ~1 z-score in phonological awareness measures within 6 months An improvement in passage fluency scores are reported in comparison with other intervention programs used in the study
Reading mastery Trains explicit instruction (phonological awareness, sound–letter correspondence, blending), fluency and comprehension (Gunn, Smolkowski, Biglan, Black, & Blair 2005)	Teacher 1: 1-3 Explicit instruction	✓	✓	✓		K-3	English	First year: 4-5 months Second year: 9 months	Daily	30 min	Oral reading fluency: Treatment group mean gain score was 59.17 for T1 to T4, compared with control group mean gain score of 46.87; $F = 7.462, p = .007, d = 0.40$ Orthography: WJ Letter-Word ID: Treatment group mean gain score was 23.26 for T1 to T4, compared with control group mean gain score of 18.85; $F = 2.139, p = .145, d = 0.22$ WJ WA: Treatment group mean gain score was 12.76 for T1 to T4, compared with control group mean gain score of 2.78; $F = 10.301, p = .002, d = 0.46$ Reading comprehension: WJ PC: Treatment group mean gain score was 35.11 at T4, compared with control group mean gain score of 29.56; $F = 3.191, p = .076, d = 0.26$ Vocabulary: Treatment group mean gain score was 29.66 at T4, compared with control group mean gain score of 29.56; $F = 2.813, p = .095, d = 0.24$ Note. All scores are reported as NCE scores

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Table 4. (continued)

Program name	Type of program	Emphasis on			Age (years)	Language	Duration			Outcomes
		Decoding	Fluency	Comprehension			Weeks	Times per week	Length of sessions	
Repeated reading Trains fluency and comprehension Assessed on non-transfer measures (rereading same passage) and transfer measures (reading new passage) (Therrien, 2004; Vadasz & Sanders, 2008, p. 272)	Teacher/peer	✓	✓	✓	second and third grade	English	15 weeks	4 days	30 min	Fluency: Students with LD had a mean fluency ES of 0.75 ($SE = .161$) on non-transfer measures and 0.79 ($SE = .124$) on transfer measures, compared with non-disabled students who had a mean ES of 0.85 ($SE = .075$) on non-transferable measures and 0.59 ($SE = .11$) on transfer measures. Comprehension: Students with LD had a mean comprehension ES of 0.73 ($SE = .153$) on non-transfer measures and 0.41 ($SE = .173$) on transfer measures, compared with non-disabled students who had a mean ES of 0.64 ($SE = .094$) on non-transfer measures and 0.18 ($SE = .126$) on transfer measures.
*Multi-component Tier 2: Small-group reading instruction for children at risk. K: Focus on segmentation of spoken words and letter-sound instruction. First grade: Decoding words, building sight words, and integration in connected text. Monthly assessments enabled to relocate students and change content accordingly. Tier 3: Daily instruction delivered individually or in pair	Teacher	✓	✓	✓	9-12	English	Tier 2: K, first grade—Varied from 8 weeks to several years Tier 3: NA	Tier 2: K—3 times per week, first grade—3 times a week Tier 3: 5 days a week	Tier 2: K—10-15 min; first grade—20-25 min Tier 3: 30 min	Decoding: WJ WA: Children with RD in Tiers 2 and 3 had a mean SS of 99.3, controls had a mean SS of 83.6; $ES = 1.8$ Orthography: WJ Word ID: Children with RD in Tiers 2 and 3 had a mean SS of 89.5, controls had a mean SS of 86.4; $ES = 0.4$ Comprehension: WJ Comprehension: Children with RD in Tiers 2 and 3 had a mean SS of 93.8, controls had a mean SS of 81.5; $ES = 1.0$ Fluency: Children with RD in Tiers 2 and 3 had a mean SS of 65.1, controls had a mean SS of 34.2; $ES = 1.4$ Receptive vocabulary: PPVT-III: Children with RD in Tiers 2 and 3 had a mean SS of 93.9, controls had a mean SS of 95.3
Trains comprehension (O'Connor, Harty, & Fulmer, 2005) Earobics (Pokorni, Worthington, & Jamison, 2004)	Computer	✓	✓	✓	8.7	English		20 days	3 hr	Phonological processing: Blending phonemes: Increased raw scores from 6.0 to 6.6 Segmenting phonemes: Increased raw scores from 1.3 to 3.2 Overall effect of training on phonemic awareness $F(1, 15) = 6.06, p < .01$ (the measure used for this calculation was not provided) Comprehension: WLPB-R: No significant increases between T1 and T2. T1 had a mean of 87.3. T2 had a mean of 86.1 No significant improvements in decoding, orthography, and comprehension
Lindamood-Bell LIPS (Pokorni et al., 2004)	Teacher 1: 4 Explicit instruction Trained tutor 1:1	✓	✓	✓	8.6	English		20 days	3 hr	Phonological processing: Hearing and recording sounds: Increase in raw scores from 9.14 to 34.97 Decoding: Text level: Increase in raw scores from 0.61 to 12.35 Orthography: Ohio Word Test: Increase in raw scores from 0.81 to 14.94 Concepts about print: Increase in raw scores from 10.92 to 19.35 The study does not report a direct effect of intervention on the examined population. No significant changes observed in letter ID
Reading recovery (Schwartz, 2005)		✓	✓	✓	6.45	English	12 to 20 weeks or until student demonstrated mastery	5	30 min	Phonological processing: Hearing and recording sounds: Increase in raw scores from 9.14 to 34.97 Decoding: Text level: Increase in raw scores from 0.61 to 12.35 Orthography: Ohio Word Test: Increase in raw scores from 0.81 to 14.94 Concepts about print: Increase in raw scores from 10.92 to 19.35 The study does not report a direct effect of intervention on the examined population. No significant changes observed in letter ID

(continued)

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Program name	Type of program	Emphasis on			Age (years)	Language	Duration			Outcomes
		Decoding	Fluency	Comprehension			Weeks	Times per week	Length of sessions	
Reading recovery (Pinnell, DeFord, & Lyons, 1988)	Trained teachers	✓	✓	✓	First grade	English	12-20 weeks	5	30 min	Orthography: Word reading: Children in the reading recovery group showed an increase from 2.11 to 13.62, children in the control group showed an increase from 2.01 to 11.98 Letter ID: Children in the reading recovery group showed an increase from 40.56 to 52.66, children in the control group showed an increase from 33.29 to 49.61 Comprehension: Children in the reading recovery group showed an increase from 1.82 to 9.95, children in the control group showed an increase from 1.65 to 6.96 (results reported here are raw scores and are based on the Comprehensive test of basic skills battery) Orthography: Reading words: Reading recovery group reached a scaled score of 141.2, and the control group (alternative training) showed a scaled score of 136.7. Treatment effect: 4.56, $p < .001$ Comprehension: Reading recovery group reached a scaled score of 140 and the control group (alternative training) showed a scaled score of 135.5. Treatment effect: 4.51, $p < .001$ (Results are taken from the Iowa Tests of Basic Skills)
Reading recovery (May et al., 2013)	Trained teachers	✓	✓	✓	First grade	English	12-20 weeks	5	30 min	

Note. ES = effect size; OG = Orton-Gillingham; T1 = Treatment Group 1; T2 = Treatment Group 2; T4 = Treatment Group 4; TOPA = Test of Phonological Awareness; SS = standard score; WJ-RMT-R = Woodcock-Johnson Reading Mastery Test-Revised; GMRT = Gates-MacGinitie Reading Test; DTP = Dyslexia Training Program; FEW = Fast ForWord; LAC = Lindamood Auditory Conceptualization Test; WI = Word Identification; WA = Word Attack; PC = Passage Comprehension; OWLS = Oral and Written Language Scales; WJ-RMT = Woodcock-Johnson Reading Mastery Test; ID = Identification; CELF-3 = Comprehensive Evaluation of Language Fundamentals—Third Edition; ADD = Auditory Discrimination in Depth; EP = Embedded Phonics; GORT-III = Gray Oral Reading Tests—Third Edition; PHAB/DI = Phonological Analysis and Blending/Direct Instruction; WIIST = Word Identification Strategy Training; ROSS = Reading with Orthographic and Speech Support; DIBELS = Dynamic Indicators of Basic Early Literacy Skills; CWPM = correct words per minute; ISF = Initial Sound Fluency; PSF = Phoneme Segmentation Fluency; NWF = Non-word Fluency; PPVT-III = Peabody Picture Vocabulary Test—Third Edition; EOWPVT-III = Expressive One-Word Vocabulary Test—Third Edition; NCE = normal curve equivalent; LD = learning disabilities; RD = reading difficulty.

* $p < .05$.

(Breznitz & Share, 1992). However, until inferential statistics using experimental research methodologies come into play concerning functional magnetic resonance imaging (fMRI), we must be careful not to overgeneralize correlational-based findings (Goswami, 2008).

As noted, it is now acknowledged that in addition to the linguistic domains that reading relies on (phonology, orthography, and semantics), fluent reading will be achieved by also relying on intact executive functions (Brosnan et al., 2002). A deficit in several domains of executive functions is common in individuals with reading difficulties and, specifically, in those with dyslexia. These challenges included difficulties in attention (Facoetti, Paganoni, Turatto, Marzola, & Mascetti, 2000; Shaywitz & Shaywitz, 2008), inhibition (Brosnan et al., 2002), working memory (Ackerman & Dykman, 1993; Helland & Asbjørnsen, 2004; Swanson & Ashbaker, 2000), shifting (Kraus & Horowitz-Kraus, 2014), and self-monitoring (a deficit in error monitoring in non-linguistic and linguistic domains; Horowitz-Kraus & Breznitz, 2008, 2009). However, although executive-functions training has been shown to improve school readiness (Diamond & Lee, 2011), the number of studies looking at the effect of executive-functions training specifically on reading ability is limited (Franceschini et al., 2013; Horowitz-Kraus & Breznitz, 2009). Breznitz and colleagues (2013) demonstrated that an executive functions–based fluent-reading program that trains reading by forcing the reader to allocate his or her visual attention toward the written material in a speeded manner (i.e., the RAP) had a greater effect on reading fluency and comprehension as compared with the same program without the speeded manipulation. We suggest that a short executive-functions “warm-up” training prior to a reading session may be beneficial for better reading outcomes for children with reading difficulties. However, future research should verify this point with in-depth study.

Interestingly, in addition to the observed improvement in the fluency and multi-component domains, it seems that training with the comprehension-based reading intervention GR also shows an improvement in all reading components. GR is a research-based instructional strategy that has proven to be effective in all sub-domains of literacy. This small-group, homogeneous teaching approach provides students with intentional and intensive literacy support that is differentiated to meet their unique learning needs (Fountas & Pinnell, 2012). Daily GR lessons use a balanced literacy approach and include explicit instruction in fluency, oral language, and vocabulary development; direct instruction in phonemic awareness and phonics; and opportunities to write about reading (Pinnell & Fountas, 2010). We relate this improvement to the fluency domain that is trained using the GR program (Pinnell & Fountas, 1998). Regular formative reading assessments that measure rate and accuracy, both components of reading fluency, are also recommended components of GR (Pinnell & Fountas, 1998). In-depth research into the speed elements involved in GR, compared with the

effect of a fluency-based intervention program (such as the RAP), is warranted and can verify whether the fluency component drives the positive effect of GR or whether it is due to the inclusion of other reading domains as well.

In addition to the improvement of all reading domains following fluency training, our review demonstrates that multi-component reading intervention programs that remediate different combinations of sub-components of reading result in a massive improvement in several domains of reading (see Table 4). Some examples for such programs are reading recovery, multi-components, treatment mastery, word building, Auditory Discrimination in Depth (ADD), and Fast ForWord (FFW). The reason for the positive effect of the multi-component intervention programs is obviously the treatment provided in each of the examined reading domains. However, probably due to this reason, the intervention time ranges from a couple of weeks to several years. These programs may use some of the training time to train non-impaired domains that are part of the program curricula instead of devoting time specifically to the reading domains in which each individual child shows the greatest impairments. As mentioned, the most effective program (Multi-component Tier 2, by O'Connor, Harty, & Fulmer, 2005) lasts about 3 years. This long intervention period should be considered if a limited time is available for intervention or if a short-term intervention is needed. Again, due to our inability to compare standard scores across studies, we cannot compare the effect of the RAP fluency training program with that of the Multi-component Tier 2 program. Although in the clinical arena the use of non-standardized tests for the use of intervention planning and instruction is acceptable, for the purpose of our review, it is challenging to objectively define the effect of interventions between the different studies. A future study should verify this point in depth to examine which program will have a greater effect on all reading domains. Also, educators and parents should pay particular attention to each child's needs, according to the individual's reading and cognitive ability relative to the expected age-matched scores, and invest their time to remediate the specific weaknesses of each child.

The effect of reading intervention administered by computer versus an intervention delivered by a tutor or teacher is yet to be clearly understood. Obviously there are advantages for a personal connection and the established relationship that a teacher has that can affect the child's overall performance. However, when the human interaction is limited, as often is the case in schools with large class sizes, computer programs have some advantages, such as the lack of judgmental feedback, the potential positive effect of working in a group with peers, and the capacity to provide manipulations that may be impossible without using a computer. Other advantages of computer-based instruction programs are the ability to use digitized speech (Foster, Erickson, & Foster, 1994) and the tailored instruction the child receives combined with an individualized feedback, which may increase

motivation (Speziale & La-France, 1992). Mioduser, Tur-Kaspa, and Leitner (2000) showed that a computer-based versus a teacher-based reading instruction for 5-to-6-year-old children at risk of developing reading difficulties resulted in significantly higher scores in phonological awareness, word recognition, and letter-naming skills in children using the computer-based instruction versus their teacher-instructed peers. These results highlight the relative benefit that a computer-based instruction may have on reading acquisition, such as learning the letter-sound relationship using the special auditory/visual characteristics of the computer environment. Future studies to examine the effect of the instruction and the same curricula administered by computer versus a teacher, even in typical developing children, may verify which condition is better than the other. Alternatively, these two types of instruction/intervention modalities could be complementary to one another, a point that should be examined in depth.

Reading intervention is a labor-intensive process. A large number of studies recommend intensive phonological-based intervention programs, even for a couple of years (e.g., Alphabetic Phonics, Orton-Gillingham). Educators, reading specialists, and parents are seeking the most effective, yet efficient, intervention for their student/child to not lengthen the gap in reading achievements. Effective reading intervention, as explained by Nicolson and colleagues (1999) needs to be systematic and comprehensive, which may be costly, but also cost-effective. Despite the desire to achieve an effect as soon as possible, especially due to the overall concern regarding the quality of the American education system and the economic consequences of long interventions (National Commission on Excellence in Education, 1983; Task Force on Education for Economic Growth, 1983), it is important to remember that reading is a developmental, explicitly acquired ability. Each domain in it relies on an intact acquisition of the previous one. Knowing which reading domain should come next may guide the choice to a specific intervention. The Frith (1985) reading acquisition model describes how children transition from stage to stage in a Piaget manner until reading is completely mastered; from contextual to logographic reading, to partial and full decoding, and then to the orthographical stage of automatic word recognition. Interestingly, both the Frith model and the Chall (1983) developmental model describe automatic word recognition, which leads to fluent reading, as the stage at which children master reading and can devote their attention to comprehension (see also LaBerge & Samuels, 1974).

One limitation of the current review is that it describes the results as reported by other researchers, who used different tests to measure the effectiveness of the examined intervention. Hence, we are unable to report the results of a meta-analysis among the different domains. Such meta-analysis would have to take into account the variety of tests that were used to assess reading improvement, most of which are very different from one study to the other, as well as the

differences in training intensity and the involvement of a tutor (or alternatively, a computerized program), and the different ages of the children who trained on the program. However, such meta-analysis has the potential to provide in-depth and quantified information regarding the reading intervention program or programs that affect the most components of reading.

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