Differential effects of reading trainings on reading processes: A comparison in Grade 2

Differenzielle Effekte von Lesetrainings auf Leseprozesse: Ein Vergleich in Klasse 2

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Abstract

Phonics, fluency, and reading strategy trainings are evidence-based interventions that foster the reading skills of poor readers in primary school. The purpose of the present study was to compare differential effects of the three types of trainings on the efficiency of component processes on word, sentence, and text level immediately after the training and at a 3-month follow-up. The 235 poor readers were randomly allocated to one of the reading interventions or to a control condition. All interventions consisted of 25 sessions that were scheduled twice a week and lasted 45 minutes. Results indicated short-term effects of the phonics training and the strategy training on the efficiency of a broad range of word-level and sentence-level processes. None of the treatment effects persisted over the long term, indicating the need for instructional efforts to regularly practice the acquired skills after the actual training.

Keywords: cognitive processes in reading, differential treatment effects, fluency training, phonics instruction, reading strategy training, struggling readers

Phonics-, Leseflüssigkeits- und Lesestrategietrainings sind evidenzbasierte Maßnahmen zur Förderung schwacher Leser(innen) im Grundschulalter. Anliegen der hier vorgestellten Studie war die Gegenüberstellung differenzieller kurzfristiger (unmittelbar nach dem Training) und langfristiger Trainingseffekte (nach drei Monaten) auf die Effizienz kognitiver Teilprozesse des Lesens auf Wort-, Satz- und Textebene. Die teilnehmenden 235 leseschwachen Zweitklässler(inne)n wurden per Zufall einem der drei Lesetrainings oder dem Kontrolltraining zugewiesen. Jedes Training bestand aus 25 Sitzungen die zwei Mal wöchentlich im Umfang von jeweils 45 Minuten durchgeführt wurden. Die Ergebnisse zeigen kurzfristige und breite Effekte des Phonics- und Strategietrainings auf Teilprozesse der Worterkennung und der Integrationsprozesse auf Satzebene. Demgegenüber zeigen sich keine langfristigen Trainingseffekte, was die Notwendigkeit unterstreicht, die Aufrechterhaltung und Einübung der neu gelernten Fähigkeiten auch nach dem Training durch geeignete unterrichtliche Maßnahmen sicherzustellen.

Keywords: differenzielle Trainingseffekte, kognitive Prozesse beim Lesen Leseflüssigkeitstraining, Lesestrategietraining, Phonics-Training, schwache Leser(innen)

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1. Introduction

Teaching students how to read is an important objective of primary education. However, many students experience learning to read as challenging. Individual differences in reading comprehension crystallize soon and the gap between good and poor readers remains stable or even increases during reading development (Pfost et al., 2014). Therefore, it is important to devise reading interventions that effectively help poor readers in primary school to catch up with the reading level of their peers. Psychological and educational research has identified three types of reading intervention that promise to work in primary school (NICHD, 2000): (1) Phonics training that aims at improving word recognition skills through strengthening grapheme-phoneme associations, (2) fluency training that aims at improving word- and sentence-level processes by increasing fluent reading, and (3) reading strategy training that aims at fostering strategic processes to improve the comprehension of coherent texts. Despite the fact that these types of training focus on specific and quite different component processes of reading, previous research evaluating the effectiveness of reading interventions has concentrated mainly on the two gross indicators word recognition skill and text comprehension (e.g., Ehri et al., 2001; Slavin et al., 2009; Suggate, 2014). In contrast, the current research compared the effects of a typical phonics, fluency, and reading strategy training on the efficiency of component processes of reading on the word, the sentence, and the text level. These effects were assessed immediately and then three months after the training with a computerized test battery that allows a detailed assessment of component processes of reading. This perspective can contribute to a better understanding of *why* reading interventions, which are likely to be effective, actually work.

1.1 Reading Comprehension: Cognitive Processes and Individual Differences

From a cognitive perspective, reading comprehension is a multifaceted construct based on individual differences in the mastery of a bunch of cognitive processes. These processes operate on the word level (visual word recognition), on the sentence level (syntactic and semantic integration), and on the text level (establishing coherence between different parts of the text) and will be described next (based on Richter et al., 2012; see also Müller and Richter, 2014).

1.1.1 Word-level processes. The recognition of written words (i.e., assigning the word to an entry in the mental lexicon), is a core requirement in reading. Moreover, in contrast to higher-level comprehension skills, the ability to recognize written words is specific to reading (Gough and Tunmer, 1986; Knoepke et al., 2013). Therefore, it comes as no surprise that accurate and efficient recognition of written words and access to associated lexical information is a prerequisite of good reading comprehension (e.g., see the lexical quality hypothesis, Perfetti and Hart, 2002, or the interactive-compensatory model, Stanovich, 1980). Readers with inefficient, badly routinized visual word recognition processes need to invest cognitive resources that are no longer available for higher-level comprehension processes (Perfetti, 1985). According to dual route models, visual word recognition rests on three different component processes (Coltheart et al., 2001). One of these processes is *phonological recoding* by which readers translate the graphemes of a written word into a phonological representation according to phoneme-grapheme correspondence rules. This phonological representation is then used to recognize the word and retrieve relevant information (e.g., word meanings) from the mental lexicon. Given that phonological recoding is the key to reading acquisition in alphabetical writing systems, deficits in phonological recoding are regarded as one major cause of dyslexia (Vellutino et al., 2004). This indirect route of word recognition through phonological recoding is prevalent in beginning readers (alphabetic strategy, Frith, 1986) but continues to be an important strategy even in skilled readers when encountering infrequent or unfamiliar words.

As readers become more familiar with written words through reading practice, they recognize more and more words directly by means of orthographic word forms stored in their mental lexicon (orthographic decoding). Eventually, the direct (lexical) route of word recognition replaces phonological recoding as the principal way of visual word recognition (Cunningham and Stanovich, 1990; orthographic strategy, Frith, 1986). In skilled readers, the direct route is the default way of recognizing frequent words and those with an irregular spelling (i.e., words that deviate from language-specific grapheme-phoneme correspondence rules; e.g., Andrews, 1982; Paap and Noel, 1991).

When learning to read a transparent orthography such as German with consistent grapheme-phoneme mappings, most readers in Grade 2, which is the age group that the present study focuses on, have already acquired a sight vocabulary that allows them to directly recognize frequent words. However, it is important to note that phonological recoding remains a relevant way of recognizing written words at this stage of reading development, because unfamiliar words cannot be recognized through orthographic decoding. Even if the orthographic word form is represented in the mental lexicon, access to this representation needs to be well-routinized for orthographic decoding to outperform phonological recoding. Thus, phonological recoding remains an important strategy for poor readers in Grade 2 whose orthographic decoding processes are often inefficient (Richter et al., 2012). Empirical evidence for this processing was found in a study of German-speaking children in which individual differences in phonological recoding explained unique variance in reading comprehension skill even when individual differences in orthographic decoding were controlled for. This relationship held for children in Grades 2 till4 (Knoepke et al., 2014).

Another important aspect of reading is that readers need to retrieve semantic information about a word from the mental lexicon, which is the basis of comprehending sentences and texts. Individual differences consist in the quality and amount of knowledge of word meanings (vocabulary, e.g., McKeown et al., 1983) but also in the efficiency of accessing word meanings in the mental lexicon. Deficits in knowledge of word meanings (e.g., Oulette, 2006) and in the efficiency of meaning access (e.g., Nation and Snowling, 1998, 1999) are likely causes of reading comprehension difficulties over and above deficits in phonological recoding or orthographical decoding.

1.1.2 Sentence-level processes. Most cognitive research on individual differences in reading comprehension and dyslexia has focused on lower-level reading skills on the word level (Vellutino et al., 2004). However, it is important to note that deficient sentence- and text-level processes can also be independent sources of reading comprehension difficulties.

On the sentence level, readers need to analyze the grammatical structure of a sentence (syntactic parsing) and to integrate the meaning of individual words into a coherent sentence meaning (semantic integration). The questions whether these two types of processes operate independently (modularity of syntactic processing) or whether they interact during sentence comprehension is a classic debate in psycholinguistics (Pickering and Van Gompel, 2006). Although readers seem to rely on formal syntactic principles (e.g., minimal attachment and late closure, Frazier, 1987), ample evidence has shown that semantic cues can affect the syntactic interpretation of a sentence (e.g., McRae et al., 1998). Moreover, the sentence context can influence word recognition and the access to word meanings (by means of context-based predictions, Pickering and Garrod, 2007). Even though syntactic and semantic integration processes do not operate in modular fashion, individual differences in mastering of syntactic and semantic integration processes can make independent contributions to general reading comprehension. For example, Graesser et al. (1980) showed that the cognitive load imposed by syntactic and semantic complexity is greater in poor compared to good readers. Good readers are also better at suppressing word meanings that do not fit the sentence context (Gernsbacher and Faust, 1991), and they are better at making context-based predictions (Murray and Burke, 2003).

1.1.3 Text-level processes. When reading longer texts, readers also need to establish coherence between sentences, both locally and globally. Skilled readers are able to relate new text information to previously read information and to relevant prior knowledge. They integrate these three types of information to construct a situation model, that is, a mental representation of the state of affairs described in a text (Van Dijk and Kintsch, 1983). A type of cognitive processing essential for text comprehension is the construction of local coherence relations between adjacent sentences. For example, readers need to identify the referents of nominal and pronominal expressions (anaphorical inferences, Garrod and Sanford, 1990). Moreover, they need to establish additive (e.g., temporal) and causal relationships between sentences, which are often not explicit, requiring readers to draw inferences (bridging inferences, Graesser et al., 1994; Singer, 1993). Elementary school children differ in the efficiency of these processes and these individual differences can explain variance in general reading comprehension over and above word level (e.g., Oakhill et al., 2003). It should be noted that deficits in text-level processes such as inferencing are major sources of reading comprehension problems already in 7- and 8-year-old children (Cain and Oakhill, 1999), which is the investigated age group of the present study.

1.2 Evidence-based Reading Interventions in Primary School

According to meta-analytic results (NICHD, 2000; Suggate, 2010, 2014), three widely used approaches - phonics training, reading fluency training, and the training of reading strategies - are generally effective in primary school (see Ise et al., 2012, for supporting evidence of training effectiveness in German-speaking children using these approaches). These approaches differ in the extent to which they focus on improving word-level and comprehension processes on the sentence and the text level.

Phonics training (phonics instruction) is an empirically well-established class of instructional methods that foster accuracy and fluency of word recognition skills (NICHD, 2000). Phonics trainings stress cognitive processes at the word level or below (letters and syllables) to consolidate the alphabetic principle and its use for deciding unknown words. Children are taught to make use of grapheme-phoneme association rules and spelling patterns. Phonics instructions have been shown to foster the accuracy of word reading skills especially at the beginning of reading instruction (Ehri et al., 2001; McArthur et al., 2013; NICHD, 2000; Suggate, 2010, 2014; Torgesen et al., 1999). Poor readers benefit from phonics instruction even beyond Grade 1 if the treatment ameliorates the mental word representations (Faulkner and Levy, 1999; NICHD, 2000). A recent meta-analysis focusing on experimental intervention studies found that a phonics-based training seems to be the only intervention that consistently fosters the development of poor readers (Galuschka et al., 2014). However, in contrast to the results of studies concentrating on gains in lower-level reading skills, the results concerning the effect of phonics training on text-level reading comprehension are mixed (cf. no effects reported by Kuhn and Stahl, 2003; Slavin et al., 2009; Suggate, 2014; Torgesen et al., 1999; and small to moderate positive gains reported by Ehri et al., 2001; McCandliss et al., 2003; Torgesen et al., 2001).

Fluency training is a second way to foster word recognition skills (NICHD, 2000). By focusing on the ability to read accurate, fast, and with expression, fluency training may be regarded as bridging lower- and higher-order reading processes (Kuhn and Stahl, 2003). The most commonly used training method that fosters fluent reading is *repeated reading*, developed by Samuels (1979) and based on LaBerge and Samuels' (1974) automaticity theory. The theory emphasizes that only when the reading processes at the word level are routinized cognitive capacities for higher-order reading processes at the sentence and text level become available. In repeated reading, children read short meaningful sections of a text repeatedly while being assisted by an adult. Several variants of this method have been developed (e.g., paired reading, Fuchs et al., 2000; Topping, 1995; or reading while listening, Le Fevre et al., 2003). The overall effects of fluency instructions on word recognition and text comprehension are empirically well established by meta-analytic results (e.g., Kuhn and Stahl, 2003; NICHD, 2000; Therrien, 2004). However, these findings are based on studies with samples from a wide range of grade levels (Grades 1-12). Suggate (2014) concluded that for primary school children fluency trainings improve word recognition but not reading comprehension. Furthermore, a study by Huemer et al. (2008) with a German-speaking sample of poor readers in Grades 2 and 4 revealed that the treatment effect of reading fluency was correlated with the students' rapid naming speed, an indirect measure of the accessibility of phonological representations. The faster the naming skills before the intervention the higher was the gain in fluent word reading after six weeks of treatment.

The basic idea of *reading strategy trainings* is to improve reading comprehension directly by fostering the self-regulated meaning-making from texts. Such trainings involve the teaching and extensive practice of cognitive and metacognitive strategies, such as generating questions (e.g., McMaster et al., 2012; Rosenshine et al., 1996) and inferences (e.g., Oakhill, 1993) to integrate the text information to a locally and globally coherent representation (Graesser et al., 1994), summarizing text content (e.g., Dole et al., 1991), and activating prior knowledge to connect and enrich the information of the text for constructing a mental model of the text (e.g., Cain and Oakhill, 1999). The overall effectiveness of teaching reading strategies systematically to foster reading comprehension in several grades is well established by meta-analytic results (e.g., Edmonds et al., 2009; NICHD, 2000; Slavin et al., 2009). Some studies suggest effects on also word recognition (e.g., Suggate, 2010, 2014). In many of the successful reading strategies trainings strategy instruction is combined with peer-learning techniques, for example, in the well-known evidence-based examples of *reciprocal teaching* (Palincsar and Brown, 1984) and the *peer-assisted learning strategies* (PALS, Fuchs et al., 1997). Both techniques have been shown to be superior to regular reading instruction for gains in reading comprehension in Grades 3 and 4. The effects of teaching strategies are mixed for children below Grade 3 (e.g., for positive results, see Brown et al., 1996; Fuchs and Fuchs, 2007; Van Keer and Verhaeghe, 2005; Yuill and Oakhill, 1988; for null results, see Klicpera et al., 2005; for a meta-analysis yielding mixed results, see Rosenshine and Meister, 1994).

1.3 The Current Study

The studies discussed in the previous section provide ample evidence that phonics, fluency, and reading strategy trainings can all be effective in fostering poor readers in elementary school, although the relative strength of each training seem to depend on grade level. As summarized by Suggate (2010) phonics instructions and fluency trainings are more effective in Grade 1 and 2, after which reading strategy trainings reached higher effect sizes on reading scores. Treatment effects are usually evaluated using word recognition or reading comprehension measures at the text level. Explicit measures at the sentence level, however, are rare. Consequently, little is known about differential effects of the three types of trainings on reading processes on word, sentence, and text level, although these effects are strongly suggested by the theory behind the trainings. The primary aim of the current study was to examine such differential effects by using a battery of process-oriented tests (ProDi-L, Richter et al., 2012). These tests assess the efficiency of component processes of reading at the word level (phonological recoding, orthographic decoding, meaning access), the sentence level (semantic/syntactic integration), and the text level (establishing local coherence) with reaction time-based measures. A second aim of the present study was to explore whether the effects of the three types of reading trainings persist after the reading intervention has ended. Evidently, this inquiry is highly relevant for implementing reading trainings in educational practice. To determine such long-term effects in addition to short-term effects, which have been the focus of most previous training experiments (cf. Suggate, 2014), we repeated the assessment of component processes of reading with the ProDi-L tests three months after the final training session.

The theory behind the three types of training suggests straightforward hypotheses concerning differential effects. The *phonics training* is designed to systematically strengthen grapheme-phoneme associations. Consequently, it may be expected to make phonological recoding processes more efficient. However, the efficiency of other component processes might also have beneficial effects on word-level processing, such as orthographic decoding and meaning access. The *fluency training* should strengthen the efficiency of word-level processes through reading practice but also syntactic and semantic integration at the sentence level when it succeeds in training prosodic features that help readers to structure the sentence into meaningful and functional units (Kuhn and Stahl, 2003). Finally, the *reading strategy* *training* should improve primarily the efficiency of higher-level comprehension processes on the sentence level and the text level (e.g., McMaster et al., 2012). However, considering previous studies that have found effects on visual word recognition (Suggate, 2014), such (presumably indirect) effects are also likely to occur in the present study. Results concerning long-term effects of the three trainings are mixed. Thus, we make no predictions as to whether the hypothesized effects occur in the short term only or persist over three months.

All three trainings were implemented in a peer-tutored learning setting with poor readers acting as tutees and good readers acting as tutors. Peer learning is a common used instructional technique in reading instruction. Peer tutoring is a structured learning process based on dyads of peers with fixed interaction rules. Most often, the higher-skilled student is the tutor who acts as a model for their lower-skilled tutee in each dyad (Topping, 2006). The effectiveness of peer tutoring in primary school has been demonstrated for the acquisition of knowledge in various academic domains (d = .26, meta-analysis of 26 studies, Rohrbeck et al., 2003).

2. Method

2.1 Design and Procedure

The study was based on an experimental pre-/post-test design with a follow-up three months after the final training session. The children were randomly allocated at the class level to one of the treatment groups or the control condition. All interventions were implemented in a peer-tutored learning setting (i.e., dyads consisting of poor readers acting as tutees and good readers acting as tutors).

Students were first screened with a standardized German-speaking reading comprehension test (ELFE 1-6, Lenhard and Schneider, 2006). We ranked the results of all participating children per class and selected the five children with the best reading comprehension scores above the class average as tutors and the five children with the lowest reading comprehension scores below the class average as tutees. When the number of children with a permission to participate was not sufficient to select 10 children, we ranked the children of two classes together and based the assignments to the group of tutors or tutees on these rankings. The average z-standardized ELFE reading scores of the classes varied between -0.85 and 0.61 (M = -0.11, SD = 0.27). For the selected children, the accuracy and efficiency of component processes of reading were tested with the German-speaking instrument ProDi-L (Richter et al., 2012). General intellectual ability was assessed with subtests of CFT 1 (Cattell et al., 1997).

The groups of 10 children (5 poor and 5 good readers) were randomly allocated to one of the three treatment conditions or the control group. All treatments consisted of 25 sessions, each lasting 45 minutes. The training sessions occurred in addition to regular school curriculum twice a week. The children’s reading processes were assessed again after the final training session with ProDi-L. To investigate long-term effects of the treatments, the ProDi-L assessment was repeated 3 months after the last intervention session. In this article, we only focus on the data of the poor readers (tutees) for whom the interventions were designed.

2.1 Participants

The participating tutees (poor readers) were 235 children from 52 primary school classes in Giessen and Kassel (Germany). Treatment group allocation (random assignment) comprised 56 children in the phonics instruction, 45 poor readers in the fluency training, and 74 children in the reading strategy training, and the remaining 60 were assigned to the control group. The proportion of boys and girls was nearly equal (see Table 1). The data analyzed in the current study were obtained from a longitudinal study investigating the effects of reading interventions in several grades in primary school. The allocation to the treatment condition was balanced on grade level leading to the different sample sizes, and no significant differences were found between the children in the treatment conditions and the control group in intelligence scores (F (3, 215) = 1.10, *ns*, Table 1).

- TABLE 1 ABOUT HERE -

2.2 Assessment of Component Processes of Reading

The reliability and efficiency of the reading processes at the word, sentence, and text level were assessed with the computerized reading skills test ProDi-L (Richter et al., 2012). ProDi-L consists of six subtests with well-defined reading tasks that specifically require component processes on the word level (phonological recoding, orthographic decoding, access to word meanings) and on the sentence and text level (syntactic integration, semantic integration, establishing local coherence). Each subtest has a dichotomous response format (yes/no). Accuracy and latency of responses (provided with two response keys) are recorded to capture the reliability and efficiency of each component. Latency scores were computed as the mean reaction times of the logarithmically transformed response times of all items when at least three items per scale had valid responses. All six latency scores reached good internal consistencies (Cronbach's α = .74 - .96, see Table 2). Accuracy scores were computed as the proportion of correct responses per subtest when at least three items per scale had valid responses. The internal consistency of the accuracy scores were low but with the exception of orthographical decoding, meaning, and syntactic integration acceptable (α = .60 - .72, Table 2). Parallel versions of each subtest were constructed for the three measurement points.

(1) *Phonological recoding* skills were measured with a phonological comparison task based on 16 pairs of pseudowords (one to four open syllables) in each of the three test versions. The first pseudoword in each pair was presented auditorily and the second one visually. The children's task was to decide whether the written pseudoword matched the spoken pseudoword (e.g., *tebedika-tebudiki*). (2) A lexical decision task with 16 items was used to assess *orthographical decoding* skills. The children were required to decide whether a string of letters was a real word or a pseudoword. The 16 items, half of which were real words and the other half (orthographically and phonologically legal) pseudowords, varied systematically in length, frequency, and number of orthographical neighbors. (3) A categorization task with 10 items was used to measure *access to word meanings*. In each item, a category name was presented auditorily (e.g., *Obst / fruit*), followed by a written target word after a delay of 200ms (e.g.*, Banana / banana*). The children were asked to decide whether the target word matched the superordinate category. (4) *Syntactic integration* skills were measured with a grammatical judgment task with 20 items (sentences). Children

were asked to decide for individual sentences whether they were grammatically well-formed or not. Half of the sentences were morpho-syntactically correct, the other half were not (e.g., *Lisa hat einen Brief schrieb. / Lisa has wrote a letter.*). (5) A sentence verification task with 16 items (sentences) was used to assess *semantic integration* skills. Children were required to judge whether each of 16 statements expressed a true or false statement about the world. Half of the items contained a true statement and the other half a false one (e.g., *Treppen sind ein rotes Gemüse. / Stairs are red vegetables.*). (6) The children's *local coherence* processes were measured with the help of a text verification task. Children read either two consecutive coherent or incoherent sentences, and decided whether the two sentences were connected. The task contained 24 two-sentence texts (12 coherent, 12 incoherent, e.g.*, Katrin muss ins Krankenhaus. Sie ist nämlich ganz gesund. / Katrin needs to go to the hospital. She is healthy.*).

- TABLE 2 ABOUT HERE -

2.3 Reading Interventions and Control Training

Student assistants (prospective teachers or psychology undergraduates) conducted the 25 sessions of each training. They provided standardized spoken instructions to tutors and tutees. Tutors were expected to support their tutees in reading the material and implement the instructions using standardized feedback rules. The materials and manuals for all treatments were designed by the authors and tested in a pilot study (Müller et al., 2013).

2.3.1 Phonics Training. The phonics training was based on five exercises dealing with different syllables, consonant clusters, diphthongs, or affixes to foster word recognition processes by improving grapheme-phoneme associations. Exercises consisted of reading aloud blocks of syllables and short words (with a maximum length of four syllables), analyzing the syllabic structure of words and finding the consonants in words, and combining consonants used as affixes with various suffixes. Afterwards, cards with single words were presented which children were required to read aloud as fast as they could. All exercises consisted of reading aloud single words precisely and fast. Integration and coherence processes at the sentence and text level were not the focus of the training. In sum, the phonics training guided children to practice visual word recognition processes.

2.3.2 Fluency Training. The fluency training aimed at improving reading speed and accuracy. A repeated reading method was used to read two books (Topping, 2006), that is, the student assistant read the chapter aloud together with tutors and tutees. Subsequently, the chapter was repeated in the dyads: Tutors and tutees read the beginning of the chapter together until the tutees signaled that they were ready to read alone. While the tutees read, tutors followed silently and alerted tutees of any mistakes according to standardized feedback rules (i.e., by saying "stop", giving the tutee the chance to correct the mistake, and assisting the tutee when necessary). After correcting the mistake, the tutees resumed reading at the beginning of the sentence where the mistake occurred. The chapter was repeated in the dyads until the fluency rate increased and the reading mistakes decreased. Later, reading with expression was included while repeating the chapter. Hence, as in the phonics training, the efficiency of word recognition processes was in focus of the fluency training. In contrast to the phonics training, words were read in the context of sentences and not as single words.

2.3.3 Reading Strategy Training. The reading strategy training conveyed knowledge about three strategies to foster reading comprehension at the text level: (1) thinking about the headline to activate prior knowledge about vocabulary and the previous events taking place in the book and to anticipate what might happen in the chapter, (2) reading phrase-by-phrase and rehearsing the content of each sentence to keep the decoded information of each sentence available for further processing, and (3) summarizing the chapter to encourage the construction of a globally coherent representation of the text. Similar to previous implementations of strategy trainings (e.g., Gold et al., 2004) the training was embedded in a detective story. Children practiced the strategies with the same text book as in the fluency treatment. However, no special attention was paid on the accuracy of reading.

2.3.4 Control Training. Children in the control condition received a training of the visuospatial working memory. Labyrinths and abstract forms were used to teach four strategies to memorize and recall spatial arrangements. All instructions were given orally by the student assistants. We did not expect any beneficial effect of this training on the reading skills of the participants, because the visuospatial working memory is not of central importance for reading comprehension (with the exception of comprehending spatial descriptions, Baddeley, 1986).

3. Results

3.1 Data Analysis

To examine short-term and long-term treatment effects of the three reading interventions on the efficiency of the children's reading processes, we used moderated regression analyses (Aiken and West, 1991; Hayes and Matthes, 2009). We ran separate analyses for latency scores and accuracy scores of the reading processes at word, sentence, and text level as dependent variables. In addition, we considered measures at the post-test for assessing short-term treatment effects and measures at the follow-up for assessing long-term treatment effects. We computed indicator variables ($I_{X=x}$) for the treatment conditions with the control group as reference (control: x = 0, phonics: x = 1, fluency: x = 2, and strategy: x = 3). All indicator variables were entered simultaneously into the analyses. The children's corresponding pre-test accuracy score was entered as a continuous covariate in the models with accuracy as the dependent variable. Likewise, the corresponding pre-test latency score was entered as a covariate in the models with latency as the dependent variable. The interaction terms of the treatments' indicators with the pre-test score were also included.

For example, consider the latency of phonological recoding at the post-test as dependent variable (Y) and the corresponding latency of phonological recoding at the pre-test as covariate (Z). The equation for the moderated regression can be written using intercept and effect functions (Mayer et al., 2014; Steyer and Partchev, 2008) as follows:

$$E(Y|X,Z) = g_0(Z) + g_1(Z)\, I_{X=1} + g_2(Z)\, I_{X=2} + g_3(Z)\, I_{X=3} \quad (1)$$

$$g_0(Z) = \gamma_{00} + \gamma_{01}\, Z \quad (2)$$

$$g_1(Z) = \gamma_{10} + \gamma_{11}\, Z \quad (3)$$

$$g_2(Z) = \gamma_{20} + \gamma_{21}\, Z \quad (4)$$

$$g_3(Z) = \gamma_{30} + \gamma_{31}\, Z \quad (5).$$

Inserting Equations 2 to 5 for the intercept and effect functions in Equation 1 gives the full equation for the moderated regression model. The values of the effect functions are the conditional treatment effects of the phonics training (g_1-function), the fluency training (g_2-function), and the strategy training (g_3-function) on the post-test phonological recoding. For example, inserting the value 8 of the covariate Z in the effect function g_1 will provide the effect of the phonics treatment compared to the control group for a child with pre-test value 8. The average effect is defined as the unconditional expectation of an effect function, for example, for the phonics training: $AE_{10} = E[g_1(Z)] = \gamma_{10} + \gamma_{11} E(Z)$. The average effect refers to the effect of the phonics training on a child with average skills (average pre-test scores) and can be estimated by inserting estimates for the γ-coefficients and the expectation of the pre-test. The definition of the average effects of the fluency and the strategy training is analogous. Similar results for average effects could be obtained using traditional centering methods in ordinary least squares regression (cf. Aiken and West, 1991; Hayes and Matthes, 2009). However, mean centering ignores uncertainty in estimating sample means and can therefore lead to biased standard errors.

The parameters of the moderated regression model were estimated simultaneously based on a multi-group structural equation model with the R package lavaan (Rosseel, 2012). The input syntax for lavaan was generated with EffectLiteR (Mayer et al., submitted). Full information maximum likelihood estimation was used to account for missing values. The treatment effects were computed based on estimates of model parameters and the expectation of the pre-test. Standard errors were obtained by the delta method (e.g., Raykov and Marcoulides, 2004).

3.2 Effects of the three Treatment Conditions

In this section we report short- and long-term average effects of all three treatments on latency and accuracy scores at word, sentence, and text level. Significance tests were based on a type I error probability of .05. The effect sizes were computed as the difference between the adjusted means divided by the standard deviation of the outcome variable of the control group.

The results on the latency scores of the ProDi-L subtests are shown in Table 3. Smaller values (i.e., faster response times) indicate more efficient cognitive processes. Hence, if a treatment effect carries a negative sign, the reading intervention is effective in the sense that it caused faster response times compared to the control group. Figures 1 and 2 illustrate the adjusted means for the latency scores per treatment condition at post-test and follow-up graphically.

- TABLE 3, FIGURE 1 AND FIGURE 2 ABOUT HERE –

The short- and long-term average treatment effects on accuracies of the reading processes are summarized in Table 4. Note that greater accuracy values represent more accurate responses. Thus, if a treatment effect carries a positive sign, children who had received the reading intervention gave more accurate responses than children in the control condition.

- TABLE 4 ABOUT HERE -

3.2.1 Results of the Phonics Training. The phonics training exerted a number of short-term effects on the ProDi-L latency scores. As expected, there was a small to medium effect on orthographical decoding (Estimate = -0.11, $p < .05$, ES = -0.36). In addition, the analyses revealed a medium effect on syntactic integration (Est. = -0.27, $p < .05$, ES = -0.49), a small to medium effect on establishing local coherence (Est. = -0.30, $p < .05$, ES = -0.38), and a trend of an effect on semantic integration (Est. = -0.23, $p = .07$, ES = -0.33). However, the effects of the phonics training were not significant at the 3-month follow-up test. In sum, there was evidence for short-term effects of the phonics training on the efficiency of a broad range of reading processes but not for long-term effects.

The analysis of accuracy revealed a positive short-term effect on phonological recoding (Est. = 0.08, $p < .05$, ES = 0.49), but no effects were found at sentence or text level. We found a negative long-term effect on meaning access (Est. = -0.08, $p < .05$, ES = -0.48), indicating that children in the phonics training reached lower accuracy scores in their access to word meaning than the controls.

3.2.2 Effects of the Fluency Training. No significant effects on the latency scores were found for fluency training at post-test or follow-up. However, the training had a medium long-term effect on the accuracy of orthographical decoding (Est. = 0.06, $p < .05$, ES = 0.51). Against our expectation, there were no systematic effects on the latency or accuracy of children reading processes at word and sentence level.

3.2.3 Results of the Strategy Training. The strategy training affected the latencies at word and sentence level. A strong effect on orthographical decoding (Est. = -0.20, $p < .05$, ES = -0.65), a small to medium effect on meaning access (Est. = -0.14, $p < .05$, ES = -0.35), and medium effects on syntactic integration (Est. = -0.30, $p < .01$, ES = -0.53) and semantic integration (Est. = -0.29, $p < .05$, ES = -0.42) were obtained. Unexpectedly, the effect on establishing local coherence was not significant. There were no significant effects on the accuracy scores. In sum, similar to the phonics training, we found evidence for short-term effects of the strategy training on the efficiency of a broad range of cognitive processes at word and sentence level but none of the effects remained at the follow-up.

3.3 Summary of Effects

In sum, we observed only short-term effects of the phonics and the strategy training on latencies, but the effects did not persist over the long term. Against our expectations, the treatment effects were not restricted to specific reading processes. Both treatments ameliorated the efficiency of the children’s orthographic decoding and integration processes. Children in the phonics training showed faster local coherence processes at the post-test, whereas children in the strategy group increased their access to word meaning. However, the effects on the latencies did not match the results on the accuracy scores. Children in the phonics and strategy group gave the correct answer faster, but their overall accuracy did not increase on the same reading processes.

One general concern with using latency data as an indicator of performance or even ability (i.e., the efficiency of cognitive processes involved in reading as in the present study) is that a higher response speed may also be the result of a less accurate response process (speed-accuracy trade-off, Pachella, 1974). Could a speed-accuracy trade-off account for the short-term effects of the phonics and the strategy training on the latency scores? The fact that the faster responses in these two groups were not accompanied by less accurate responses militates against this interpretation. To further test the possibility of a speed-accuracy trade-off, we repeated the analyses for the latency data using the children's accuracy at the post-test as an additional predictor. Essentially, accuracy as an additional predictor did not change the pattern of effects. Only the treatment effect of phonics on establishing local coherence and the effect of strategy on meaning access were no longer significant.

4. Discussion

The aim of the present study was the analysis of differential treatment effects of phonics, fluency, and reading strategy interventions for poor readers in Grade 2 in the short and the long term. Each of the three reading interventions provided exercises for fostering specific reading processes. The phonics training focused on exercises with single syllables and words, the fluency training focused on accurate and fluent reading of short texts, and the strategy training focused on extensive practice of three cognitive reading strategies at the sentence and text level. The effects of the three interventions were compared to the results of a visuospatial working memory training that served as a control condition.

The findings indicate that the phonics training and the strategy training both improved component processes of reading. Unexpectedly, however, the treatment effects were not restricted to the specific cognitive processes targeted by the two interventions. Consistent with our predictions, the *phonics training* increased the efficiency of orthographic decoding component process at the word level. It also improved the accuracy (but not the efficiency) of phonological recoding processes. However, the phonics training also increased the efficiency of component processes at the sentence and even the text level. The *strategy training*, in contrast, not only increased the efficiency of sentence-level processes (syntactic and semantic integration) but also the efficiency of two word-level processes (orthographic decoding and meaning access) with medium to strong effect sizes. Thus, despite the fact that the phonics and strategy training were effective in the short term, we cannot conclude that their effects were specific to the focused processes of the two training approaches. Instead, both types of training resulted in rather broad effects on a range of component processes of reading.

One interpretation of the unexpectedly broad effects of the *phonics training* is that sentence-level and text-level processes benefitted from the increased efficiency of orthographic decoding and the enhanced accuracy of phonological recoding. According to Perfetti and Hart (2002), high-quality word representations are a crucial precondition for good reading comprehension (lexical quality hypothesis). Reliable and easily accessible representations allow readers to allocate cognitive resources (working memory capacity) to higher-order comprehension processes at the sentence and the text level (Perfetti, 1985). The short-term effect of the phonics training on the integration processes and the local coherence is in line with this argumentation.

The broad short-term effect of the reading *strategy training* might also be explained as a mixture of direct and indirect effects. The cognitive strategies taught in the training seem to have direct effects on sentence-level processes (albeit unexpectedly not on text-level processes). However, the exercises designed to practice these strategies always involved the focused and concentrated reading of texts. This might have created a learning opportunity that also allowed practicing visual word recognition even though word recognition was not the focus of the training. The effect of the strategy training on orthographic decoding was even stronger than that of the phonics training. Maybe word recognition practice is more motivating with meaningful texts than with single words. However, we can present no data to support this interpretation.

Generally speaking, the broad effects of the phonics training and the strategy training point to the observation that the component processes of reading on word, sentence, and text level develop in close association and strongly interact with each other in Grade 2. Against the background of this general assumption, reasoning that phonics training improves text-level processes (by releasing cognitive resources that can be used for comprehending the text rather than recognizing words) and that strategy training can also improve word recognition through decoding practice makes sense.

The phonics and the strategy training exerted effects mainly on the efficiency of reading processes (with the exception of the effect of the phonics training on the accuracy of phonological recoding). This pattern of findings is likely to be due to characteristics of the ProDi-L tests that assess efficiency rather than accuracy (Richter et al., 2012). Related to this point, the so-called reading fluency impairment of poor German-speaking readers in primary school might also add to the discussion. Several studies (e.g., Frith et al., 1998; Wimmer et al., 1998) showed that poor readers read unfamiliar words and even pseudowords as accurate as their same-age peers with average reading abilities. However, they read these stimuli much more slowly, indicating that the routinization of basic reading processes was impaired. Thus, inefficient word recognition processes in transparent orthographies seem to be a more severe problem than inaccurate reading processes. From this perspective, it is to be expected and even desirable that reading trainings for poor readers improve the efficiency of basic reading processes first. However, it might be interesting to investigate in further studies the level of accuracy necessary to make improvements in efficiency. Juul et al. (2014) reported that the speed of word recognition of children in Grade 1 and 2 mainly develops after a child reaches an accuracy level of 70%. In our study, establishing local coherence was the most difficult subtest in terms of accuracy compared to the other subtests. Maybe the lack of effects on efficiency of processes establishing local coherence can be explained by an overall insufficient level of accuracy of such processes.

In contrast to the phonics and the strategy training, the *fluency training* lacked systematic effects on the efficiency or accuracy of children's reading processes. The absence of any positive effects of the fluency training is surprising. For example, we found in an earlier study an effect of a similarly structured fluency training on the development of poor readers' reading fluency after only 20 treatment sessions (Müller et al., 2013). One possibility is that the poor readers in Grade 2 who participated in the present study were overtaxed by the fluency training because of the lack of relevant cognitive prerequisites. As Huemer et al. (2008) suggested, it might be fruitful to train phonological recoding before beginning with the actual fluency training. Furthermore, the meta-analytic results of the National Reading Panel (NICHD, 2000, Chapter 3) suggest that fluency treatment might be more effective for average than for poor readers. It might be advisable for further studies to take a closer look at aptitude-treatment interactions of children's component skills of reading and the effects of fluency interventions.

Finally, it is noteworthy that none of the trainings exerted long-term effects on the efficiency of the reading processes. These results are in line with the findings of a published meta-analysis by Suggate (2014) investigating long-term effects of phonics, fluency, and reading strategy trainings from pre-school up to Grade 6. Grade level was a significant moderating variable. Although all three trainings reached the highest short-term effects for poor readers in Grades 1 and 2, long-term effects for struggling readers were only significant from Grade 3 onward. Poor readers in Grade 2 probably need more time to transfer the techniques and strategies learned within the treatments to their daily reading routines. As Zimmermann (2002) suggested in his theory of self-regulated learning, learners need to be prompted repeatedly to use newly learned strategies before these strategies eventually become routinized.

To conclude, the present study provides evidence for positive effects of phonics and reading strategy trainings (but not fluency training) on the efficiency of reading processes in Grade 2. These effects were surprisingly broad, that is, they were not restricted to the specific processes that were in the focus of the two reading interventions. However, they were also short-lived, given that none of the effects found immediately after the training were still present at the follow-up three months later. These findings have implications for practitioners. Phonics training and a rather simple version of a reading strategy training are both promising methods to foster poor reader’s reading skills on a broad basis. However, practitioners should be aware that the effects of such trainings vanish quickly if no instructional measures are taken after the training to prompt students to apply the newly learned strategies.

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Tables

Table 1

Demographic Characteristics of the Sample

	Total sample	Phonics group	Fluency group	Strategy group	Control group
N	235	56	45	74	60
Number of females	124	28	21	42	33
Number of non-German native speakers[a]	46	9	13	15	9
Intelligence *M* (*SD*) (standardized *T*-values)	51.11 (8.25)	52.24 (8.25)	51.38 (8.20)	49.68 (8.37)	51.64 (8.13)

Note. Intelligence = subtests Classification, Similarities, and Matrices of CFT 1 (age norms).
[a] For 59 children the first language information was missing.

Table 2

Reliability Estimates (Cronbach's α) of the ProDi-L Subtests

	Latency	Accuracy
Phonological recoding	0.80	0.60
Orthographical decoding	0.89	0.41
Meaning access	0.74	0.37
Syntactic integration	0.94	0.50
Semantic integration	0.94	0.72
Establishing local coherence	0.96	0.70

Note. The reliability was computed with the pre-test measures.

Table 3

Estimates for Short- and Long-term Average Treatment Effects on Latency Scores for Reading Processes at Word, Sentence, and Text Level.

	Word level								
	Phonological recoding			Orthographical decoding			Meaning access		
	Est.	*p*	*ES*	Est.	*P*	*ES*	Est.	*p*	*ES*
Post-test									
Phonics	0.06	.28	0.19	**-0.11**	**.05**	**-0.36**	-0.06	.40	-0.16
Fluency	0.09	.16	0.27	-0.03	.65	-0.09	-0.06	.45	-0.15
Strategy	-0.03	.56	-0.10	**-0.20**	**< .01**	**-0.65**	**-0.14**	**.05**	**-0.35**
Follow-up									
Phonics	-0.09	.13	-0.30	-0.12	.14	-0.29	-0.08	.23	-0.21
Fluency	0.01	.94	0.02	0.01	.87	0.03	-0.02	.81	-0.05
Strategy	-0.02	.75	-0.06	-0.10	.19	-0.25	0.03	.71	0.06

	Sentence level						Text level		
	Syntactic integration			Semantic integration			Local coherence		
	Est.	*p*	*ES*	Est.	*P*	*ES*	Est.	*p*	*ES*
Post-test									
Phonics	**-0.27**	**.01**	**-0.49**	-0.23	.07	-0.33	**-0.30**	**.03**	**-0.38**
Fluency	0.02	.88	0.03	-0.07	.63	-0.10	-0.09	.56	-0.11
Strategy	**-0.30**	**< .01**	**-0.53**	**-0.29**	**.02**	**-0.42**	-0.14	.28	-0.18
Follow-up									
Phonics	-0.12	.38	-0.18	0.14	.44	0.15	-0.18	.31	-0.18
Fluency	0.08	.58	0.12	0.19	.31	0.21	0.04	.84	0.04
Strategy	-0.03	.81	-0.05	0.20	.22	0.23	0.05	.77	0.05

Note. Significant effects are highlighted in bold. Post-test = short-term effect after the treatment. Follow-up = long-term effect three months after the treatment. All treatments were dummy-coded with the control group as reference. Est. = Estimate of average treatment effect. *p* = two-tailed p-value. *ES* = effect size for average treatment effect (difference of adjusted means/standard deviation of the control group).

Table 4

Estimates for Short- and Long-term Average Treatment Effects on Accuracy Scores for Reading Processes at Word, Sentence, and Text Level.

	Word level								
	Phonological recoding			Orthographical decoding			Meaning access		
	Est.	*p*	*ES*	Est.	*p*	*ES*	Est.	*p*	*ES*
Post-test									
Phonics	**0.08**	**< .01**	**0.49**	-0.01	.75	-0.06	-0.03	.42	-0.15
Fluency	0.06	.07	0.35	0.00	.94	-0.01	-0.04	.28	-0.22
Strategy	0.03	.21	0.20	0.00	.85	0.03	-0.06	.07	-0.32
Follow-up									
Phonics	0.02	.40	0.16	0.02	.55	0.12	**-0.08**	**.01**	**-0.48**
Fluency	0.05	.11	0.33	**0.06**	**.01**	**0.51**	0.01	.82	0.05
Strategy	0.04	.19	0.24	0.04	.10	0.31	-0.01	.64	-0.09

	Sentence level						Text level		
	Syntactic integration			Semantic integration			Local coherence		
	Est.	*p*	*ES*	Est.	*p*	*ES*	Est.	*p*	*ES*
Post-test									
Phonics	-0.02	.47	-0.13	-0.04	.10	-0.30	-0.02	.55	-0.11
Fluency	0.02	.60	0.10	-0.03	.29	-0.21	-0.02	.60	-0.10
Strategy	0.01	.81	0.04	-0.04	.12	-0.27	-0.04	.12	-0.27
Follow-up									
Phonics	0.00	.99	0.00	0.01	.88	0.03	0.01	.68	0.08
Fluency	0.02	.62	0.11	0.02	.53	0.13	0.04	.15	0.30
Strategy	0.00	.95	-0.01	0.01	.66	0.08	0.02	.33	0.18

Note. Significant effects are highlighted in bold. Post-test = short-term effect after the treatment. Follow-up = long-term effect three months after the treatment. All treatments were dummy-coded with the control group as reference. Est. = Estimate of average treatment effect. *p* = two-tailed p-value. *ES* = effect size for average treatment effect (difference of adjusted means/standard deviation of the control group).

Figures

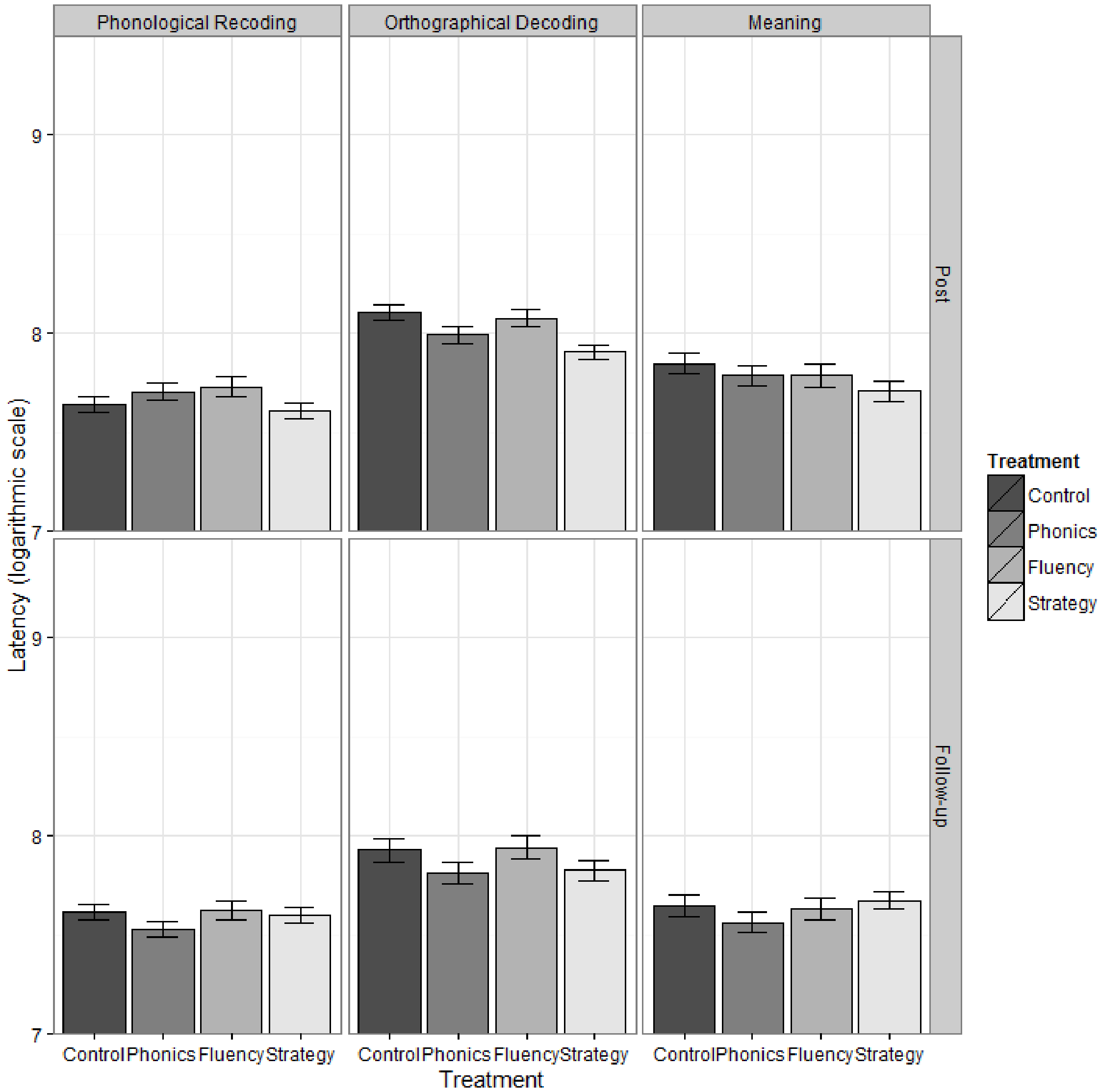

Figure 1 Adjusted means for the latency scores at the word level per treatment condition at post-test and follow-up. Smaller values (i.e., faster reaction times) represent a more efficient reading process.

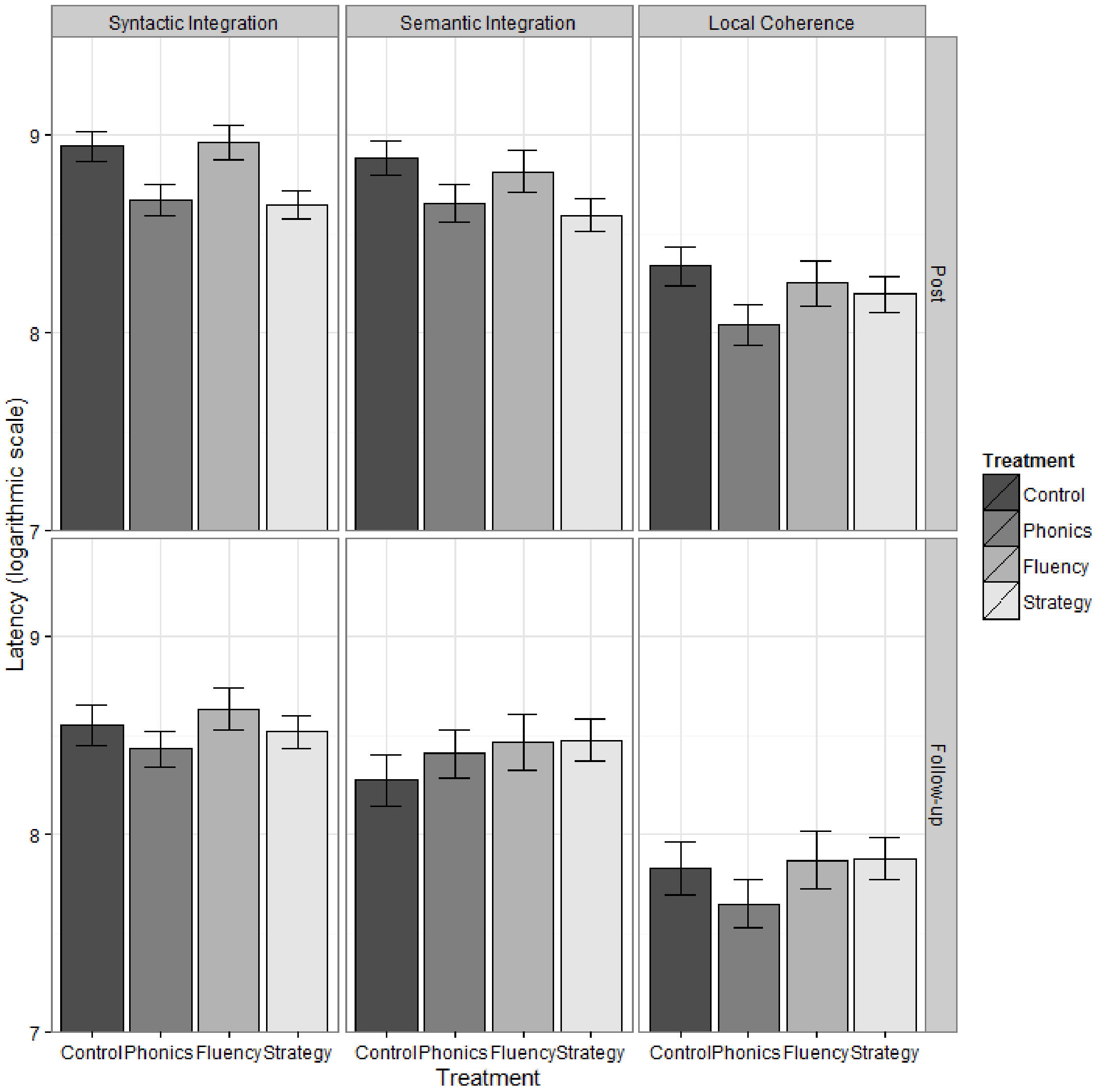

Figure 2 Adjusted means for the latency scores at the sentence and the text level, per treatment condition at post-test and follow-up. Smaller values (i.e., faster reaction times) represent a more efficient reading process.