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Profiles of French poor readers: Underlying difficulties and effects of computerized training programs

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ABSTRACT

Three subgroups of poor readers were identified within a sample of French 2nd Graders ($n = 258$): children with Specific Decoding Difficulty (SDD), children with Specific Comprehension Difficulty (SCD) and children with General Reading Difficulty (GRD). We first compared them on skills related to either decoding or comprehension (or to both reading skills). This analysis showed that although specific underlying difficulties characterized each subgroup (e.g., phonological and decoding difficulties for SDD and vocabulary and monitoring difficulties for SCD), all subgroups showed impaired performance on certain skills (e.g., memory). Second, each subgroup received a computerized training to promote the component of reading for which they initially presented the greatest difficulty (decoding or comprehension). While the decoding training tended to induce more specific improvements in word reading and phonology, the effects of the comprehension training tended instead to be more general. These results are discussed in terms of their pedagogical implications.

1. Introduction

Reading is a critical skill for success in school, because most of the knowledge transmitted in formal education is based on written material. The ability to read well is also strongly predictive of economic well-being as well as of personal and social development (Snow, 2002). The standardized Program for International Student Assessment (PISA) conducted by the OECD (Organization for Economic Cooperation and Development) reveals "about 20% of students in OECD countries, on average, do not attain the baseline level of proficiency in reading. This proportion has remained stable since 2009" (OECD, 2016, p. 4). Similarly, Fluss et al.'s (2008) study, conducted among 1062 French pupils, revealed that approximately 13% of 1st and 2nd Graders had word reading difficulties (i.e. decoding scores below the 10th percentile and reading speed one standard deviation below the norm). Continuity of reading disabilities has been shown in longitudinal studies in different orthographies (in English: e.g. Parrila, Aunola, Leskinen, Nurmi, & Kirby, 2005, Finnish: Eklund, Torppa, Aro, Leppänen, & Lyytinen, 2015 and German: Landerl & Wimmer, 2008). This high percentage of poor readers in the early stages of reading acquisition, and the number of such readers that persist at the end of compulsory education, clearly emphasizes the importance of the early detection of poor readers as a prerequisite for the implementation of suitable reading interventions. Nevertheless, not all poor readers are the same. Consequently, it is necessary to determine the deficits that could underlie different types of reading difficulties in order to offer specific remediation.

1.1. Different profiles of poor readers

Not all poor readers present the same types of reading difficulties. According to the *Simple View of Reading* model (Gough & Tunmer, 1986, see also more recently Kendeou, Van Den Broek, Helder, & Karlsson, 2014), reading can be considered as the product of two components: Written word decoding and language comprehension. The first component is specific to the activity of reading and implies either the identification of written words via a direct association from visual input to lexical representation or the use of grapheme-phoneme correspondence to decode the word. The second component - comprehension - however, is seen as a general ability, i.e., not specific to the written format. Similar comprehension processes are indeed likely to be employed to understand not only written but also oral or pictorial information (see, for example, Berl et al., 2010; Gernsbacher, Varner, & Faust, 1990; Kendeou, Bohn, White, & van den Broek, 2008).

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In order to extract meaning from a text - which generally represents the aim of the reading process - a reader should be able both to decode written words quickly and precisely, on the one hand, and to have adequate comprehension skills on the other. These two components are generally considered to be highly interrelated. As a result, reading appears to be deficient if either of these two components is impaired. According to the verbal efficiency hypothesis (Perfetti, 1992), decoding and comprehension share a fixed amount of cognitive resources. Thus, the more resources are devoted to decoding, the less there are available for comprehension. As decoding processes become increasingly automated, resources are released for comprehension (e.g., Roberts, Good, & Corcoran, 2005).

However, the two processes are also partially independent. Difficulties in reading can indeed be specifically related to one or other of these reading components (Catts, Compton, Tomblin, & Bridges, 2012), thus resulting in three profiles of poor readers (Aaron, 1991; Catts, Hogan, & Fey, 2003; Elwér, Keenan, Olson, Byrne, & Samuelsson, 2013). Hence, a “poor” reader can have a) difficulties in word reading but good comprehension skills (i.e., *poor decoder*), b) difficulties in comprehension but good word reading skills (i.e., *poor comprehender*) or c) difficulties in both components (i.e., *general poor reader*). Developmental and genetic studies (Harlaar et al., 2010; Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006) further support the hypothesis that decoding and comprehension skills are dissociated and follow independent development trajectories.

1.2. Cognitive and linguistic skills associated with the two reading components

On the one hand, learning to read in an alphabetic system (e.g. French) requires the understanding of the alphabetic principle, namely that written units (graphemes) represent phonological units (phonemes). Emerging readers further need to understand that spoken words are composed of phonological units. They have to be able to identify and consciously manipulate them (for a review, see Castles & Coltheart, 2004; Melby-Lervåg, Lyster, & Hulme, 2012; Ziegler et al., 2010). In other words, they have to acquire phonological skills. On the other hand, different factors predict success in reading and listening comprehension (Hulme & Snowling, 2011; Oakhill, Cain, & Bryant, 2003). These comprehension-related factors relate to vocabulary (Lonigan, Burgess, & Anthony, 2000; Oakhill & Cain, 2011; Oakhill et al., 2003; Vellutino, Tunmer, Jaccard, & Chen, 2007), comprehension monitoring (i.e., the ability to evaluate one's own comprehension of a text; Cain, 1999; Oakhill, Hartt, & Samols, 2005) and working memory (Carretti, Cornoldi, De Beni, & Romanò, 2005; Florit, Roch, Altoè, & Levorato, 2009; Swanson, Howard, & Saez, 2006).

Each of the aforementioned subgroups (poor decoders, poor comprehenders and general poor readers) is therefore likely to exhibit particular and specific underlying difficulties. In a longitudinal follow-up study from preschool to Grade 4, Elwér et al. (2013) analyzed the cognitive and linguistic predictors of decoding and comprehension in specific poor decoders and specific poor listening comprehenders. They observed that poor decoders had lower performances in phonological awareness, whereas poor listening comprehenders had lower performances in vocabulary and verbal memory. These results are consistent with the literature (e.g., De Jong & Van der Leij, 1999; Lynch et al., 2008; Oakhill & Cain, 2011; Potocki, Ecalle, & Magnan, 2016; Wagner, Torgesen, & Rashotte, 1994; Wimmer, Mayringer, & Landerl, 2000), which suggests that these factors are important predictors of decoding and comprehension, respectively.

In addition, Catts et al.'s (2003) data suggest that the identified subgroups of poor readers are relatively stable over time, meaning that reading difficulties are not likely to decrease spontaneously. These observations (Aaron, 1991; Catts et al., 2003; Elwér et al., 2013) highlight the need to provide training that specifically remediates each subgroup's underlying difficulties.

1.3. Reading interventions

Several intervention programs have been shown to provide effective support for struggling readers. As regards the decoding component, training aimed at fostering phonemic awareness generally leads to improvements in decoding skills (see the meta-analysis by Suggate, 2010). More precisely, training combining the presentation of phonological information with visual-orthographic information is likely to be the most beneficial for poor decoders. In French, the syllable appears to be an important phonological unit in French pre-readers (see Duncan, Seymour, Colé, & Magnan, 2006). This is also an important orthographic unit in French readers (Doignon-Camus & Zagar, 2014). Various studies using different experimental paradigms (e.g. Chetail & Mathey, 2009; Colé, Magnan, & Grainger, 1999; Doignon & Zagar, 2006; Maïonchi-Pino, De Cara, Ecalle, & Magnan, 2012a; Maïonchi-Pino, De Cara, Ecalle, & Magnan, 2012b; Maïonchi-Pino, Magnan, & Ecalle, 2010a, 2010b) confirm this idea. As a result, grapho-syllabic training in French poor readers has been shown to improve written word identification (Ecalle, Kleinsz, & Magnan, 2013; Ecalle, Magnan, & Calmus, 2009). To be fully effective, programs designed to encourage decoding abilities have a) to focus on phonological skills and grapho-phonological correspondences, b) to take place individually or in small groups, and c) to be explicit, repetitive and provide positive feedback (see the meta-analysis by Suggate, 2010). In French readers, these programs should be based on the syllabic unit since this appears to be a functional unit in word recognition.

As far as comprehension is concerned, numerous studies have demonstrated that comprehension skills can also be improved through explicit training (for reviews, see Edmonds et al., 2009; Gersten, Fuchs, Williams, & Baker, 2001; Solis et al., 2012). The National Reading Panel (2000) identifies six different strategies for enhancing comprehension skills (e.g., identifying the structure of a text, answering questions about the text). The training of inferential skills appears to be the most beneficial for remediating comprehension difficulties (e.g., Elbro & Buch-Iversen, 2013; Potocki, Ecalle, & Magnan, 2013a). The ability to generate inferences is indeed a critical component of good text comprehension and poor comprehenders generally exhibit difficulties in this skill (Cain & Oakhill, 2006; Oakhill & Cain, 2011). Different types of inference can be drawn when attempting to understand a text (Cain & Oakhill, 1999). Some of them (text-connecting inferences) are necessary in order to connect successive textual statements, while others (knowledge-based inferences) make use of the reader's background knowledge in order to fill in the gaps that can occur in the story. Comprehension programs that could foster these different aspects of text comprehension, and especially inferencing skills, are likely to be particularly suitable for helping poor comprehenders to overcome their difficulties (see, for example, Potocki et al., 2013a; Yuill & Joscelyne, 1988; Yuill & Oakhill, 1988).

1.4. Use of computer assisted reading programs

One way to implement reading interventions is to make use of computer-assisted (CA) programs. CA programs have indeed proved their worth as components in educational programs for children. The various advantages CA programs provide over traditional learning include greater motivation (e.g. Wild, 2009) and a higher level of attention (e.g. Karemaker, Pitchford, & O'Malley, 2010). This is probably due to their multimedia approach. However, the presentation of too much multi-modal information can be distracting and seems to be unnecessary since the greatest benefits are achieved by simply combining the oral and visual modalities (Ricci & Beal, 2002). This observation is of particular interest for CA reading programs. Indeed, the bimodal (e.g. oral and visual) presentation of a word can increase word recognition by improving the mapping between orthographic and phonological word representations (e.g., Ecalle et al., 2009; Ehri et al., 2001; Karemaker et al., 2010). This bimodal presentation is also of interest for the training of reading and listening comprehension as it makes it possible to train comprehension skills even in beginning readers or poor decoders (Potocki, Ecalle, & Magnan, 2015; Potocki et al., 2013a).

CA programs also present other beneficial features, such as the possibility to provide immediate feedback (e.g. Blok, Oostdam, Otter, & Overmaat, 2002). Feedback from the computer also seems to be perceived as less emotionally charged than feedback from the classroom teacher (Wild, 2009), leading to more positive attitudes towards reading. In a longitudinal study designed to investigate this assumption in 12 children aged from 3 to 6 years, Levy (2009) concluded that beginning readers do indeed handle print on computer screens with a high degree of confidence. Thus, there is a body of evidence suggesting that CA programs may lead to better results than traditional learning, especially when it comes to remediating reading difficulties (e.g. Ecalle et al., 2009; Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011). A number of recent reviews, meta-analyses and syntheses confirm this idea, even if the reported overall positive effect is sometimes small (e.g. Cheung & Slavin, 2012, 2013; Slavin, Lake, Davis, & Madden, 2011; see Archer et al., 2014 for explanatory hypotheses of modest CA effectiveness). The present study will make use of CA programs to foster decoding and comprehension skills in different profiles of poor readers. To date, however, intervention studies focusing on the decoding and comprehension components of reading have been conducted in divergent ways. One of the aims of the present study was therefore to investigate the effects of two types of reading training administered in parallel to different subgroups of poor readers.

1.5. Objectives of the study and hypotheses

The present experiment had two main objectives. After identifying different subgroups of poor readers (i.e. specific poor decoders,[1] specific poor comprehenders and general poor readers) among a sample of French 2nd Graders, we examined each subgroup's underlying difficulties in different linguistic and cognitive skills. We thought that children with decoding difficulties would be likely to exhibit difficulties in tasks involving phonological processing and decoding fluency, while children with poor comprehension would be more likely to present difficulties in working memory, vocabulary and monitoring. Children with general reading difficulties should be likely to show impaired performance in all of these tasks. Second, each subgroup of poor readers received a computerized training targeting the component of reading on which they initially presented the greatest difficulty (written word recognition or comprehension). Specific poor decoders were therefore trained with a CA program fostering decoding skills via the training of grapho-syllabic correspondences (labeled GST for Grapho-Syllabic Training; Ecalle et al., 2013), while specific poor comprehenders received CA training promoting both literal and inferential comprehension processes (labeled CoT for Comprehension Training; Potocki, Ecalle, & Magnan, 2013b; 2015a). Both of these programs were implemented for the children with general reading difficulties (random assignment of half of the children with general reading difficulties to one of these two training programs) in order to test which type of training would be the most beneficial for them. We hypothesized that decoding, decoding-related measures and possibly also reading comprehension (although only indirectly via the automation of decoding skills), but not listening comprehension, would improve in the children trained on grapho-syllabic correspondences (SDD and half of the GRD group). In contrast, we expected children trained in text comprehension (SCD and half of the GRD group) to make progress in both listening and reading comprehension, as well as in comprehension-related measures, but not in decoding. In other words, we expected specific improvements to occur in response to the GST and the CoT, i.e. two approaches that have already proven their effectiveness in French struggling readers (Ecalle et al., 2013; Potocki et al., 2013b; 2015a).

2. Method

2.1. Participants

The initial population consisted of 258 children in 2nd Grade who were attending 7 primary schools that agreed to participate in the study. Half of the schools were located in an urban area, the other half in rural areas. Both types of schools served mixed catchment areas. Parental consent was obtained prior to the testing sessions. Consents from local educational authorities were also obtained before starting the experiments. All the children agreed to participate in the study and its activities. They were informed that they could stop the experiment whenever they wanted to. They had typical or corrected vision and hearing skills, were normally developing children and had no specific problems. Children who had repeated at least one school year were excluded in order to remove children with major difficulties (/possible comorbidity) from the sample. From this initial population, the poorest readers were selected (n = 76) based on an analysis of their z scores.

2.1.1. Participants in the first part of the study (i.e. examination of difficulties)

We calculated z scores for each child's written word recognition and listening comprehension performance. Children with a z score below the selection criterion (− 1.35 as in Ramus et al., 2003) in written word recognition and/or listening comprehension were selected as the poorest readers. More specifically, we found 73 children with a z score below the cut-off in written word recognition and 63 children with a z score below the cut-off in listening comprehension. Among these samples, n = 35 had z scores below the cut-off in both tasks and these participants constituted the GRD group. The SDD group therefore consisted of n = 38 (= 73–35) and the SCD group of n = 28 (= 63–35). After excluding children who had repeated one or more school years, we obtained n = 76 poor readers in 3 subgroups: 25 children with a profile of poor word reading but adequate comprehension (*specific decoding difficulty* or SDD), 19 children with a profile of poor comprehension but adequate word reading (*specific comprehension difficulty* or SCD) and 32 children with a profile of poor word reading and comprehension (*general reading difficulty* or GRD).

2.1.2. Participants in the second part of the study (i.e. implementation of the training program)

Among these 76 poor readers, 44 took part in all training sessions of the intervention program. This loss of children was due to the fact that two classes could not participate in the entire program throughout the full five weeks of training. In addition, children who missed at least one training session were removed from the analyses of the training data. The different subgroups of children were allocated to one of the two intervention programs as a function of their pattern of reading difficulties in the pre-test measures. As a result, 12 participants with SDD were trained with a program called *Chassymo*, designed to improve decoding by means of a grapho-syllabic approach (labeled GST for *Grapho-Syllabic Training*), and 11 participants with SCD were trained with a program called *LoCoTex* designed to improve comprehension skills (labeled CoT for *Comprehension Training*; see section ‘Computerized training programs’ for a description of the two programs). Of the children with *general reading difficulties* (GRD), half (n = 9) were trained with the GST program, while the other half (n = 12) received the CoT training.

Fig. 1 shows the number of participants in the different groups in the different parts of this study.

[1] The term “poor decoder” is used here and throughout the text, tables and figures as an abbreviation for readers with specific difficulties in a written word recognition task (see ‘Material’-section for detailed description).

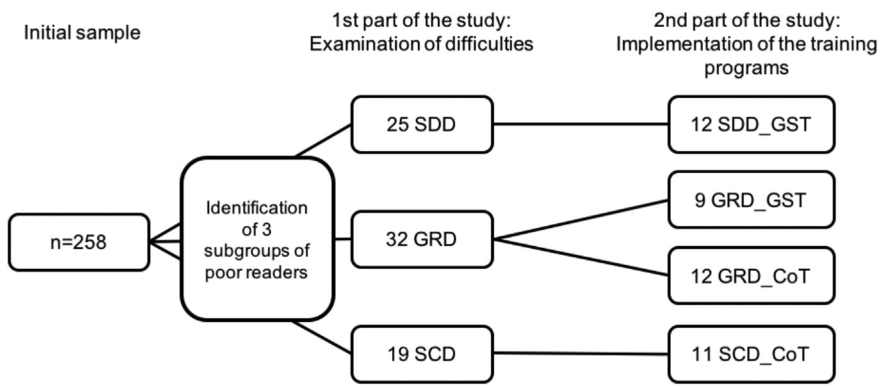

Fig. 1. Numbers of participants in first (i.e. examination of difficulties) and second (i.e. implementation of the training program) parts of the study.

2.2. *Material*

2.2.1. *Word reading and comprehension measures*

As testing took place during school time, the battery of skills tested here (and thus the time children spent away from the classroom) was limited to the principal reading-related skills for each reading component.

2.2.1.1. Written word recognition. We used a standardized test of word reading (Timé2; Ecalle, 2003) consisting of 3 tasks. In each, the children had to identify written target words corresponding to 1) a word presented orally by the experimenter, 2) a picture and 3) a semantically associated written word. They had to choose the correct response from a list of 5 items consisting of the orthographically correct word and 4 pseudo-words. The dependent variable was the total number of correct responses (max = 36; α = 0.94).

2.2.1.2. Listening comprehension. Listening comprehension was assessed using a short narrative text (Potocki, Bouchafa, Magnan, & Ecalle, 2014). This contained 110 words whose frequency was controlled for (Lété, Sprenger-Charolles, & Colé, 2004). All the words were items frequently encountered by French primary school children. The experimenter read the text aloud and then asked 12 multiple-choice questions: Four questions referred to the explicit information in the text, four questions required the generation of coherence inferences and four questions required the production of knowledge-based inferences. For each question, three possible responses were presented: the correct response and two distractors. One distractor was a word picked from the text and another distractor was a plausible answer which was not, however, present in the text. The children were informed that only one response was correct. The dependent variable was the total number of correct responses (max = 12; α = 0.61). For the post-test, a new text (93 words) following the same procedure (three types of multiple choice questions) and also taken from Potocki et al. (2014) was administered to the children (α = 0.73).

2.2.1.3. Reading comprehension. Reading comprehension was assessed using the same material as for the listening comprehension task (Potocki et al., 2014). In these tasks, the children had to read the texts silently to themselves and then answer the 12 multiple-choice questions by circling the response they thought correct. No specific time was allocated to perform the task. The dependent variable was the total number of correct responses (max = 12; α = 0.63).

2.2.2. *Measures used to examine each subgroup's underlying difficulties*

All 76 poor readers with one of the 3 established profiles completed a set of tests in order to examine skills related to decoding (decoding, phonological skills, decoding fluency), skills related to listening and reading comprehension (vocabulary and comprehension monitoring, working memory) and a background-measure (non-verbal reasoning).

2.2.2.1. Decoding. The children had to read aloud 10 pseudo-words from a standardized French reading test (ODéDys; Jacquier-Roux, Valdois, & Zorman, 2005). The dependent variable was the number of successfully read items (max = 10; α = 0.71).

2.2.2.2. Phonological skills. We used a sub-test from a standardized French test of phonological skills (THaPHo; Ecalle, 2007). The children had to extract the common phonological unit (6 syllables and 6 phonemes) from orally presented pairs of words. The dependent variable was the number of correctly extracted units (max = 12; α = 0.71).

2.2.2.3. Decoding fluency. To assess the fluency with which the children could read 10 pseudo-words aloud, we calculated a speed-accuracy index (SAI)[2] that takes account of the response speed of correct responses. This index illustrates the degree of automatization of the decoding process. The higher the SAI, the more accurate and fluent reading is.

2.2.2.4. Vocabulary. We used 20 items from the Peabody Picture Vocabulary Test-Revised (Dunn, Theriault-Whalen, & Dunn, 1993), which evaluates receptive vocabulary and has been adapted for use with French-speaking children. The children had to correctly identify a named picture from four possible black-and-white drawings. We chose 10 items corresponding to the children's mean age, 5 to the age above and 5 to the age below. The total number of correct answers constituted the total raw score (max = 20; α = 0.84).

2.2.2.5. Comprehension monitoring. We used a task designed by Cain and Oakhill (2006) and adapted it for French-speaking children. In this task, the children had to detect inconsistencies in seven short narratives read aloud by the experimenter. Four texts contained inconsistencies (i.e., contradictory statements; e.g., "There was a cat named Bob. Its fur was completely black and very soft. It had big green eyes and long whiskers. All the cats in the neighborhood wanted to have its white fur") and three did not. Two scores were calculated: One to assess the children's ability to correctly identify consistent and inconsistent stories (max = 7), and another for the correct identification of the inconsistent statements in the text (max = 4). The sum of these two scores constituted the dependent variable (max = 11; α = 0.67).

2.2.2.6. Working memory. An updating task was used to assess working memory (Potocki et al., 2013b). The children had to observe a series of pictures presented on a computer screen and to recall the second to last (n-2) picture seen. They were informed that the trials would be of varying lengths, with the result that they needed to use updating processes in which the item maintained in memory changed continuously. This task consisted of 5 trials. Each trial contained from

[2] SAI = (1 / (time processing / success rate) ∗ 1000)

5 to 7 pictures. The dependent variable was the total raw score and corresponded to the number of target pictures correctly identified (max = 5; α = 0.66).

2.2.2.7. Non-verbal reasoning. Non-verbal reasoning was assessed using a task taken from the ECS (Evaluation des Compétences Scolaires [Assessment of school skills]; Khomsi, 1997). This test is similar to the well-known Raven Progressive Matrix. Children had to identify the missing part of a drawing by applying logical reasoning to non-verbal material. The dependent variable was the number of correct responses (max = 12; α = 0.73).

2.2.3. Computerized training programs

2.2.3.1. Grapho-syllabic training (GST). The program (*Chassymo*; Ecalle et al., 2013) encourages grapho-syllabic word processing (and is therefore labeled 'grapho-syllabic training' or GST). The children first heard a syllable, then saw the syllable and finally heard a word. They had to indicate the position in the word (initial, median, final) at which the seen and heard syllable occurred. They then received a corrective feedback. The program consisted of 600 words. Half of the items were bi-syllabic words and the other half were tri-syllabic words. The linguistic properties of the words used in *Chassymo* were carefully controlled (for a detailed description of the program, see Ecalle et al., 2013). This program proved its efficiency in remediating first graders' difficulties in word identification (Ecalle et al., 2013).

2.2.3.2. Comprehension training (CoT). This program (*LoCoTex*; Potocki et al., 2013b) promotes two aspects of text comprehension (and is therefore labeled 'comprehension training' or CoT): Literal and inferential comprehension skills (for a more detailed description of the program, see Potocki et al., 2013b). It consists of 36 texts (both orally and visually presented) and three different modules. In the first module, which is designed to encourage literal comprehension skills, the children had to answer five questions referring to the information that was explicitly stated in the text. In the second module, they had to match each anaphoric substitute in the text with its correct referent. This module is thought to foster text-connecting inferences. Finally, the third module is designed to foster knowledge-based inferential skills. In this module, the children first had to answer an inferential question (e.g., "Where does this scene take place?") and then to click on the "clue words" in the text permitting them to correctly answer the question (see Yuill & Joscelyne, 1988). In all the modules, corrective feedback was provided to the children. This program has proved its efficiency in a population of specific poor comprehenders in second Grade (see Potocki et al., 2013b).

2.3. Procedure

2.3.1. Identification of 3 subgroups of poor readers

First of all, we performed measures to examine 258 all-comers from 2nd Grade in order to identify the poor readers in the population and assign them to one of the three subgroups. While written word recognition (Ecalle, 2003) and reading comprehension (Potocki et al., 2014) were assessed in a collective classroom session, listening comprehension (Potocki et al., 2014) was individually tested in a quiet place next to the classroom, after the collective session. Reading comprehension was always assessed prior to listening comprehension. These skills were assessed both in the pre-test (i.e. February of the school year) and in the post-test (i.e. in April, immediately after the training).

A period of at least three weeks was respected between the administration of the two comprehension tasks to avoid a too important memory effect of the text (see Lecocq, Casalis, Leuwers, & Watteau, 1996).

2.3.2. Examination of difficulties

The 76 identified poor readers were then assessed on different decoding-related and comprehension-related measure as well as on a background-measure. The experimenters (i.e. first and second author) individually administered the test battery to each child in a quiet room next to the classroom. Each individual testing session lasted 30 min. The order in which these tests were administered was randomized. These skills were assessed both in the pre-test and in the post-test, which took place during the weeks immediately before and after the training, that is to say in February and April of the school year.

2.3.3. Implementation of the training programs

The 44 poor readers who completed all the training sessions were trained for 30 min a day, 4 days a week, over a period of 5 weeks (March–April of the school year), resulting in a total of 10 h of CA training. Training took place in the schools' computer rooms, where each child was equipped with headphones and worked in complete autonomy in front of a computer screen. Training modules were administered by the first and second author; they supervised training and helped the children in the event of technical problems with the computer or the program. A classical training paradigm was used following the usual pre-test/training/post-test design. The specific effects of the different training types were examined for three different skills of interest: Written word recognition, listening comprehension and reading comprehension (see 'Material' above). These skills were assessed both in the pre-test and in the post-test, that took place during the week immediately after the 5 weeks of training, that is to say in February and April of the school year.

3. Results

This section includes three sub-sections. First, an analysis of the underlying difficulties of each subgroup of poor readers is presented. The means of the three groups on the different measures (i.e. word reading and comprehension measures, measures related to decoding and measures related to comprehension) are compared with each other and with the mean of a normative group. A correlation matrix between the word reading and comprehension measures has also been computed. Second, the effects of training programs on word reading and comprehension measures (i.e. written word recognition, listening and reading comprehension) were analyzed. Third, the training effect on measures related to decoding and comprehension was analyzed.

3.1. Underlying difficulties of each subgroup of poor readers

Descriptive statistics for the three subgroups of poor readers on all collected measures, performances of a normative group as well as results of post-hoc comparisons between subgroups are presented in Table 1. The normality assumption was satisfied for the measures.

A series of one-way ANOVAs was conducted on the word reading and comprehension measures as well as on the measures related to decoding and those related to comprehension in order to examine the differences between the three subgroups of poor readers in these tasks. In order to investigate each profile's underlying difficulties, the means of each group were compared with the mean of a normative group.

We observed an expected Subgroup effect in written word reading, $F(2, 73) = 54.67$; $p < 0.0001$. Post-hoc analyses between subgroups revealed that the SCD children outperformed the SDD and GRD children in this task. SDD children ($t(24) = 13.86$; $p < 0.0001$) and GRD children ($t(31) = 13.52$, $p < 0.0001$) had scores below the norm while the difference with the normative group was not significant for SCD. Similarly, we observed a significant Subgroup effect in listening comprehension, $F(2, 73) = 84.02$; $p < 0.0001$, with the SDD group outperforming the SCD and GRD groups. SCD ($t(18) = 24.86$; $p < 0.0001$) and GRD ($t(31) = 20.68$, $p < 0.0001$) achieving performances below the norm, while the difference with the normative

Table 1
Means (SD) of the 3 subgroups of poor readers ($N = 76$) on the different measures, means of a normative group and results of post-hoc comparisons between subgroups.

	Measure	Normative group $n = 174$	SDD $n = 25$	SCD $n = 19$	GRD $n = 32$	p	Comparison between subgroups
Word reading and comprehension measures	Written word recognition /36	28.9° (3.6)	20.7* (2.2)	28.8 (2.2)	20.2* (3.6)	.000	SCD > SDD, GRD
	Listening comprehension /12	9.4° (1.7)	9.1 (1.4)	6.3* (0.5)	6.2* (0.9)	.000	SDD > SCD, GRD
	Reading comprehension /12	9.8° (2.3)	7.4* (1.5)	6.3* (1.3)	6.2* (2.2)	*ns*	–
Measures related to decoding	Decoding /10	7.7° (1.7)	7.0 (2.0)	8.3 (1.9)	7.0* (1.6)	.002	SCD > SDD, GRD
	Phonological skills /12	10.3° (2.3)	7.4* (3.0)	7.1* (3.9)	7.0* (3.4)	*ns*	–
	Decoding fluency	0.5 (0.3)	0.4* (0.2)	0.7* (0.3)	0.5 (0.3)	.05	SCD > SDD, GRD
Measures related to comprehension	Vocabulary /20	17.1° (2.9)	16.9 (2.0)	15.7* (2.8)	15.1* (3.7)	.05	SDD > SCD, GRD
	Comprehension monitoring /11	6.2 (2.6)	6.9 (2.5)	5.5* (2.6)	6.1 (2.7)	.05	SDD > SCD, GRD
	Working memory /5	2.5 (1.5)	1.9 (1.4)	1.5* (1.2)	1.7* (1.1)	*ns*	–
Background measures	Non–verbal reasoning /12	7.5° (2.4)	3.4* (2.4)	4.2* (2.5)	4.2* (2.5)	*ns*	–
	Gender ratio (boys: girls)	–	7:12	12:13	14:18		–
	Age (months)	–	90.3 (3.4)	93.0 (4.9)	92.3 (5.4)	*ns*	–

*$p < 0.05$: significant difference from the mean of the normative group.

group was not significant for SDD. The three groups did not differ in reading comprehension ($F < 1$); all three groups achieved performances below the norm (SDD: $t(24) = 7.82$; $p < 0.0001$; SCD: $t(18) = 10.99$, $p < 0.0001$; and GRD: $t(31) = 9.39$, $p < 0.0001$).

Concerning the measures related to decoding, the results revealed a significant Subgroup effect in decoding, $F(2, 72) = 6.61$; $p = 0.002$, and in decoding fluency, $F(2, 72) = 4.98$; $p < 0.05$ with the SDD and GRD having lower scores than the SCD. In decoding, only the GRD children scored significantly below the norm ($t(31) = 2.32$, $p < 0.05$), while the differences with the normative group for the SCD and SDD was not significant. In decoding fluency, the SDD children's scores were significantly below those of the normative group ($t(24) = 2.19$, $p < 0.05$), whereas the scores of the SCD children were significantly above the norm in decoding fluency ($t(18) = 2.37$, $p < 0.05$). However, we did not observe a significant Subgroup effect in phonological awareness ($F < 1$), meaning that the three groups did not differ in this task. However, they all scored significantly below the norm ($t(18) = 3.58$, $p < 0.01$ for SCD; $t(24) = 4.79$, $p < 0.001$ for SCD; and $t(31) = 5.58$, $p < 0.001$ for GRD).

With regard to the measures related to comprehension, the analyses revealed a significant Subgroup effect in vocabulary, $F(2, 72) = 5.59$; $p < 0.05$, and in comprehension monitoring, $F(2, 72) = 3.06$; $p < 0.05$ with the SCD and GRD children having lower scores than the SDD children. In vocabulary, the SCD and GRD children also exhibited scores below the norm ($t(18) = 2.2$, $p = 0.04$ and $t(31) = 3.05$, $p < 0.01$ respectively). In comprehension monitoring, only the SCD children scored below the norm ($t(18) = 15.14$, $p < 0.001$). The mean of the SDD children in these two tasks did not differ significantly from the norm. The analyses did not reveal any significant difference between subgroups in terms of working memory ($F < 1$). For this task, both the SCD and GRD children achieved scores below the norm ($t(18) = 3.62$, $p < 0.01$ and $t(31) = 3.86$, $p < 0.001$ respectively), while the difference with the norm in the SDD children was marginal only ($t(24) = 2.05$, $p = 0.051$).

Finally, we did not observe any significant Subgroup effect in the background-measure 'non-verbal reasoning' ($F < 1$) meaning that there was no difference between the three groups. However, all three groups scored significantly below the norm on this task ($t(18) = 3.59$, $p < 0.01$ for the SCD; $t(24) = 5.05$, $p < 0.001$; and $t(31) = 4.06$, $p < 0.001$).

Furthermore, a matrix of correlations between the word reading and comprehension measures has been computed and the results are presented in Table 2.

3.2. Training effects on word reading and comprehension measures

Given the small sample sizes, a series of Wilcoxon signed-rank tests for matched samples were computed for each of the dependent variables of interest (written word recognition, listening and reading comprehension) and for each subgroup. To account for children's comprehension abilities in the post-test, analyses were performed on two texts (one was similar to the text presented at the pre-test and one was completely new; see Sections 2.2.1.2 and 2.2.1.3). In each analysis, we examined the Training effect by contrasting scores before (pre-test measures or t0) and after the training (post-test measures or t1). We also compared the scores of each subgroup of poor readers before and after the training with the norm for the tests obtained from 174 children of the same chronological age using one-sample Wilcoxon signed-rank tests.

3.2.1. Grapho-syllabic training

The data resulting from an analysis of the measures of the two

Table 2
Matrix of correlations for the word reading and comprehension measures.

	Measures		GST				CoT				
			SDD *n = 12*		GRD *n = 9*		SCD *n = 11*			GRD *n = 12*	
			t0	t1	t0	t1	t0	t1	t1	t0	t1
Word reading and comprehension measures	Written word recognition /36		20.7 (2.2)	24.4* (3.5)	21.2 (1.7)	23.9* (4.3)	22.3 (2.9)	25.8* (3.3)	28.2 (4.3)	22.3 (2.9)	25.8* (3.3)
	Listening comprehension /12	text 1	9.1 (1.4)	9.8 (1.5)	6.6 (2.3)	8.4 (2.1)	6.5 (1.2)	8.3* (2.1)	8* (1.2)	6.5 (1.2)	8.3* (2.1)
		text 2		9.3 (2.6)		9.7 (1.9)		8.7* (1.7)	10* (1.7)		8.7* (1.7)
	Reading comprehension /12	text 1	7.4 (1.5)	8 (2.5)	6.9 (3.4)	7 (2.2)	6.4 (1.4)	6.9* (1.4)	8.2* (1.2)	6.4 (1.4)	6.9* (1.4)
		text 2		8.2 (2.5)		7.4 (3.2)		8.3 (1.6)	9.5* (1.5)		8.3 (1.6)
Measures related to decoding	Decoding /10		7.3 (2.1)	8.1 (1.3)	6.3 (1.9)	7.9 (2)	6.8 (1.1)	7.8* (1.3)	9.3 (1)	6.8 (1.1)	7.8* (1.3)
	Phonological skills /12		7 (2.3)	9.1* (2.3)	6.3 (3.7)	9.3* (3.1)	7.8 (3.5)	7.8 (2.7)	9.4 (2.6)	7.8 (3.5)	7.8 (2.7)
	Decoding fluency		0.5 (0.2)	0.6* (0.2)	0.4 (0.3)	0.5 (0.2)	0.5 (0.3)	0.7 (0.5)	1.2* (0.4)	0.5 (0.3)	0.7 (0.5)
Measures related to comprehension	Vocabulary /20		16.6 (1.6)	17.3* (1.6)	14.5 (2.6)	15.1 (4.1)	14.7 (4.2)	16.4* (2.6)	16.6* (2.7)	14.7 (4.2)	16.4* (2.6)
	Comprehension monitoring /11		6.2 (2.2)	8.1* (2.5)	7.4 (3.2)	7.9 (2.6)	6.3 (2.7)	7.7 (2.8)	7.7* (1.7)	6.3 (2.7)	7.7 (2.8)

*$p < 0.05$.

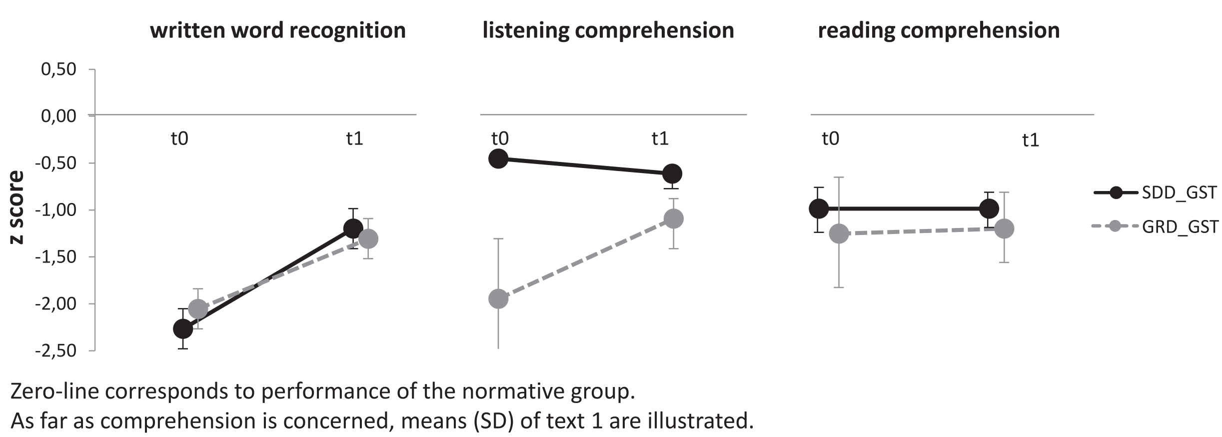

Fig. 2. Mean scores in pre-test (t0) and post-test (t1) for both groups with decoding difficulty (SDD and GRD) that received the Grapho-Syllabic-Training (GST), in written word reading, listening comprehension and reading comprehension.

groups of poor decoders (SDD and GRD) who received the grapho-syllabic training (GST) show significant improvements in written word recognition in both groups ($Z = 2.76$; $p = 0.006$; $r = 0.80$ for the SDD_GST, and $Z = 2.52$; $p = 0.01$; $r = 0.84$, for the GRD_GST). In both groups, the scores obtained for this task differed significantly from the norm at the pre-test ($Z = 3.06$, $p = 0.002$, $r = 0.88$ for the SDD_GST and $Z = 2.66$, $p = 0.008$, $r = 0.89$ for the GRD_GST, see Fig. 2) but not at the post-test for the SDD group ($Z = 1.02$, $p = 0.30$). However, and despite their progress, the scores of the children in the GRD group were still below the norm at the post-test ($Z = 2.31$, $p = 0.02$, $r = 0.67$). In contrast, the analyses conducted for listening and reading comprehension did not reveal any significant improvements in these groups for both comprehension tests (all $p > 0.10$). The scores of the SDD_GST were within the norm at both the pre- and the post-test for the listening comprehension task but remained below the norm for the reading comprehension task (pre-test, $Z = 2.82$, $p = 0.004$, $r = 0.81$ and post-test, $Z = 1.97$, $p = 0.04$, $r = 0.57$ for the first text; $Z = 2.93$, $p = 003$, $r = 0.85$ for the second text). The scores of the GRD_GST were significantly below the norm at both the pre- and the post-test sessions in listening comprehension (pre-test, $Z = 2.55$, $p = 0.01$, $r = 0.85$ and post-test, $Z = 2.31$, $p = 0.02$, $r = 0.77$) and reading comprehension (pre-test, $Z = 1.96$, $p = 0.04$, $r = 0.65$ and post-test, $Z = 2.19$,

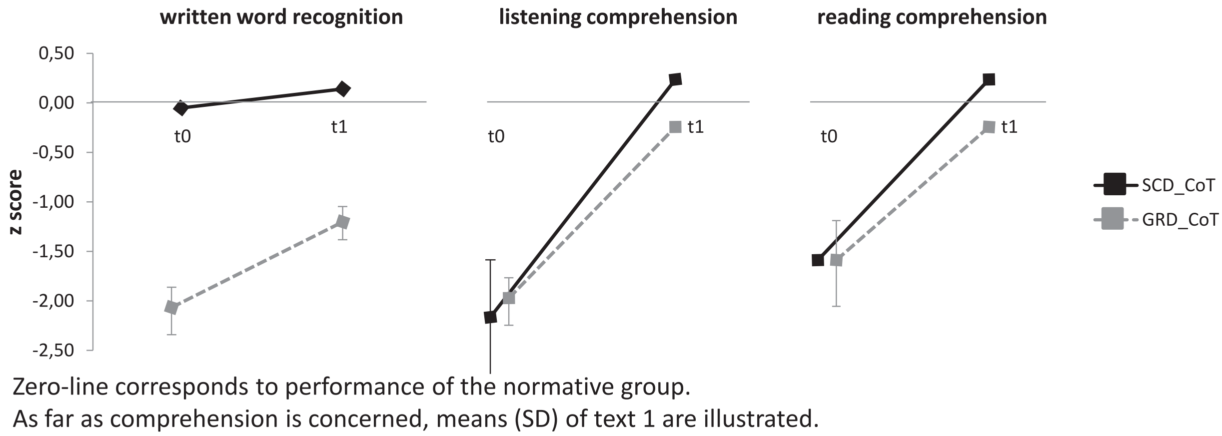

Fig. 3. Mean scores in pre-test (t0) and post-test (t1) for both groups with comprehension difficulty (SCD and GRD) that received the Comprehension Training (CoT), in written word reading, listening comprehension and reading comprehension.

$p = 0.02$, $r = 0.89$ for the first text; $Z = 2.31$, $p = 0.02$, $r = 0.67$ for the second text).

3.2.2. Comprehension training

The analyses conducted on the group of specific poor comprehenders (SCD) trained with the CoT revealed significant improvements in listening comprehension ($Z = 2.93$; $p = 0.003$; $r = 0.88$ for the first text; $Z = 2.8$; $p = 0.005$; $r = 0.85$ for the second text) and reading comprehension ($Z = 2.93$; $p = 0.003$; $r = 0.88$ for the first text; $Z = 2.8$; $p = 0.005$; $r = 0.85$ for the second text), but not in written word recognition ($p > 0.50$), as the SCD children's written word recognition performance was already good in the pre-test. The performance of this subgroup was significantly different from the norm of the listening and reading comprehension tasks at the pre-test ($Z = 2.93$, $p = 0.003$, $r = 0.85$ for the listening comprehension task and $Z = 2.93$, $p = 0.003$, $r = 0.88$ for the reading comprehension task, see Fig. 3), but this was no longer the case at the post-test ($Z = 1.69$, $p = 0.09$ and $Z = 0.98$, $p = 0.33$ for the two tasks, respectively). Finally, as far as the group of GRD children trained with the CoT is concerned, we observed significant improvements in written word recognition ($Z = 2.8$; $p = 0.005$; $r = 0.81$), listening comprehension ($Z = 2.80$; $p = 0.005$; $r = 0.81$ for the first text; $Z = 2.5$; $p = 0.01$; $r = 0.72$ for the second text) and reading comprehension ($Z = 2.7$; $p = 0.006$; $r = 0.78$ for the first text; marginal effect for the second text $Z = 1.8$; $p = 0.07$; $r = 0.52$). The scores of these children differed significantly from the norm at the pre-test in written word recognition ($Z = 3.06$, $p = 0.002$, $r = 0.88$), listening comprehension ($Z = 3.06$, $p = 0.002$, $r = 0.88$) and reading comprehension ($Z = 3.06$, $p = 0.002$, $r = 0.88$). However, these differences were no longer significant at the post-test ($Z = 1.88$, $p = 0.06$ for the written word recognition task; $Z = 0.39$, $p = 0.69$ for the listening comprehension task and $Z = 1.3$, $p = 0.18$ for the reading comprehension task).

3.3. Training effects on the measures related to decoding and to comprehension

The training effects on the measures for which the different subgroups of poor readers exhibited a difficulty before the training (see Section 3.1) were examined for each type of intervention and each subgroup of readers. The means of each group in these measures before and after the training are presented in Table 3 below.

3.3.1. Grapho-syllabic training

Both groups of poor decoders (SDD and GRD) who received the grapho-syllabic training (GST) showed significant improvements in the phonological task ($Z = 2.26$; $p = 0.02$; $r = 0.65$ for the SDD_GST group, and $Z = 2.1$; $p = 0.03$; $r = 0.7$, for the GRD_GST group). The children in the SDD_GST group also improved significantly in decoding fluency ($Z = 2.04$, $p = 0.04$; $r = 0.59$), while the children in the GRD_GST group exhibited a marginal improvement in terms of decoding accuracy ($Z = 1.7$, $p = 0.08$; $r = 0.57$). Interestingly, specific poor decoders (SDD_GST) also improved significantly in two comprehension-related measures: vocabulary ($Z = 2.36$, $p = 0.02$; $r = 0.68$) and comprehension monitoring ($Z = 2.04$, $p = 0.04$; $r = 0.59$).

3.3.2. Comprehension training

The analyses conducted on the two groups with initial comprehension difficulties trained with the CoT (SCD_CoT and GRD_CoT) revealed significant improvements in both groups in vocabulary ($Z = 2.17$, $p = 0.02$; $r = 0.66$ for the SCD_CoT group and $Z = 2.11$, $p = 0.03$; $r = 0.61$ for the GRD_CoT group). The improvement in the comprehension monitoring task was also significant in the SCD_CoT group ($Z = 2.19$, $p = 0.02$; $r = 0.66$) and marginal in the GRD_CoT group ($Z = 1.82$, $p = 0.06$; $r = 0.53$). Finally, we also observed that both groups improved in decoding, with the SCD_CoT group improving in terms of decoding fluency ($Z = 2.22$, $p = 0.02$; $r = 0.67$) and the GRD_CoT in terms of decoding accuracy ($Z = 2.44$, $p = 0.01$; $r = 0.71$).

4. Discussion

In this study, our aims were to a) analyze specific underlying difficulties of 3 subgroups of poor readers and b) implement CA reading training for each of these. Analyses conducted on written word recognition and listening comprehension performance in a sample of beginning readers ($N = 258$) confirmed for French-speaking children the existence of three different subgroups of poor readers (Catts et al., 2003; Elwér et al., 2013; Torppa et al., 2007): A group of children with difficulties in word reading, but adequate listening comprehension skills (SDD group; $n = 25$); a group of children with difficulties in listening comprehension but adequate word reading skills (SCD group; $n = 19$); and a third group of children with difficulties in both reading components (GRD group; $n = 32$). These poor readers are likely to exhibit specific cognitive and linguistic profiles as well as different underlying difficulties, which might possibly explain their difficulties in one or other of the reading components. In the light of these difficulties, each profile might need an intervention program specifically reinforcing their deficient reading component.

4.1. Differences in reading-related measures in the subgroups of poor readers

Comparisons with a normative group and between the three subgroups of poor readers on several linguistic and cognitive reading-

Table 3
Means (SD) of the trained groups ($N = 44$) on measures related to decoding and to comprehension, in pre-test (10) and post-test (t1).

	Measures		GST				CoT				
			SDD $n = 12$		GRD $n = 9$		SCD $n = 11$			GRD $n = 12$	
			t0	t1	t0	t1	t0	t1	t1	t0	t1
Word reading and comprehension measures	Written word recognition/36		20.7 (2.2)	24.4* (3.5)	21.2 (1.7)	23.9* (4.3)	22.3 (2.9)	25.8* (3.3)	28.2 (4.3)	22.3 (2.9)	25.8* (3.3)
	Listening comprehension/12	text 1	9.1 (1.4)	9.8 (1.5)	6.6 (2.3)	8.4 (2.1)	6.5 (1.2)	8.3* (2.1)	8* (1.2)	6.5 (1.2)	8.3* (2.1)
		text 2		9.3 (2.6)		9.7 (1.9)		8.7* (1.7)	10* (1.7)		8.7* (1.7)
	Reading comprehension/12	text 1	7.4 (1.5)	8 (2.5)	6.9 (3.4)	7 (2.2)	6.4 (1.4)	6.9* (1.4)	8.2* (1.2)	6.4 (1.4)	6.9* (1.4)
		text 2		8.2 (2.5)		7.4 (3.2)		8.3 (1.6)	9.5* (1.5)		8.3 (1.6)
Measures related to decoding	Decoding/10		7.3 (2.1)	8.1 (1.3)	6.3 (1.9)	7.9 (2)	6.8 (1.1)	7.8* (1.3)	9.3 (1)	6.8 (1.1)	7.8* (1.3)
	Phonological skills/12		7 (2.3)	9.1* (2.3)	6.3 (3.7)	9.3* (3.1)	7.8 (3.5)	7.8 (2.7)	9.4 (2.6)	7.8 (3.5)	7.8 (2.7)
	Decoding fluency		0.5 (0.2)	0.6* (0.2)	0.4 (0.3)	0.5 (0.2)	0.5 (0.3)	0.7 (0.5)	1.2* (0.4)	0.5 (0.3)	0.7 (0.5)
Measures related to comprehension	Vocabulary/20		16.6 (1.6)	17.3* (1.6)	14.5 (2.6)	15.1 (4.1)	14.7 (4.2)	16.4* (2.6)	16.6* (2.7)	14.7 (4.2)	16.4* (2.6)
	Comprehension monitoring/11		6.2 (2.2)	8.1* (2.5)	7.4 (3.2)	7.9 (2.6)	6.3 (2.7)	7.7 (2.8)	7.7* (1.7)	6.3 (2.7)	7.7 (2.8)

* $p < 0.05$: significant difference between t1 and t0.

related measures revealed that each subgroup seemed indeed to be characterized by particular underlying difficulties. The children with word reading difficulties (SDD and GRD) performed less well in decoding and decoding fluency than those with a specific comprehension difficulty (SCD). More precisely, while the SDD children's performances were poorer than those of the normative group in decoding fluency, the GRD children's decoding accuracy performances were poor. Both the SDD and GRD children also experienced difficulties in phonological awareness.

In contrast, the children with comprehension difficulties (SCD and GRD) performed less well in vocabulary and comprehension monitoring than those with adequate listening comprehension (SDD children). This latter result is consistent with studies that have demonstrated the involvement of vocabulary in comprehension (e.g., Lonigan et al., 2000; Oakhill & Cain, 2011; Roth, Speece, & Cooper, 2002) and confirms that lexical knowledge impairments might lead to difficulties in higher, text-level, processes among young poor comprehenders (e.g., Potocki et al., 2016). Similarly, our results confirm that poor comprehenders have difficulties monitoring their own comprehension (see Ehrlich, Rémond, & Tardieu, 1999; Oakhill et al., 2005). Indeed, in our study, they were not able to correctly identify inconsistencies in short narratives, meaning that they find it difficult to evaluate their own comprehension. However, the ability to detect errors in texts is a central function in comprehension, which, it seems, is directly related to the ability to create a coherent mental representation of a given passage (Oakhill & Cain, 2007).

The present results also reveal that some difficulties could be common to all types of poor readers, as in the case of working memory, for example. The latter finding is at odds with those obtained by Swanson et al. (2006) or Swanson and Berninger (1995), who indicated a differentiated involvement of the different subsystems of working memory in reading. According to these authors, the phonological loop in working memory is likely to be more closely related to decoding skills, while the central executive would tend to be more closely related to comprehension skills. In the present study, only verbal material was used to assess working memory. Consequently, we hypothesize that the low scores observed here in all types of poor readers might indicate a general "verbal" difficulty in poor readers rather than a specific "memory" difficulty. Nonetheless, even though there was no difference between the three subgroups of poor readers on this task, comparisons with a normative group reveal that only the SCD and GRD children had lower-than-normal performances in this task, while the difference was only marginal in the SDD children. This issue needs to be further explored, especially given the small number of items in this task, which might have limited its variation. To a lesser extent, the reliability of the measures is a factor to be taken into account in the interpretation of all the tests.

Consistent with a possible difficulty of poor readers in processing verbal information, we also observed that all the profiles of poor readers, and even those with a specific difficulty in comprehension, performed poorly in the phonemic awareness task. This result has already been observed in the literature (e.g., Nation, Cocksey, Taylor, & Bishop, 2010; Sparks, 2001). For example, Potocki et al. (2016) reported that poor comprehenders identified in Grade 2 performed as poorly as children with word recognition difficulties in a phonological awareness task administered two years earlier in kindergarten. Some authors have suggested that such a finding may be explained by the resource limitations that all types of struggling readers might experience, especially when required to store verbal material (Carretti, Borella, Cornoldi, & De Beni, 2009; Savage, Lavers, & Pillay, 2007; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000).

Finally, it is also worth noting that if we had used only a single reading comprehension task, the differences we observed between the three subgroups of poor readers (and especially the identification of specific poor decoders) would not have come to light. Indeed, no significant difference was observed between the three groups of poor readers in reading comprehension. The three groups were also below the norm for their age on this task. However, we hypothesize that these difficulties, which appear to be equivalent in the three groups, might actually arise for different reasons in each of them. In the case of the SCD and GRD children, these difficulties could be due to the characteristics of their language comprehension difficulties, as observed in their understanding of written, oral and pictorial information (see Gernsbacher et al., 1990; Kendeou et al., 2008). In contrast, in the SDD children, these difficulties might be due to their impaired word reading abilities. The absence of correlations computed among these profiles of poor readers between the reading and listening comprehension tests seems to support this idea. Indeed, as decoding and comprehension share the same set of cognitive resources (see Perfetti, 1985, 2007), insufficiently automated decoding skills will consume resources that are then no longer available for comprehension. However, these hypotheses were not the focus of the present study and were therefore not tested specifically.

From a practical point of view, these latter suggestions highlight the need to administer at least three different tasks (word reading, listening and reading comprehension tasks) that call on the two main components of reading as a basic assessment tool capable of diagnosing specific subgroups of poor readers. Indeed, positive remediation effects are likely to occur as soon as reading intervention is appropriately adapted to each specific reading difficulty, especially in the case of children with (specific) comprehension difficulties (see Section 4.2). In terms of evaluation, the use, in the present study, of the same texts to assess listening and reading comprehension may have constituted a limitation. Although it is a commonly used procedure (see e.g. Lecocq et al., 1996; Potocki et al., 2014), it may give rise to a certain repetition effect. A second text was nevertheless also used in the post-test. Moreover, the fact that the correlation between listening and reading comprehension measures was not significant seems to indicate that the possible repetition effect in this study was minimal. It is worth noting here that the absence of correlations between reading and listening comprehension should be interpreted with caution as the analysis was computed on children with reading difficulties and might not be representative of what could be observed in typical French young readers (see e.g., Megherbi, Seigneuric, & Ehrlich, 2006). Nevertheless, future studies should rather use different but equally difficult tasks to assess children's reading and listening comprehension.

4.2. Training effects in the subgroups of poor readers

The second objective of this study was to make use of two computerized training programs specifically targeting one reading component (i.e. either decoding or comprehension). The first program (Ecalle et al., 2013) is designed to improve written word recognition and makes use of grapho-syllabic training (GST). The second program aims to improve text comprehension (CoT; Potocki et al., 2013b) by fostering both literal and inferential comprehension processes. The subgroups with specific difficulties (SDD and SCD) were trained with the program targeting their particular reading deficit. The children with general reading difficulties were randomly allocated to one of the two programs. The specific effectiveness of the interventions was tested in a pre-test/training/post-test paradigm. Data analyses revealed specific training effects. As a result, the grapho-syllabic training led to improved performance in written word recognition, while the comprehension training improved listening and reading comprehension. These results are consistent with the literature (see, for example in French, Ecalle et al., 2013 or Potocki et al., 2013b), which has been obtained in various languages (for grapho-syllabic training programs in Finnish or Italian, see e.g. Heikkilä, Aro, Närhi, Westerholm, & Ahonen, 2013; Huemer, Aro, Landerl, & Lyytinen, 2010; Tressoldi, Vio, & Iozzino, 2007; for comprehension training programs in English or German, see e.g. de Bruin, Thiede, Camp, & Redford 2011; Clarke, Snowling, Truelove, & Hulme, 2010; Spörer, Brunstein, & Kieschke, 2009; Reutzel, Smith, & Fawson, 2005). In addition, we observed that the provided training programs also led to specific positive effects in the reading-related measures that were deficient in the different subgroups before training (see Section 4.1). Thus, GST leads to improvements in phonological awareness and decoding, whereas CoT leads to improvements in vocabulary and comprehension monitoring. These results are particularly interesting given the fact that studies generally examined the opposite relationships (e.g., effects of phonological or vocabulary training on decoding or comprehension respectively). Here, we observed that training in decoding or comprehension also lead to positive transfer effects in reading-related measures. This suggests that the causal relationships between these reading-related factors and the two reading components are likely to be bi-directional. It would be interesting to obtain objective measures of the impact on other aspects such as working memory, for example.

The performed analyses also revealed unexpected results at the level of the training effects. First, training in decoding did not improve reading comprehension. Despite this, several studies had previously shown a beneficial effect of training in word recognition on reading comprehension (Edmonds et al., 2009; Rashotte, MacPhee, & Torgesen, 2001; Shaywitz et al., 2004; Stanovich, West, Cunningham, Cipielewski, & Siddiqui, 1996; Torgesen et al., 2001). If decoding and comprehension share similar cognitive resources (see Perfetti, 1985, 2007), non-automated decoding skills need resources that can therefore not be devoted to comprehension. Improving decoding skills so that they can become automatic should free up cognitive resources that might then be made available for comprehension. In our study, however, improved decoding skills in the SDD group were not accompanied by improved reading comprehension. This result might be explained to some extent by the procedure used here. As post-testing took place immediately after the last training session, any improvement in the decoding abilities might not have had enough time to have an impact on reading comprehension. Consistent with this idea is the finding that grapho-syllabic training provided to poor readers in 1st Grade has been shown to have a delayed impact on reading comprehension, observable only 16 months later at the end of Grade 2 (Ecalle et al., 2013). Including one or several delayed post-tests in this study might have made it possible to test for a possible improvement in reading comprehension in the SDD group. Another possible explanation, which is related to the first one, might be that the learning and automatization of decoding take precedence in first and second Grade. You have to learn how to successfully decode a word (or text) before you can try to understand it. Reading accuracy in French children does not reach ceiling level until the latter part of 2nd Grade (Seymour, Aro, & Erskine, 2003), and might occur even later in the poor readers in this study. To address this question, a training study with older French poor readers might be of value.

Second, the comprehension training program leads to improvements in written word recognition, decoding accuracy and decoding fluency. This result suggests that text-level training tends to bring about a general improvement in reading (i.e., for both reading components), whereas the effects of decoding (word-level) training tend to be more specific. This interpretation might need to be nuanced due to a practical aspect of the comprehension training we employed. In this study, poor comprehenders were presented with written short stories that were read to them via the computer program every day for five weeks. They could simultaneously read the story on the screen and, by mapping orthographic and phonological information, the training program designed to improve comprehension might also have improved decoding. Nevertheless, the improvement in decoding after the comprehension training was primarily observed in the GRD subgroup, which consisted of children with difficulties in both comprehension and decoding. This result is consistent with those obtained by Potocki, Magnan, and Ecalle (2015b) with older struggling readers and is encouraging given that this type of general reading difficulty is generally difficult to remediate. To some extent, these results further support the idea that multi-faceted training, which combines training in reading fluency and reading comprehension, is likely to be the most efficient way to support functional reading skills (e.g. Norton & Wolf, 2012; Steacy, Kirby, Parrila, & Compton, 2014).

Conversely, we observed unexpected improvements in the SDD children trained with the GST program in vocabulary and monitoring, two comprehension-related measures (see Section 4.1). Nonetheless, and despite this result, it seems difficult to accept that the GST training might have in some way stimulated these two comprehension-related measures. The more likely hypothesis is that given their initial high level of comprehension performance, these children improved their vocabulary and comprehension monitoring during the training period. Previous research has already reported such effects. For instance, by comparing the growth of vocabulary knowledge in two groups of good and poor comprehenders aged between 8 and 11 years, Cain and Oakhill (2011) observed the existence of a “Matthew Effect” (Stanovich et al., 1996). They found that the good comprehenders made greater gains in vocabulary than poor comprehenders during the same period. This idea is further supported in our study by the fact that the GRD children who also exhibited comprehension difficulties and who were trained with the GST program did not exhibit the same improvement in vocabulary and comprehension monitoring.

4.3. Limitations of the present study

The present study also contains inherent limitations. First, it did not include a proper control group (with another type of training or without any type of training) for the specific profiles of SDD and SCD children. This prevented any experimental test of the efficiency of the provided training programs in the SDD and SCD groups. However, it is worth noting that the aim of this study was not to test the efficiency of the programs themselves in these difficulty-specific groups (see Ecalle et al., 2013; Potocki et al., 2013b for such a validation). However, the approaches could be compared in this way in the GRD children, who were randomly assigned to one of the two programs (GRD_GST and GRD_CoT groups, respectively). The results obtained in these groups appear particularly interesting. Indeed, with regard to written word recognition, both training programs used in the present study appear to be equally efficient. However, with regard to listening and reading comprehension, only the GRD group trained with the comprehension training (GRD_CoT) achieved improved scores in both listening and reading comprehension. In other words, while the computer-assisted comprehension training used in this study improved both components of reading (word reading and comprehension), the grapho-syllabic training had specific effects only on the word identification component. Similarly, the comprehension training had positive effects on both decoding-related and comprehension-related measures (i.e., decoding and vocabulary), while the GST training specifically impacted the decoding-related measures (i.e., decoding and phonology). These results seem to indicate that it would be more beneficial to use comprehension training rather than decoding training to train poor readers with difficulties in both reading components. Again, a follow-up lasting several months (or years) appears necessary here in order to compare the long-term outcomes of this training.

Secondly, an important limitation relates to the small sample size and the caution that has to be exercised before generalizing the obtained results. Finally, another important limitation concerning the samples in the study is the high attrition rate. Particularly strict exclusion criteria in the ‘Training’ part of the study (see ‘Method’ section above) might limit the interpretation of the results. Furthermore, the attrition rate might have affected the three subgroups of poor readers differently and therefore have had an impact on the results of the present study. For instance, the SDD group was more affected by attrition than the GRD group. This could also restrict the ecological significance of the study. It seems that it would be interesting to conduct training studies in an ecological context.

5. Conclusions

This research is obviously of some interest for pedagogical practice. Indeed, it seems that improving decoding is not enough to improve reading comprehension. Conversely, it seems particularly interesting that comprehension training could also help to stimulate decoding skills and word recognition. Sometimes, educational practitioners have found it necessary to wait for word reading fluency to be achieved before introducing comprehension-based work in remediation contexts. Our results suggest that comprehension interventions could be implemented early, especially in children with difficulties in both comprehension and decoding.

Finally, the obtained results highlight the fact that the most efficient reading interventions are likely to be those that specifically target the reading difficulties observed in poor readers. In this study, we used a relatively broad criterion to classify subgroups of poor readers (contrasting word reading versus comprehension skills). More precise profiles of readers could also be established. This is especially true for poor comprehenders. Indeed, different subgroups within this profile based on their difficulties in text processing, for example at the literal versus inferential level, could be distinguished. Specific training could therefore be proposed to these subgroups of poor comprehenders in order to respond precisely to their needs (see McMaster et al., 2012; Potocki et al., 2015a).

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