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Computerized trainings in four groups of struggling readers: Specific effects on word reading and comprehension

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ABSTRACT

Four groups of poor readers were identified among a population of students with learning disabilities attending a special class in secondary school: normal readers; specific poor decoders; specific poor comprehenders, and general poor readers (deficits in both decoding and comprehension). These students were then trained with a software program designed to encourage either their word decoding skills or their text comprehension skills. After 5 weeks of training, we observed that the students experiencing word reading deficits and trained with the decoding software improved primarily in the reading fluency task while those exhibiting comprehension deficits and trained with the comprehension software showed improved performance in listening and reading comprehension. But interestingly, the latter software also led to improved performance on the word recognition task. This result suggests that, for these students, training interventions focused at the text level and its comprehension might be more beneficial for reading in general (i.e., for the two components of reading) than word-level decoding trainings.

1. Introduction

Reading and understanding what is read are central in ensuring academic achievement and social integration. Reading therefore appears to be one of the most crucial abilities children have to acquire during their elementary school years. However, even after leaving elementary school, many older students fail to master even the most basic reading skills (Denton, Wexler, Vaughn, & Bryan, 2008; Kamil, 2003; see also PISA[1] results, OECD, 2010). It appears necessary to develop efficient remedial programs designed to help these students. For many years, however, research has instead focused on improving the reading skills of elementary school children. Early intervention is indeed a key component in the remediation of reading difficulties and in preventing future reading problems. Unfortunately, not all at-risk students receive intervention at an early age and in some cases the provided interventions have proved to be ineffective. As a result, there are still a significant number of students with reading disabilities in the middle school grades (Flynn, Zheng, & Swanson, 2012). Their difficulties are not likely to decrease spontaneously over time. Indeed, children who fall behind in reading tend to dislike

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[1] PISA is an international assessment coordinated by the Organization for Economic Cooperation and Development (OECD) that measures 15-year-old students' reading, mathematics, and science literacy.

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reading and read less, and the gap between them and their skilled peers therefore increases (*Matthew effect* phenomena; Stanovich, 2000).

In France, these learning disabled students are generally placed in special classes called SEGPA (*Sections d'Enseignement Général Professionnel Adapté*; [Classes for General and Professional Adapted Teaching]). Students in SEGPA are considered as severely disabled learners since they experience considerable difficulties in literacy and numeracy skills and have also repeated a year of primary school. In the same way, as students with learning disabilities in general (e.g., Lyon & Flynn, 1991), these students are likely to form a heterogeneous group. It therefore appears necessary to precisely identify their specific reading difficulties in order to choose appropriate means to correct them (Spear-Swerling & Sternberg, 1996). Unfortunately, research into effective intervention for older readers is still scant and interventions specifically targeting severe learning disabled adolescents even more limited.

1.1. *The two components of reading: identification of poor readers' subgroups*

According to the classical model of reading (e.g., *Simple View of Reading* model; Gough & Tunmer, 1986), reading can be thought of as the product of two main components, namely decoding and comprehension. The former is specific to reading and consists in establishing a correspondence between the orthographic, phonological and semantic representations of a word to access its representation stored in the mental lexicon. The latter component does not appear to be specific to reading (e.g., Gernsbacher, Varner, & Faust, 1990; Kendeou, Bohn-Gettler, White, & van den Broek, 2008). It refers to the semantic processes that are involved in the processing of texts and that contribute to the integration of all the textual information in a single, coherent representation to ultimately construct a mental model of the situation described in a text. In typically developing readers, these two components are highly interrelated. Indeed, the progressive automation of word decoding processes during the elementary school years frees up cognitive resources which are then available for comprehension (e.g., Roberts, Good, & Corcoran, 2005). In most individuals, good decoding skills are therefore coupled with good comprehension abilities. These individuals are good readers with a mastery of both types of reading processes (labeled NDNC in this study: normal decoders/normal comprehenders). However, in the case of other individuals, the reading components can be considered to be partly independent since difficulties can specifically affect one or other of these components (e.g., Aaron, Joshi, Gooden, & Bentum, 2008). Based on this principle, it is possible to distinguish between different subgroups of readers. On the one hand, some poor readers have difficulties in decoding written words but no deficit in listening comprehension (e.g., Aaron, Joshi, & Williams, 1999; Catts, Hogan, & Fey, 2003). In the present study, these poor readers are labeled PDNC (poor decoders/normal comprehenders). Although these readers sometimes exhibit impaired reading comprehension skills, these impairments are solely due to their insufficiently automated decoding skills. On the other hand, some poor readers possess adequate decoding skills but present a persistent deficit in the comprehension of both written and oral material (e.g., Cain & Oakhill, 2006; Nation, 1999). These readers are labeled NDPC (normal decoders/poor comprehenders) in the present experiment. Finally, other readers may exhibit impaired skills on both reading components, i.e., difficulties both in identifying written words and in understanding what they hear or read (Goulandris, Snowling, & Walker, 2000; Heath, Hogben, & Clark, 1999). These readers can be referred to as garden-variety poor readers or, for the purposes of this study, PDPC (poor decoders/poor comprehenders). Although the prevalence of these different profiles of readers in the general population varies across studies and native language, they generally represent around 10%, and up to 15%, of the school age population (Torppa et al., 2007). One might expect this prevalence to be higher in special education classes such as SEGPA. However, to date no study has directly examined this issue (but see Lyon & Flynn, 1991, for other reader subtypes among learning disabled children).

1.2. *Effective interventions for encouraging reading and comprehension skills*

Several intervention programs have proved to be effective in remediating reading difficulties in readers with learning disabilities (e.g., Edmonds et al., 2009; Flynn et al., 2012; Scammacca et al., 2007; Scammacca, Roberts, Vaughn, & Stuebing, 2015). However, for several decades, these interventions have primarily focused on improving the decoding skills of poor decoders. In this regard, phonemic awareness training appears to be particularly effective (see the meta-analysis by Ehri et al., 2001). More specifically, programs that focus explicitly on the links between orthographic and phonological units are likely to be the most beneficial for poor decoders. The National Reading Panel (2000) reported that the mean effect size on reading of training that explicitly establishes orthographic and phonological associations exceeded that of phonological awareness training used in isolation. To improve decoding skills, the most effective techniques are therefore those based on the correspondences between graphemes and phonemes (e.g., Harm, McCandliss, & Seidenberg, 2003).

As far as comprehension is concerned, several studies have demonstrated that comprehension skills can also be developed through explicit teaching (e.g., Clarke, Snowling, Truelove, & Hulme, 2010; Elbro & Buch-Iversen, 2013). For example, the National Reading Panel (2000) has identified six strategies that have proved to be efficient in improving comprehension: (a) monitoring one's own comprehension, (b) using tools to visually represent the main ideas of a text, (c) identifying the structure of a text, (d) testing comprehension with immediate feedback, (e) answering questions about the text and (f) summarizing the main ideas. Instructions implementing these strategies seem to be beneficial for children and adolescents with comprehension difficulties (e.g., Corte, Verschaffel, & Ven, 2001; de Bruin, Thiede, Camp, & Redford, 2011; Gersten, Fuchs, Williams, & Baker, 2001).

In addition, in the field of remediation in general, greater gains have usually been observed when computerized programs have been used. The use of such programs in reading instruction does indeed bring about several advantages (Lynch, Fawcett, & Nicolson, 2000; Mathes, Torgesen, & Allor, 2001). Firstly, they can provide immediate individual feedback (e.g., Hall, Hughes, & Filbert, 2000). Secondly, learning with computers allows students to control the pace of learning by themselves (Case & Truscott, 1999). Thirdly, properly organized computerized courses can be run independently of one another, thus relieving teachers of some of the burden and giving students more opportunity to learn independently. Finally, the use of presentations involving different media may strengthen students' motivation to read (e.g., Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2010). This latter point appears to be particularly interesting when working with populations with special needs (see, e.g., Ecalle, Magnan, Bouchafa, & Gombert, 2009) and could be of particular value in the case of students with learning disabilities, who generally dislike reading. In his review of meta-analyses conducted in the field of special education, Forness (1997) described CAI as an intervention that ''shows promise'' in giving students effective support. Empirical evidence suggests that computer-assisted instruction can improve poor readers' performance in both decoding (e.g., Ecalle, Kleinsz, & Magnan, 2013; Jiménez et al., 2007; Macaruso, Hook, & McCabe, 2006; Wise, Ring, & Olson, 2000) and comprehension (e.g., Kim et al., 2006; Potocki, Ecalle, & Magnan, 2013; Potocki, Ecalle, & Magnan, 2015).

1.3. Aims of the present study and hypotheses

The aims of the present study were twofold. First, we wanted to determine different groups of poor readers in a population of severely disabled learners attending a special class in secondary school. We expected to find four subgroups of readers: normal readers (NDNC, with performance within the normal range in both word decoding and listening comprehension); specific poor decoders (PDNC, deficit in word decoding only); specific poor comprehenders (NDPC, deficit in comprehension only), and general poor readers (PDPC, deficits in both decoding and comprehension). Based on this distinction, we then administered a 5-week reading training program to these different groups. In this program, students worked with a software program designed to encourage either their written word decoding skills (grapho-syllabic software training; Ecalle et al., 2013a,b) or their text comprehension skills (comprehension software training; Potocki et al., 2013, 2015). After 5 weeks of training, we expected to observe improved performance in the trained skills among precisely those students who had initially exhibited a deficit in these skills. As a result, the performance of the students trained with the grapho-syllabic software (and who initially exhibited difficulties in decoding, i.e., PDNC and PDPC students) should improve in the fluency and word recognition tasks. These children might also progress in reading comprehension. However, this effect is thought to be indirect and act via the automation of the decoding processes (Rashotte, MacPhee, & Torgesen, 2001; Stanovich, West, Cunningham, Cipielewski, & Siddiqui, 1996; Torgesen et al., 2001). In contrast, the performance of the students trained with the comprehension software (and who initially exhibited deficits in comprehension, i.e., NDPC and PDPC students) was expected to improve in the reading and listening comprehension tasks. The analysis of the results should allow us to detect the differential impact of the two types of reading intervention and to test which type of training might prove to be the most effective for 13-year-old disabled learners.

2. Method

2.1. Participants

At the beginning of the study, 84 students (mean age = 157.1 months; SD = 7.1) were recruited in 6th and 7th grades in 5 secondary schools in the north-east of France. These students exhibited considerable difficulties in their literacy and numeracy skills and had all repeated a year during primary school. They were therefore attending special classes at school (15 pupils per classes) named SEGPA (*Sections d'Enseignement Général Professionnel Adapté* [Classes for General and Professional Adapted Teaching]). They also mainly came from low socio-economic status backgrounds. At the end of the study, complete data were available for 77 of these students, since some of them refused to continue the training sessions and/or were absent during one or two testing sessions.

After the first session, which was held before the start of training, the participants were subdivided into four contrasted groups (Table 1) based on their scores in the silent word reading and listening comprehension tasks (see next section): So-called poor decoders-poor comprehenders (PDPC), poor decoders-normal comprehenders (PDNC), normal decoders-poor comprehenders (NDPC) and normal decoders-normal comprehenders (NDNC). The poor decoders were the students with scores below 22 in the word identification task and poor comprehenders those with scores below 5 in the listening comprehension task. These cut-off scores were based on the means obtained for these measures. It is worth noting that the label ''normal reader'' is relative for this sample. Indeed, the mean lexical age of the participants obtained with the standardized word reading test was 111 months. This corresponds to a significant mean delay of 46 months compared to the norm of the test. However, only 5 of the participants had been diagnosed as dyslexic by a speech therapist and/or (neuro-)psychologist. However, all the children were known at school to be struggling readers.

Table 1
Means (SD) of chronological age and scores in silent word reading and listening comprehension at t0 in the four groups.

	CA	Silent word reading (/40)	Listening comprehension (/12)	Trained with Chassymo	Trained with LoCoTex
	Mean (SD)	Mean (SD)	Mean (SD)	*N*	*N*
PDPC *N* = 25	155.4 (7.1)	18.4 (3.9)	2.7 (2.6)	14	11
PDNC *N* = 16	157.3 (6.9)	15.5 (3.8)	7.9 (1.3)	8	8
NDPC *N* = 21	157.4 (6.9)	27.7 (3.4)	3.2 (1.9)	11	10
NDNC *N* = 15	159.2 (7.6)	27.2 (2.5)	7.1 (1.2)	8	7

Note. PDPC: poor decoders/poor comprehenders; PDNC: poor decoders/normal comprehenders; NDPC: normal decoders/poor comprehenders; NDNC: normal decoders/normal comprehenders. Chassymo: grapho-syllabic software training; LoCoTex: comprehension software training.

2.2. Pre- and post-test measures

In three sessions, namely a pre-test (t0), a post-test (t1) conducted just after training and a second post-test (t2) one month later, the children completed four tests. One of these took place individually (the fluency test) and the others were conducted in small groups.[2] The tests were presented randomly in each group.

2.2.1. Silent word reading

A standardized test of word reading (Timé3; Ecalle, 2006) was used. This comprised two forced-choice tasks. In each of these, the children had to identify written target words corresponding to (1) a picture (20 target words) and (2) a semantically associated written word (20 target words). They had to choose the correct response from a list of 5 items consisting of the orthographically correct word and 4 pseudowords. A lexical age was calculated on the basis of the number of correctly identified items, which was also used as dependent variable (max = 40).

2.2.2. Fluency

The children had to read words in sentences aloud for a period of 3 minutes (revised test known as Alouette; Lefavrais, 2005). The fluency indicator was obtained by calculating the number of words read correctly during this period.

2.2.3. Listening comprehension

In a semantic similarity judgment task, the children had to say whether two orally presented sentences had the same (or very similar) meanings or whether the meanings of the two sentences were very different (Ecalle, Bouchafa, Potocki, & Magnan, 2013a). After listening to the pair of sentences, they had to circle two black dots on a sheet of paper (on which the sentences were printed) if they thought that the two sentences were semantically identical or very similar (*yes* response) or circle a black and a white dot if they thought that the two sentences were semantically different (*no* response). The dependent variable was a weighted score (DV = hits – false alarms), that is to say the number of black dots circled for a *yes* response (hits) minus the number of black dots circled for a *no* response (i.e., false alarms). The maximum score was 12.

2.2.4. Reading comprehension

The children had to read two narratives to themselves. One of these was 169 words long and the other 237 words long and they were randomly presented (Potocki, Bouchafa, Magnan, & Ecalle, 2014). After the reading of each text, 12 multiple-choice questions were proposed: 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. The order of presentation of the questions was randomized. For each question, three possible responses were presented. The children were informed that only one response was correct. The dependent variable consisted of the total number of correct responses for the two texts (max = 24).

2.3. Training sessions

Each group of reader was further subdivided into two subgroups. One of these received decoding training using Chassymo, a software program that focuses on grapho-syllabic processing (see below for a description), while the other received comprehension training using a software program named LoCoTex. The children were randomly assigned to either the Chassymo or the LoCoTex training.

[2] Not enough time was allocated to the experimenter to test all the children individually in the four domains.

2.3.1. Chassymo

A grapho-syllabic training software program. This software program encourages grapho-syllabic word processing and is designed to promote word decoding skills (for more details, see Ecalle, Bouchafa, et al., 2013; Ecalle, Kleinsz, et al., 2013). The children first heard a syllable, then saw the syllable 500 ms later and, finally, heard a word after a further 500 ms. They had to use the mouse to click on the number corresponding to the seen and heard syllables in the word (initial, median, final).

2.3.2. LoCoTex

A text comprehension training software program. This software distinguishes between two aspects of text comprehension, namely literal comprehension and inferential skills (see Potocki et al., 2013, 2015 for more details). These latter included two types of inference: Coherence inferences and knowledge-based inferences. Each of these skills was trained in a specific module of the software. The children first worked with the literal comprehension module before changing over to one of the inferential modules, i.e., either the coherence inference module or the knowledge-based inference module. The main objective of the first module was to foster literal comprehension skills. The aim of the second software module was to improve the children's ability to generate coherence inferences and the third module was designed to promote knowledge-based inference production. Importantly, all the statements in LoCoTex were presented both visually and auditively, thus making it suitable for use with struggling readers.

All the children were equipped with headphones and sat alone in front of a computer screen. An experimenter was present to help any of them who experienced a technical problem with the computer and/or the software or whose attention wandered during the training phase. The children were trained for 30 min per day, 4 days a week, over a period of 4 weeks (March–April). They therefore received a total of 8 h of training.

3. Results

A series of ANCOVAs were conducted with the Training program (Chassymo or LoCoTex) and the Group (PDPC, PDNC, NDPC, or NDNC) as between-subject factors and the Session (t0, t1, and t2) as a within-subject factor. The dependent variables were the scores on the words identification, the reading fluency, the listening comprehension and the reading comprehension tasks respectively. Relevant covariates were introduced in the analyses (e.g., reading fluency for the word identification task, listening comprehension for the reading comprehension task). We expected a significant Program $\times$ Session $\times$ Group interaction for each of these analyses to provide evidence of a differential impact of the two programs over time as a function of the initial group memberships of the students. The obtained results are presented below for each dependent variable.

3.1. Word identification

For this analysis, the scores on the reading fluency task at t0 were entered as a covariate with a significant effect ($F(1, 136) = 7.26$, $p < .01$, $\eta^2 = .23$). The observed significant Group effect ($F(3, 136) = 16.05$, $p < .001$, $\eta^2 = .67$) was expected as the subgroups were constituted based on the scores on this measure. We also observed a significant effect of Session ($F(2, 136) = 3.47$, $p < .05$, $\eta^2 = .09$), meaning that all students improved their performance between the pre-test and the post-tests sessions. The double interaction Program $\times$ Session $\times$ Group was not significant ($F(6, 136) = 1.7$, $p = .11$) but planned comparisons nonetheless revealed that for the two groups of poor readers with initial difficulties in word identification (PDPC and PDNC), only the students trained with the LoCoTex software did improve their performance between the pre-test and the post-test sessions (see Fig. 1). Conversely, for the children with no initial difficulties in word identification (NDPC and NDNC), only those trained with the Chassymo software exhibited improved performance in the word identification task.

3.2. Reading fluency

The scores on the reading fluency task were converted using log transformation to respect normality assumptions. The scores on the word identification task at the pre-test were entered as a covariate. This covariate had a significant effect ($F(1, 136) = 9.8$, $p < .01$, $\eta^2 = .65$). We also observed a significant effect of Session ($F(2, 136) = 4.99$, $p < .01$, $\eta^2 = .09$) and two significant interactions. The first significant interaction between Session and Program ($F(2, 136) = 5.14$, $p < .01$, $\eta^2 = .09$) revealed that the progress between the pre-test (t0) and the first post-test (t1) was only significant for the children trained with the Chassymo software (Fig. 2). The second significant interaction between Session and Group ($F(6,136) = 3.52$, $p < .01$, $\eta^2 = .13$) indicated that only the children with initial difficulties in word reading (PDPC and PDNC) improved significantly their reading fluency after the training. The double interaction Program $\times$ Session $\times$ Group was not significant ($F(6, 136) = .72$, $p = .63$).

3.3. Listening comprehension

For this analysis, we entered the scores obtained on the reading comprehension task at the pre-test as a covariate. This covariate appeared to have a significant effect ($F(1, 136) = 12.32$, $p < .001$, $\eta^2 = .15$). The Group effect was also significant ($F(3, 136) = 19.48$, $p < .001$, $\eta^2 = .45$), which was not surprising given that the subgroups were constituted on the basis of cut-off

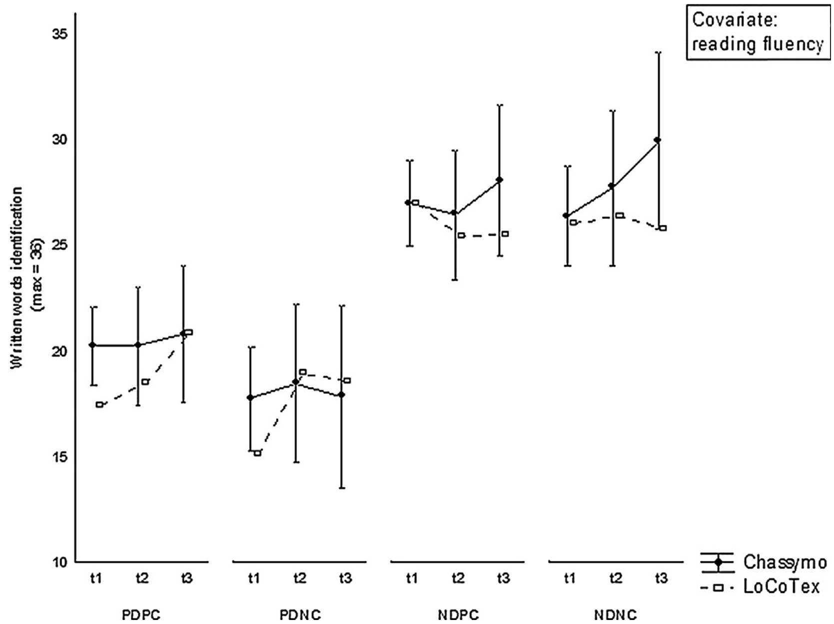

Fig. 1. Progress made by each subgroup of readers trained either with the Chassymo or the LoCoTex software in the word identification task. *Note*. PDPC: poor decoders/poor comprehenders; PDNC: poor decoders/normal comprehenders; NDPC: normal decoders/poor comprehenders; NDNC: normal decoders/normal comprehenders. Chassymo: grapho-syllabic software training; LoCoTex: comprehension software training.

scores in this measure. We also observed a significant interaction effect between Session and Group ($F(6, 136) = 3.76$, $p < .001$, $\eta^2 = .14$) indicating that only the students with initial difficulties in comprehension (PDPC and NDPC) exhibited improved listening comprehension performance after the training. The double interaction Program × Session × Group was not significant ($F(6, 136) = .35$, $p = .90$).

3.4. Reading comprehension

For this analysis, the scores on the listening comprehension tasks at the pre-test were entered as a covariate. This covariate did not prove to have a significant effect. For this measure, we only observed a significant Session × Program interaction ($F(3, 136) = 3.9$, $p < .05$, $\eta^2 = .06$). Planned comparisons revealed that only the students trained with the LoCoTex program improved their performance in reading comprehension between the pre-test and the post-test sessions (Fig. 3).

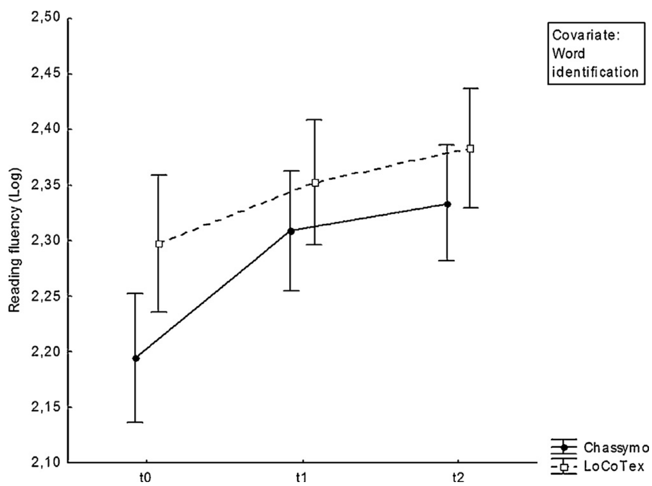

Fig. 2. Progress made by the students trained either with the Chassymo or the LoCoTex software in the reading fluency task. *Note*. Chassymo: grapho-syllabic software training; LoCoTex: comprehension software training.

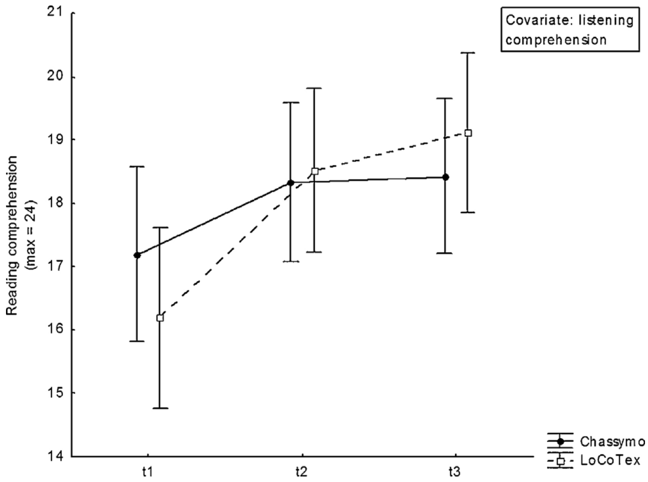

Fig. 3. Progress made by the students trained either with the Chassymo or the LoCoTex software in the reading comprehension task. *Note*. Chassymo: grapho-syllabic software training; LoCoTex: comprehension software training.

4. Discussion

The aim of the present study was to examine the effectiveness of two computerized reading interventions in a population of 13-year-old middle-school students with learning difficulties. Each of these interventions targeted one specific aspect of the reading activity, namely decoding or comprehension skills. The software designed to encourage decoding skills made use of grapho-syllabic training, while the comprehension software was designed to develop both literal and inferential comprehension processes. It has generally been accepted that the training studies that produce the largest positive effects are those that are based on an initial identification of specific subtypes of reading disabilities (Flynn et al., 2012; Lovett, Steinbach, & Frijters, 2000). We therefore first determined different groups of readers based on the *Simple View of Reading* model (Gough & Tunmer, 1986). Four groups of readers were thus identified: Normal readers (NDNC, 19.5% of the sample); specific poor decoders (PDNC, 20.7% of the sample); specific poor comprehenders (NDPC, 27.3% of the sample), and general poor readers (PDPC, 32.5% of the sample). The prevalence of the poor readers in our sample (whatever their specific subgroup was) confirms that these students in special education classes are learners with severe disabilities (only 19.5% of relatively normal readers). Within each group of readers, half of the students were trained using the decoding software, while the other half received the computerized comprehension training. This allowed us to perform a differentiated examination of the impact of the two programs.

In general, the obtained results confirm that older learning-disabled readers in middle-school may benefit from interventions focused at both the word and the text levels (Edmonds et al., 2009; Scammacca et al., 2007, 2015). Indeed, the performances of the students who took part in our intervention program improved after 5 weeks of intensive training in the skill in which they had presented the greatest deficit at the pre-test. As a result, the students trained with the grapho-syllabic software improved primarily in the reading fluency task. Conversely, the students trained with the comprehension software showed improved performance in listening and reading comprehension. Interestingly, the students experiencing initial word reading difficulties who received the comprehension training also improved on the word recognition task. This result suggests that comprehension training might also be effective in remediating word-level reading difficulties. Given that students with reading difficulties tend to spend less time reading than more capable readers, it is possible that spending 30 min a day over a period of several weeks reading texts and answering questions about them also helps improve word reading skills. Thus, the practice of daily reading and higher-level work (i.e., inference level) with entire texts can be an effective supplementary technique for increasing word reading skills (see, e.g., Rashotte & Torgesen, 1985). It has indeed been hypothesized that increasing the amount of time students spend reading by themselves is one way in which they could become more accurate readers (Krashen, 2001; Pearson & Fielding, 1991). In sum, it appears that training interventions focused at the text level (i.e., comprehension training) might be more beneficial for reading in general (i.e., for the two components of reading) than word-level (i.e., decoding) training. This could be particularly true when working with older readers with learning difficulties in middle school (e.g., Edmonds et al., 2009; Underwood & Pearson, 2004).

In contrast, no improvement in reading comprehension was observed after the grapho-syllabic training. This finding suggests that decoding training is not sufficient to ensure improvements in reading comprehension (e.g., Edmonds et al., 2009; Oakhill & Cain, 2012; Potocki et al., 2013). To encourage comprehension skills, training should instead specifically target the processes involved in understanding texts, such as literal comprehension processes and inference generation. However, for the listening comprehension task, we observed that both the children trained with the comprehension and the grapho-syllabic software programs exhibited improved performance. These improvements in listening comprehension after the grapho-syllabic training were not expected but they might only occur indirectly via the enhancement of phonological processing. Indeed, improving the phonological processing of information could help improve performance in listening comprehension. Previous studies have indeed demonstrated that phonological abilities might be involved in understanding texts (Vellutino, Tunmer, Jaccard, & Chen, 2007). Poor comprehenders might also experience resource limitations, especially when required to process verbal material (Carretti, Borella, Cornoldi, & De Beni 2009; Savage, Lavers, & Pillay, 2007; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000). Thus, fostering phonological processing might also have resulted in improved comprehension performance, especially when the texts were presented orally. However, any such effect is likely to remain relatively limited and we did not observe any improvement in reading comprehension after the grapho-syllabic training. In general, previous studies that have compared two intervention programs (phonological versus comprehension training) have actually tended to observe specific rather than general effects (i.e., improvements in decoding after phonological training and in comprehension after comprehension training; see, for example, the two studies with young children conducted by Bianco et al., 2010; Bianco Pellenq, Lambert, Bressoux, Lima, & Doyen, 2012). Our own results obtained with older children instead suggest that the effects of interventions designed to improve comprehension could also positively affect decoding abilities. This issue clearly needs to be further investigated in future studies, in particular within a developmental framework (comparing younger and older poor readers).

4.1. Conclusion and educational implications

The present results suggest that adolescence is not too late to intervene in order to help correct reading disabilities. Indeed, our reading interventions proved to be of benefit to older students, including those with severe learning disabilities in special education classes. These benefits also appear to be relatively stable as they persisted one month after the end of the intervention. However, these positive effects seem to occur in particular when the reading interventions are appropriately adapted to each student's specific reading difficulties. It therefore first appears to be necessary to determine what kinds of reading difficulties such students are experiencing. In the present study, we therefore distinguished between four groups of readers based on the *Simple View of Reading* model. Teachers and educators can make use of this classification to identify individual needs and implement suitable reading interventions.

Furthermore, our results (but see also Edmonds et al., 2009; Underwood & Pearson, 2004) suggest that in older poor readers, interventions targeting comprehension skills might be effective in improving not only text comprehension but also word recognition. In contrast, interventions targeting decoding skills only lead to more specific improvements in word reading skills. Thus, secondary teachers and educators might want to prioritize remediation programs that operate at the text level and develop higher-level skills such as inference generation, rather than lower-level phonological training.

The Program for International Student Assessment (PISA) revealed that 19.7% of French 15-year-old pupils have a literacy/reading proficiency level below level 2 (out of 6) (OECD, 2010). The results of the present study are therefore encouraging with regard to the specific population of adolescents with learning disabilities who continue to demonstrate basic reading difficulties in middle school. Such difficulties are generally not observed among their typical grade-level peers. As a result, secondary teachers often lack the tools necessary to overcome these students' reading disabilities. In this context, the use of computerized programs appears particularly interesting. Indeed, for these children with severe learning disabilities, reading activities are often experienced as very negative situations. Since feedback given by a computer might generally be perceived as less negative than feedback given by the classroom teacher (Blok Oostdam, Otter, & Overmaat 2002; Wild, 2009), computerized training could be a good way to develop more positive attitudes toward reading. During the training sessions, we did indeed observe that the students paid close attention to the tasks and generally enjoyed performing the administered exercises (see also Karemaker, Pitchford, & O'Malley, 2010). It is worth noting, however, that an adult (the experimenter) always supervised the training sessions. Indeed, computerized devices are not intended to be used in complete autonomy by students. To maximize the benefits of computer-assisted instruction, Wissick and Gardner (2000) advised that students with disabilities should not be left to their own devices but should rather receive help when needed. Thus, computer-assisted education programs constitute an interesting supplementary tool (but certainly not a substitute) that can help teachers implement effective remedial interventions for the less able readers in their classes.

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