Phonological and orthographic reading routes in French-speaking children with severe developmental language disorder

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1. Introduction

1.1. Developmental language disorder

Language disorders have recently been the subject of a wide multidisciplinary Delphi consensus study (Bishop, Snowling, Thompson, Greenhalgh, & the CATALISE-2 consortium, 2017). The authors define a developmental language disorder (DLD) as a disorder concerning comprehension and/or production, with no known biomedical conditions such as brain injury, acquired epileptic aphasia, neurodegenerative disease, cerebral palsy, hearing loss, intellectual disability or autism spectrum disorder. Moreover, a DLD is likely to continue into middle childhood and beyond.

In many previous studies, such disorders were called specific language impairment (SLI). They are heterogeneous: language profiles vary according to which linguistic domains are affected (Botting & Conti-Ramsden, 2004). Morphosyntax and phonology are frequently impaired. Phonological representations are imprecise (Leonard, 2014). For example, children with SLI perform poorly in rejecting pseudowords that differ from a familiar word by a single articulatory feature (Maillart, Schelstraete, & Hupet, 2004). In this study, when referring to previous studies, we will use the earlier denomination "SLI" as used by the authors, and the current and consensual denomination "DLD" will be used when referring to our original experiment.

This experiment is specific to French-speaking children affected by severe DLD, meaning that language scores fall into the lowest five percent, as defined in Belgium, Québec, and France (Leclercq & Veys, 2014; Thordardottir et al., 2011). In these countries, children who exhibit severe DLD are diagnosed with "dysphasia" and receive specific intensive treatments from multidisciplinary clinician teams.

Learning to read relies on spoken language abilities, therefore a non-negligible number of children with SLI experience reading difficulties. This has been evidenced using reading aloud tasks of isolated words or texts, or comprehension tasks, usually with paragraphs followed by multiple choice questions. The prevalence of reading disorders (written word recognition and/or reading comprehension) in children with DLD is estimated between 12 and 85% (for a review in English, see McArthur, Hogben, Edwards, Heath, & Mengler, 2000; in French, see Macchi, Casalis, & Schelstraete, 2016). The risk of developing a reading disorder is between two and seven times higher for these children compared to those with typical spoken language development (Pennington & Bishop, 2009). These prevalence estimates are imprecise, particularly because DLD is a heterogeneous disorder, and the criteria for identifying DLD and reading disorder vary from study to study.

1.2. Reading routes

To analyze written word recognition abilities, many studies have used the so-called "dual route" model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Ziegler, Perry, & Coltheart, 2003). It was initially proposed for acquired dyslexia, and later for developmental dyslexia (Castles & Coltheart, 1993; Sprenger-Charolles, Siegel, Jiménez, & Ziegler, 2011). It involves two routes (or "procedures") in written word recognition. The phonological route (also called the "sublexical" procedure) enables production of the phonological codes of written words by applying grapheme-phoneme conversions. The phonological route is used to read pseudowords (words that do not exist, e.g., *bluck*) and unfamiliar regular words (words that follow the grapheme-phoneme conversion rules, e.g., *crib*). The orthographic route (also called the "lexical" procedure) connects a visual stimulus to an orthographic representation stored in long-term memory. It enables the reading of familiar words, both regular (words that follow the grapheme-phoneme conversion rules, e.g., *big*) or irregular words (words that do not follow the grapheme-phoneme conversion rules, e.g., *yacht*). The development of both routes is not independent: the development of the phonological route via grapheme-phoneme conversion plays an essential role in the development of the orthographic route. As stated in Share's self-teaching hypothesis, it is through the successful and repeated use of phonological recoding that the orthographic lexicon is gradually developed (Share, 1995, 2008; Sprenger-Charolles, Siegel, Béchennec, & Serniclaes, 2003; Ziegler, Perry, & Zorzi, 2014). As a result, a deficit in the phonological route tends to lead to a deficit in the orthographic route. However, written word recognition disorders do not always affect both routes at the same level (Sprenger-Charolles, Colé, Lacert, & Serniclaes, 2000).

In the case of reading disorder, the efficiency of both routes is often assessed in comparison with that of typically developing children of the same reading level and/or of the same chronological age, through reading aloud isolated words or visual lexical decision task. In the latter case, the child has to quickly decide if strings of letters displayed on a computer screen are words belonging to his/her mother tongue or not (Paizi, De Luca, Zoccolotti, & Burani, 2013; Sprenger-Charolles et al., 2011). Regarding the reading aloud task, the phonological route is usually assessed by measuring the "lexicality effect" (i.e., the difference between abilities to process words and pseudowords). The lexicality effect increases when the phonological route is impaired, resulting in difficulty reading pseudowords. The orthographic route is usually assessed by measuring the "regularity effect" (i.e., the difference between abilities to recognize regular words and irregular words). It increases when this route does not work (difficulty in reading irregular words). Regarding lexical decision tasks, several effects are tested, in particular pseudohomophony. This latter effect corresponds to a high number of false positives with pseudohomophones (pseudowords whose phonological forms are those of real words): they are erroneously identified as correctly spelled real words. This effect is often considered as an estimate of the reliance on the phonological reading route (Sprenger-Charolles et al., 2003). Alternatively, a high rate of correct responses for pseudohomophones can be considered as the ability to identify orthographic errors of these pseudowords and interpreted as a sign of well-established orthographic route.

1.3. Reading in children with SLI

The literature shows that the more severe, widespread and persistent the SLI, the greater the risk of severe reading impairment (Bishop, 2001; Catts, Fey, Tomblin, & Zhang, 2002; Snowling, Bishop, & Stothard, 2000; Vandewalle, Boets, Boons, Ghesquière, & Zink, 2012). Written comprehension is more frequently and severely affected than written word recognition (Bishop & Adams, 1990; Simkin & Conti-Ramsden, 2006). There is a considerable diversity in reading level ranging from no delay to more than three years (Haynes & Naidoo, 1991). There are four kinds of reading profiles in children with SLI: written word recognition and written comprehension are age-appropriate, recognition is poor while comprehension is age-appropriate, comprehension is poor while recognition is age-appropriate, both recognition and comprehension are poor, which is the most frequent (Bishop & Snowling, 2004; Ricketts, 2011). Developmental pathways of reading abilities are extremely diverse (Catts, Bridges, Little, & Tomblin, 2008; Puranik, Petscher, Al Otaiba, Catts, & Lonigan, 2008; Serry, Rose, & Liamputtong, 2008). When the language disorder is mild to moderate, the difficulties occur at later stages of reading instruction, but for severe disorder, they start very early.

Most previous publications focused on prevalence levels of reading disorders or mean reading delay in children with SLI. The present study investigates the underlying mechanisms of reading with respect to written word recognition. Such mechanisms have been investigated in only two studies, to our knowledge. The first cohort involved children who exhibited an expressive phonological disorder with or without an associated SLI when they were aged five and a half on average; two years later their reading abilities were tested by Bird, Bishop, and Freeman (1995). In the study of Macchi, Schelstraete, and Casalis (2014), the children had a mean age eleven years and exhibited an expressive phonological disorder and an associated SLI (Macchi et al., 2014). In both studies, authors used reading aloud tasks of isolated words and pseudowords. They showed an increased lexicality effect in children with SLI compared to children of the same general reading level, which indicates a deficit in the phonological route. However, there may be a bias since reading aloud can be affected by a deficit in the speech motor output programming. Indeed, despite the absence of basic oral-motor dysfunction, children with SLI have difficulty performing articulatory movements. They exhibit problems with speech rate, particularly when they produce increasingly complex phonemic and word sequences (Sanjeevan et al., 2015).

To overcome this limitation in the reading aloud task, in the present study, we use a silent recognition task: a visual lexical decision task. This has several advantages. Firstly, silent reading is the most common form of reading. To our knowledge, nothing has yet been published about reading routes with a silent task in children with DLD. Secondly, silent reading involves different cognitive processes to those of aloud reading and is of interest, per se. Lexical decision tends to reduce phonological effects, and to emphasize lexicality effects. By contrast, aloud reading involves pronunciation; this task therefore tends to emphasize phonological effects as articulation requires phonological information (Carreiras, Mechelli, Estévez, & Price, 2007). Therefore, the lexical decision task is suitable for assessing lexical mechanisms.

1.4. Aim of the present study

The aim of the present study is to analyze, within the dual route model, the mechanisms of written word recognition in French-speaking children with severe DLD, by comparing the efficiency of their phonological and orthographic routes to that of control children. The visual lexical decision task involves a set of items designed to explore reading routes and was subdivided into several conditions. The first condition includes target words (e.g., voiture - /vwatyʁ/ - [car]). There are also three associated pseudoword conditions, in which we manipulated both the phonological and the visual distance of the letter(s) modified between the pseudoword and the target word. The items correspond to specific words of the first condition. (1) There are pseudohomophones (phonologically identical to their words but orthographically dissimilar, e.g., voiturre - /vwatyʁ/). The aim of this condition is to evaluate the use of the orthographic reading route because, as mentioned in the introduction, a high rate of correct responses (rejections) can be considered as the ability to identify the orthographic errors related to pseudohomophones. (2) There are phonologically close and visually distant pseudowords (e.g., voicure - /vwakyʁ/). This condition aims to assess the phonological recoding skills, that is the use of the phonological reading route, and the accuracy of phonological representations. (3) There are visually close and phonologically distant pseudowords (e.g., voifure - /vwafyʁ/). This condition aims to assess the precision of orthographic representations.

We recruited three groups: (1) children with severe DLD, (2) reading control (RC) children matched with severe DLD children on their reading level (the word acceptance rate of the lexical decision task), (3) age control (AC) children matched with severe DLD children on their chronological age.

We assumed that children with severe DLD would not present a simple reading delay, but rather a developmental deviance. If they had a simple reading delay, they should succeed similarly to the RC children, for each of the three pseudoword conditions. In fact, we predicted that the pattern of children with severe DLD would be different than that of RC children, indicating a different balance between the two reading routes in both these populations. Due to their phonological weaknesses, the phonological reading route of children with severe DLD should be less efficient than that of RC children: children with severe DLD should perform below RC children for the pseudowords phonologically close and visually distant to the words. Again because of their phonological weaknesses, children with severe DLD were expected to rely more on the orthographic reading route than on the phonological one, compared to RC children: they should be better than RC children for the pseudohomophones. Since accurate phonological recoding is needed to establish accurate orthographic representations, we hypothesized that the orthographic representations of children with severe DLD will be imprecise. They should perform less well than RC children for visually close and phonologically distant pseudowords.

Compared with AC children, we predicted that children with severe DLD would be significantly less successful for all the pseudowords (considered together) and for each of the three pseudoword conditions. Indeed, these children exhibit phonological weakness that hinder the development of their phonological reading route; that is why they may be less successful than AC children for the pseudowords phonologically close and visually distant to the words. Since the phonological reading route is needed to establish accurate orthographic representations, the orthographic route of children with severe DLD should be less efficient than that of AC children; that is why they should be less successful than AC children for the pseudohomophones. Their orthographic representations should be less precise; thus, they should be less successful than AC children for the visually close and phonologically distant pseudowords.

2. Methods

2.1. Participants

The children were all French-speaking and monolingual, with normal corrected or uncorrected vision and normal nonverbal intellectual abilities: their scores were above the 10th percentile in the Matrices subtest of the WNV battery (Wechsler & Naglieri, 2009). All parents signed consent forms. They were informed that the data collected would be processed anonymously, and that they could withdraw from the experiment at any time, without having to justify their decision. Children provided oral consent. The protocol followed the ethical rules stated by the Helsinki guidelines for human experimental work and was approved by the committee of the Psychological Sciences Research Institute in the Université Catholique de Louvain (Louvain-la-Neuve, Belgium).

2.1.1. French-speaking children with severe DLD

To allow a better understanding of the underlying language processes in children with severe DLD, the intragroup heterogeneity was reduced by selecting only children with severe DLD. Nineteen children with severe DLD (15 boys, 4 girls) aged between 9.24 and 12.90 years (*M* = 11.01; *SD* = 1.23) participated in the study. They were recruited from specialized social health care establishments providing education and care to children with severe DLD, and from speech and language therapists in private practice or social health care services following children receiving multidisciplinary care and regular schooling. They all received speech and language therapy and were labelled with a clinical diagnosis of severe DLD ("dysphasia") by a multidisciplinary team (neuropsychologists, speech and language pathologists, and child neurologists) from the neuropediatric hospital departments of the Hauts-de-France (France). Accordingly, the language deficit could not be explained by a psychological or neurological disorder, or by any auditory impairment. None of these children were diagnosed with dysarthria or childhood apraxia of speech. Yet, they were likely to incur certain speech motor problems (Sanjeevan et al., 2015). Repetition of pseudowords and sentences are among the best diagnosis tasks for DLD (Archibald & Joanisse, 2009; Conti-Ramsden, Botting, & Faragher, 2001; Leclercq, Quémart, Magis, & Maillart, 2014; Riches, 2012; Thordardottir et al., 2011). Moreover, expressive morphosyntax of these children is known to be weak (Leonard, 2014). This is why the severity of DLD of each child was confirmed by his/her scores in each of the following three tasks: pseudoword repetition, sentence repetition, and sentence completion, using two standardized language battery of tests (ELO, Khomsi, 2001; L2MA-2, Chevrie-Muller et al., 2010, see the Materials section for more details). In each of these tasks, each child obtained a score below -1.64 *SD* (the 5th percentile), which is a pathological threshold used for the definition of severe DLD and corresponds to the 5% cut-off generally applied in group analyses in human sciences. Regarding written language, each child with a severe DLD was exposed to explicit learning to read for more than one year. Among the 19 children with a severe DLD, 17 (approximately 90%) had a reading delay of more than 24 months on the Alouette reading aloud test (see Materials section), one had a delay between 18 and 24 months, and one had a delay of 9 months. These results are consistent with other studies with children with significant language impairment (Haynes & Naidoo, 1991; Macchi et al., 2014).

2.1.2. Control children

Children were recruited from mainstreams schools. They had neither repeated nor skipped grades. None of them had hearing loss, a speech sound disorder, or a developmental language disorder. For the subtests of pseudoword repetition and sentence completion (see the Materials section), the scores of each control child were above -1.28 *SD* (the 10th percentile). No child was dyslexic: no delay above 11.00 months was observed with the "*Alouette*" test (Lefavrais, 1967), bearing in mind that the pathological threshold is between 18 and 24 months (Casalis, 2004).

Matching between the severe DLD group and each of the control groups was one-to-one matching, done in such a way as to optimize matching as a priority on reading level for RC children, and on chronological age for AC children, and secondarily on sex. The RC group comprised 19 children (14 boys, 5 girls) aged 7.34 to 9.53 years (*M* = 8.12; *SD* = 0.52). They were enrolled in Grades 2 to 4. This matching was done on the basis of reading level, that is on the percentages of correct answers for the words of the visual lexical decision task (children with DLD: 89.21 % of correct answers on average, RC children: 89.21%, Table 2). Reading these words calls upon both the phonological and the orthographic routes (see Materials section for details). With this matching, it turned out that children with severe DLD and RC children were similar with respect to their general reading aloud level (in years) as measured by the French Alouette reading test (Lefavrais, 1967), with objective and subjective scorings (see the Materials section for more details). Matching on the reading level with the Alouette test is frequently used in studies comparing two groups of the same reading level in French (e.g., Demont, 2003; Quémart & Casalis, 2017).

The AC group comprised 19 children (16 boys, 3 girls) aged 9.35 to 12.32 years (*M* = 10.84; *SD* = 0.92). They were enrolled in Grades 4 to 7.

Chronological age, nonverbal intellectual abilities, spoken language and reading aloud skills of the three groups are presented in Table 1. Reading skills for words of the lexical decision are shown in Table 2. Comparisons between groups (using Bonferroni tests in a one-way ANOVA) are shown in both tables. There was a significant difference for chronological age between children with severe DLD and RC children but not between children with severe DLD and AC children. For lexical decision of the words and for reading aloud of the Alouette text, there was a significant difference between children with severe DLD and AC children but not between children with severe DLD and RC children. Regarding nonverbal intellectual abilities, there was no significant difference between the groups, although the raw scores of RC children were lower than those of children with severe DLD, which were lower than those of AC children. For pseudoword repetition and sentence completion, children with severe DLD scored significantly lower than RC children, whose scores were lower than those of AC children.

INSERT TABLE 1 ABOUT HERE

2.2. Materials

Children with severe DLD were administered all nine tasks described below. We administered only 5 of the 9 tasks to RC and AC children: The Matrices subtest of the WNV battery (nonverbal intellectual skills), the repetition subtest of pseudowords of the L2MA-2 battery (phonological skills), the sentence completion subtest of the ELO battery (morphosyntactic expressive skills), the Alouette reading of a text, the visual lexical decision task (reading skills).

2.2.1. Nonverbal intellectual skills

Nonverbal intellectual skills were assessed with the Matrices subtest of the WNV battery (Wechsler Nonverbal Scale of Ability, Wechsler & Naglieri, 2009). The child observes several geometric figures of which part is missing and point to the missing part from four or five proposals presented below each figure.

2.2.2. Spoken language skills

Phonological skills

The repetition subtest of pseudowords of the standardized L2MA-2 battery was used (Oral language, written language, memory, and attention skills, Chevrie-Muller et al., 2010). This semi-computerized battery aims to assess spoken and written language skills, memory and attention of children aged 7 to 12. This subtest consists of the repetition of 20 pseudowords (10 with a simple phonological structure, 10 with a complex structure), starting with short items (two syllables) and continuing with longer ones (up to five syllables). Pseudowords were recorded on a laptop computer and the child heard them with a headset and repeated them. One point was assigned to each pseudoword correctly repeated.

Lexical skills

Lexical receptive skills were assessed with the '*Lexique En Réception* [Receptive lexicon] subtest from the standardized ELO [Oral language assessment] battery (Khomsi, 2001). This battery includes several subtests to describe and assess several spoken language skills in children of kindergarten or elementary age. For this subtest, of four pictures, the child had to point to the one corresponding to the word produced by the examiner (20 items).

Lexical expressive skills were assessed with the '*Lexique En Production'* [Productive lexicon] subtest from the ELO battery (Khomsi, 2001). The child had to name pictures and was assigned one point to each correct answer (50 items).

Morphosyntactic skills

Morphosyntactic receptive skills were assessed with the '*Compréhension'* subtest from the ELO battery. The child had to point to one of the four pictures corresponding to the sentence spoken by the examiner. One point was assigned to each correct answer (32 items).

Morphosyntactic expressive skills were assessed with the '*Production D'Énoncés*' [Sentence completion] subtest also from the ELO battery. A picture helped the child to complete a sentence triggered by the examiner (e.g., Examiner: "Here, the car *pushes the truck*; here, the car..."; Child: "*is pushed by the truck*"), with one point assigned to each correct answer (25 items).

Sentence repetition task

The above mentioned L2MA-2 subtest involves the repetition of sentences, with one point assigned to each word properly produced (9 to 15 sentences, 98 to 192 words, according to the child's age).

2.2.3. Reading skills

Aloud reading of a text

To assess aloud reading of a text, the "*Alouette*" test was used (Lefavrais, 1967). It is the most frequently used in France, both for clinical and research purposes (Bertrand, Fluss, Billard, & Ziegler, 2010). The final score is determined by both accuracy and speed and provides the child's reading age. The test was scored in two ways. In the first method, all reading mistakes were scored (objective scoring). The second method followed the test instruction manual: a mistake probably due to an expressive phonological disorder was disregarded. For instance, the word '*doux*' - /du/ - [soft] read as /tu/ was not considered a mistake if the child often produced /t/ instead of /d/ in everyday life (subjective scoring).

Visual lexical decision task

We created a visual lexical decision task (Appendix A). For the comparison with RC children, five conditions were used: target words, pseudohomophones, phonologically close pseudowords, phonologically distant pseudowords and filler words.

In the first condition (word condition), there were 20 real words (e.g., voiture - /vwatyʁ/ - [car]). The second, third and fourth condition, each included 20 pseudowords respectively associated to the 20 target words through three different modifications. This route ensured a fully reliable matching between the four conditions (target words and pseudowords). As in pseudowords all items were orthographically dissimilar to words. The visual distance was also manipulated.

In the pseudohomophone condition, there were 20 pseudohomophones. Each item was phonologically similar to its target word, but orthographically different. In terms of visual similarity, they were considered distant: 30% of the pseudohomophones had the same number of letters as its target word but one letter was substituted with a visually distant letter (c/k, c/s, a/e, g/j, e.g., cartable/kartable); 50% had one more letter (or less) than its target word (r, e, l, p, t, a, e.g., voiture/voiturre); 20% had one more letter (or less) and also had one letter substituted (o/au, ê/ai, f/ph, c/qu, e.g., zero/zérau).

In the phonologically close and visually distant pseudoword condition, there were 20 pseudowords that were phonologically close to their corresponding target words, i.e., differing by one articulatory feature: the place of articulation or the character voice vs. the unvoiced (e.g., voicure - /vwakyʁ/). These pseudowords were visually distant from their target words: 20% had one more letter (or less) and also one letter substituted (g/ch, j/ch, ph/v, ch/j; e.g., nuage/nuache); 80% had the same number of letters but one letter was substituted with a visually distant letter (c/t, t/d, s/f, j/z, d/g, v/f, c/g, s/z, e.g., camion/tamion).

In the visually close and phonologically distant pseudoword condition, there were 20 pseudowords which were visually close to their corresponding target words (in Comic Sans font). Each pseudoword had the same number of letters as the target word, but one visually close letter was substituted. This slight visual difference corresponded either to the addition of a line (l/t, e.g. joli/joti), the addition or removal of a tiny curve (t/f, b/h), to the transformation of a line into a bend and conversely (o/a), or to a horizontal symmetry (n/u). These pseudowords had a large phonological distance from the corresponding target words, i.e., differing from them by 2.2 (on average) articulatory features.

A fifth condition of filler words was added with 40 items, to reach a 50% level of correct answers in case of random response. Thus, the total number of items was 120.

Several psycholinguistic variables were controlled. The target and filler words had a low acquisition age (M = 2.44 years, SD = 0.77, according to the judgment of 22 adults) in order to decrease the influence of the child's vocabulary knowledge. Moreover, to base the group matching on both the phonological and the orthographic reading routes, using the French Manulex database (Ortéga & Lété, 2010), we controlled the cumulative written frequency and the consistency of the word condition. Consistency is a statistical index that measures the level of ambiguity in the phonological coding of written words (for the grapheme-phoneme correspondences), and in the orthographic coding of spoken language (for the phoneme-grapheme correspondences). We took into account the average of grapho-phonological and phono-graphemic consistencies[1], based on the textual frequency of words (Peereman, Lété, & Sprenger-Charolles, 2007). Consistent and rare words tend to be processed by the phonological reading route, while inconsistent and frequent words tend to be processed by the orthographic route.

The words selected in the lexical decision task were low to high frequency (M = 190.44; SD = 266.23; Mdn = 94.24; range: 26-2140) and low to high consistency (M = 80.13, SD = 9.53, Mdn = 81.05, range: 45-98). There was the same number of words (targets as well as fillers) in each of the five following groups: very low frequency (25-50 occurrences per million), low frequency (50-75 per million), moderate frequency (75-150 per million), high frequency (150-250 per million), and very high frequency (> 250 per million). For each frequency group, a quarter of the words (targets as well as fillers) had a low consistency (≤ 75%), half had a moderate consistency (75-85%), and a quarter had a high consistency (> 85%). Numbers of letters, $F(4, 115) = 1.50$, $p = .21$, $\eta^2 = .05$, phonemes, $F(4, 115) = 1.38$, $p = .24$, $\eta^2 = .04$, and syllables ($F < 1$) were

[1] Grapho-phonological consistency is equal to the frequency with which a grapheme-phoneme association appears in children's school textbooks, divided by the total frequency of the grapheme regardless of its pronunciation, multiplied by 100. Phono-graphemic consistency is equal to the frequency with which a phoneme-grapheme association appears regardless of how the phoneme is spelled, divided by the total phoneme frequency, multiplied by 100.

similar in the five conditions. Comparing the filler words condition to the target words condition, there was no significant difference in the written cumulative frequencies ($U = 390$, $p = .88$, $z = -0.16$), the cumulative frequencies of orthographic neighbors ($U = 346$, $p = .37$, $z = -0.90$), the consistencies ($t < 1$), the acquisition ages ($t < 1$), or the grammatical categories, $\chi^2(1) = 0.40$, $p = .53$, $V = 0.08$. The locations (within the items) of the orthographic modifications were similar in the three pseudowords conditions, $F(2, 57) = 1.69$, $p = .19$, $\eta^2 = .06$. For the pseudowords with the same number of letters as their target words, the visual distances between these pseudowords and their targets were different for the three pseudoword conditions, $\chi^2(2) = 27.41$, $p < .01$ (Courrieu, Farioli, & Grainger, 2004). It was smaller for the visually close and phonologically distant pseudowords (mean rank of visual distance: 11.25) than for both the pseudohomophones (mean rank: 33.67), $U = 2$, $p < .01$, and for the phonologically close and visually distant pseudowords (mean rank: 29.75), $U = 13$, $p < .01$; while it was similar for pseudohomophones and visually distant and phonologically close pseudowords, $U = 33$, $p = .79$. The locations (within the items) of the phonological modifications were similar for phonologically close or distant pseudowords, $t(38) = 1.09$; $p = .28$, $d = 0.34$.

For the word conditions (targets and fillers), internal consistency was satisfactory (Kuder-Richardson Formula 20: 0.80). All the children performed the task at a level significantly better than chance with the binomial test, for the word condition (target plus filler), and for the condition of words plus pseudowords (ps < .05).

2.3. Procedure

The experiment was conducted in 5 sessions including 28 tasks for 7 children with severe DLD, in 3 sessions including 17 tasks for 12 children with DLD, and in 3 sessions including 12 tasks for the RC and AC children. Only nine tasks (administered to all children) are analyzed in this article. For all children, each session was individual, containing several tasks and lasting 30 to 40 minutes. There were approximately 16 days between each session. The tasks were presented in a fixed order; tasks related to nonverbal intellectual abilities and spoken language were administered before those of written language. We have taken into account possible individual constraints (e.g., delaying a task if the child lost concentration).

For the visual lexical decision task, words or pseudowords were displayed on a laptop screen (size: 15.6 inches). The child was sitting at a comfortable distance and used an Xbox 360 console controller, with a corresponding button for each hand. S/he had to decide if the sequence of letters displayed on the screen was a true word or a false word. S/he was told that a true word was a word that exists and was spelled correctly, and a false word was a word that does not exist or was misspelled. For a target or filler word, the child had to quickly press the button using their dominant index finger. For a pseudoword, s/he had to press the button with their nondominant index finger. The software E-prime 2 (Schneider, Eschman, & Zuccolotto, 2012) was used to present the stimuli and record accuracy and latency of the answers. The 120 items of the task were split into two blocks of 60 items, each block presented during one of the sessions. The blocks were presented in a counterbalanced order across participants. In each block, there were two of the four items (target word plus its three associated pseudowords), e.g., voiturre and voicure in the same block. The items were presented in randomized order, except that two items associated to the same word were never displayed consecutively (e.g., never voiturre after voicure or voiture). The task started with twelve prior trials. There was a short break every 20 items. For each item, the following procedure was used. A fixation white cross (+) was displayed in the middle of the black screen for 1000 ms. Then a white rectangle was presented for 60 ms, followed by the written item (word or pseudoword) displayed on a black background in white bold 25-point Comic Sans font. The item remained visible until the child pressed a button, which triggered the next fixation cross. However, if the child did not press a button before 5000 ms the item disappeared and a black screen was shown for an additional 3000 ms where the child could still press a button, which triggered the next fixation cross. Finally, if the child pressed no button before 8000 ms, the next cross (+) appeared.

2.4. Data analysis

Our aim was to analyze, within the dual route model, the reading routes in children with severe DLD, by comparing their performance to AC and RC children, using a lexical decision task. For this purpose, percentage of correct answers for pseudowords were computed for the three groups. Latency scores were not computed: the high percentage of errors for pseudowords makes the use of reaction time data less reliable, as suggested in several developmental studies on reading acquisition (e.g., Goswami, Ziegler, Dalton, & Schneider, 2001; Grainger, Lété, Bertand, Dufau, & Ziegler, 2012).

The mean percentages of correct answers were calculated across items for the by-participant analysis (F_1) and across participants for the by-item analysis (F_2). Data were processed using ANOVA with repeated measures. *Group* (DLD, RC, AC) was treated as a *between factor* in the by-participant analyses and as a *within factor* in the by-item analyses. *Type of pseudowords* (pseudohomophones, phonologically close and visually distant, visually close and phonologically distant) was treated as a *within factor* in the by-participant analyses and as a *between factor* in the by-item analyses.

In order to check *a posteriori* the validity conditions of the ANOVA models, quantile-quantile plots were used and showed that the residual errors had a normal distribution. We also checked that their variance was independent of the predicted value.

3. Results

Percentage of correct answers for pseudowords for each of the three groups are presented in Table 2.

INSERT TABLE 2 ABOUT HERE

There was a main effect of group, $F_1(2,54) = 23.97$, $p < .01$, $\eta^2_p = .47$, $F_2(2,114) = 177.62$, $p < .01$, $\eta^2_p = .76$: the scores of the children with severe DLD did not differ from those of the RC children; each of these two groups was less successful than the AC children (DLD: 65.61%; RC: 65.79%; AC: 89.82%). There was a main effect of pseudoword type, $F_1(2,87) = 99.19$, $p < .01$, Greenhouse-Geisser corrected, $\eta^2_p = .65$, $F_2(2,57) = 22.20$, $p < .01$, $\eta^2_p = .44$. In the by-participant analysis, the phonologically close and visually distant pseudowords were processed more successfully than the visually close and phonologically distant pseudowords, the latter being processed more successfully than the pseudohomophones (phonologically close: 83.60%, phonologically distant: 78.68%; pseudohomophones: 58.95%). In the by-item analysis, the achievement level of the phonologically close and visually distant pseudowords was similar to that of the visually close and phonologically distant pseudowords, each of these two types of pseudowords being better achieved than the pseudohomophones.

There was a significant interaction between group and pseudoword type, $F_1(3, 87) = 18.70$, $p < .01$, Greenhouse-Geisser corrected, $\eta^2_p = .41$, $F_2(4,114) = 29.38$, $p < .01$, $\eta^2_p = .51$ (Figure 1). The multiple comparison tests of Bonferroni confirmed a difference between each of the three groups for the pseudohomophones. The children with severe DLD were more successful than the RC children (F_1: $p = .03$, $d = 0.79$, F_2: $p < .01$, $d = 0.91$), but less successful than the AC children, F_1: $p < .01$, $d = -1.84$, F_2: $p < .01$, $d = -2.93$, (DLD: 53.95% of correct answers; RC: 38.68%; AC: 84.21%).

For the phonologically close and visually distant pseudowords, a nonsignificant trend toward a difference between children with severe DLD and RC children was observed in the by-participant analysis (F_1: $p = .06$, $d = -0.65$), the difference between these two groups was significant in the by-item analysis (F_2: $p < .01$, $d = -1.05$): the children with severe DLD demonstrated poorer achievement than the RC children. The children with severe DLD also demonstrated poorer achievement than the AC children, F_1: $p < .01$, $d = -1.63$, F_2: $p < .01$, $d = -4.03$. The RC children did less well than the AC children F_1: $p = .01$, $d = -1.46$, F_2: $p < .01$, $d = -2.75$ (DLD: 71.58% of correct answers; RC: 82.63%; AC: 96.58%).

For the visually close and phonologically distant pseudowords, children with severe DLD did not differ from the RC children (F_1: $p = .72$, F_2: $p = .20$) but did differ from the AC children (F_1: $p < .01$, $d = -1.27$, F_2: $p < .01$, $d = -1.08$): children with severe DLD were less successful than the AC children. The RC children did less well than the AC children F_1: $p = .01$, $d = -1.33$, F_2: $p < .01$, $d = -0.77$ (DLD: 71.32% of correct answers; RC: 76.05%; AC: 88.68%).

INSERT FIGURE 1 ABOUT HERE

4. Discussion

This study aimed to analyze the routes of written word recognition in children with a severe DLD compared to RC children and AC children, by using a lexical decision task with three pseudoword conditions: (1) pseudohomophones to assess the use of the orthographic reading route; (2) phonologically close and visually distant pseudowords to assess the use of the phonological reading route, and the precision of phonological representations; (3) visually close and phonologically distant pseudowords to assess the precision of orthographic representations.

There was a significant interaction between groups and pseudoword types indicating that the three groups of children did not process pseudowords in the same way. The scores of children with severe DLD were lower than those of AC children for each of the three pseudoword types. The same was true for RC children's scores compared to AC children. Compared to RC children, for the pseudohomophones the scores of children with a severe DLD were higher, for phonologically close and visually distant pseudo-words they tended to be lower, for visually close and phonologically distant pseudowords they were similar.

We had predicted that, due to their significant phonological weaknesses, children with severe DLD would be less successful in rejecting phonologically close and visually distant pseudowords (e.g., voicure - /vwakyʁ/) compared to RC children. Our results confirm this hypothesis and can be explained by the fragility of the phonological reading route of these children. Their knowledge of grapheme-phoneme conversions would not be sufficiently correct or stable, to allow them to reject a pseudoword moving away from the true word by a single phoneme-grapheme: these pseudowords would be erroneously identified as true words (e.g. voicure - /vwakyʁ/ read as voiture - /vwatyʁ/). One alternative hypothesis is that children with severe DLD have difficulty rejecting phonologically close and visually distant pseudowords because they have strong mastery of all the grapheme-phoneme conversions of these pseudowords (e.g., voicure read /vwakyʁ/) but have imprecise phonological representations of the true words related to the pseudowords. Indeed, in spoken modality, these children experience difficulties in rejecting pseudowords that differ slightly from familiar words (Maillart et al., 2004). A third interpretation is possible. Phonemes-graphemes correspondences are based on the establishment of solid links between phonemic representations - phonemes - and orthographic representations - graphemes - (Van Reybroeck & Michiels, 2018). The imprecision of the phonemic representations of these children may have hindered their learning of graphemes-phonemes correspondences. Their lack of mastery of these correspondences would have reduced the possibility that exposure to the orthographic form of words would correct their imprecise phonological representations, despite on average 4.5 years of learning to write[2]. Our experimental design does not allow us to adjudicate between these three hypotheses. The examination of these hypotheses could be the subject of a future research project.

We also predicted that because of their phonological weaknesses, children with a severe DLD would rely more on their orthographic reading route than on their phonological route: they would be more successful than RC children in rejecting pseudohomophones (pseudowords with a phonological form identical to true words and a different orthographic form). This was the case. Children with severe DLD therefore seem to use the orthographic route more than RC children.

We also predicted that the spelling representations of these children would be imprecise, since accurate phonological recoding is needed to establish precise orthographic representations: we thought they would be less successful than RC children for visually close and phonologically distant pseudowords. In reality, both groups did not differ. The precision of the orthographic representations of children with severe DLD is therefore that expected for their reading level.

Overall, compared to RC children, children with severe DLD seem to rely more on their orthographic route of reading than on their phonological route. The balance between their two reading routes does not seem to correspond to that expected for their reading level. Thus, the results somewhat support our hypothesis that children with DLD show different, deviant development of reading routes.

Compared with AC children, we predicted that children with severe DLD would be significantly less successful for all the pseudowords (considered together), and for each of the three pseudoword conditions. This was indeed the case. Their lower success rates for the

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2 Learning to read begins around the age of 6.5 in France. The average age of children with severe DLD is 11 years. Therefore, they started learning to read approximately 4.5 years before.

phonologically close and visually distant pseudowords, compared to AC children, suggests that the phonological weaknesses of these children impede the development of their phonological reading route. Their lower success rates for the pseudohomophones and for the visually close and phonologically distant pseudowords suggests that children with severe DLD have a less efficient orthographic reading route and that their orthographic representations are less precise than AC children. This can be explained by the fact that the phonological reading route is needed to establish accurate orthographic representations (Share, 1995, 2008; Sprenger-Charolles et al., 2003; Ziegler et al., 2014). These results suggest that children with severe DLD do not compensate for the weakness of their phonological reading route by further developing their orthographic route. Indeed, if it were a true compensation, children with a severe DLD would be at least as effective as AC children, for all the pseudowords (considered together) and for the pseudohomophone condition. This was not the case. It is more likely that their phonological difficulties hinder the development of their phonological reading route, which in turn impedes the development of their orthographic route. In short, their phonological difficulties seem to hinder the development of their two reading routes.

Our results are consistent with the two studies that, to date and to our knowledge, have examined reading routes in children with SLI (Bird et al., 1995; Macchi et al., 2014). These two studies, one with native English-speakers and the other with native French-speakers, show an increased lexicality effect in children with SLI compared to typically developing children of the same general reading level and suggest a weakness in their phonological route. Both of these studies used an aloud reading task, where results could have been biased because children with SLI frequently exhibit speech motor difficulties (Sanjeevan et al., 2015). Using a silent reading task, the present study confirms the difficulties in written word recognition of children with DLD, and the imbalance between their two reading routes compared to children of the same reading level.

Our results are also in line with several studies showing a weakness of the phonological route of spelling in children with SLI. Firstly, English-speaking children with SLI, aged 7-13 years, were assessed in a cross-sectional study using a written narrative task. They made more phonetically unacceptable spelling errors than children with a similar vocabulary level (Bishop & Clarkson, 2003). The second study involving Swedish-speaking children with SLI and control children of the same age evaluated longitudinally in Grades 1, 3, 4 and 12 with an isolated word dictation task in a sentence context (Nauclér, 2004). Here again, they made more phonetically unacceptable errors than the control children. In the third study with a dictation task of graphemes and isolated words, Dutch-speaking children with SLI showed a weakness in grapheme mastery from the beginning of grade 1.

Limitations of the study

The spoken language measures of the control children focused only on their phonological skills (using a pseudoword repetition task) and their morphosyntactic expressive skills (using a sentence completion task), that were within the normal range. We did not collect any measure to assess their lexical receptive skills, their lexical expressive skills, or their morphosyntactic receptive skills. However, several pieces of information suggest that these children did not exhibit any spoken or written language difficulties. They had scores within the normal range at a pseudoword repetition task, which is recognized as a very good tool to distinguish children with DLD from typically developing children (Dollaghan & Campbell, 1998; Ellis Weismer et al., 2000). They were not undergoing any speech or language therapy, prior to or during the study. Their grade level corresponded to their chronological age. Their teachers and parents did not report any particular difficulty with these children. Finally, each of them obtained scores within the normal range for a standardized reading test (the Alouette text reading test).

It might have been interesting to propose a word repetition task to children with a severe DLD to assess how many of them had a speech-and-sound disorder and to more precisely establish the links between speech sound disorder and/or DLD and reading impairment.

Our study suggests that children with severe DLD are likely to rely more on the orthographic route than on the phonological route, compared to typically developing children of the same reading level. This interpretation is based on data collected from 19 children with a DLD, 19 RC children, and 19 AC children. To test the robustness of this result, it would be desirable to carry out identical or similar experiments with other samples, if possible with more participants. For our study, the limited number of participants is explained by our rigorous inclusion criteria aimed at: (1) reducing the heterogeneity of our population by focusing on children with severe DLD (scores below -1.64 *SD* in repetition of pseudowords and sentences, and in sentence completion); (2) ensuring that each child with severe DLD achieves the lexical decision task at a level greater than the random. These criteria were necessary from a methodological point of view.

The first inclusion criteria was to target a specific population - children with severe DLD - to circumscribe our research question. The conclusions suggested by the present study can only be applied to children with severe DLD. Reading routes in children with a less severe DLD remain to be investigated.

4.3. Practical implications

Our results have two practical implications for professionals (teachers and clinicians) educating children with severe DLD. First, since children with severe DLD have a deficit of both reading routes compared to children of the same age, it may be useful to train both in routes.

Secondly, since children with severe DLD appear to rely less on the phonological route than on the orthographic reading route, compared to children of the same reading level, the phonological route has to be trained. For this purpose, a training of phonological abilities (phonemic awareness, grapheme-phoneme conversions) could be especially useful. Some previous studies in children with SLI have confirmed the efficacy of this type of training at the early stages of reading instruction (Gillon, 2000, 2002; Schiff, Ben-Shushan, & Ben-Artzi, 2015). For instance, the longitudinal study of Gillon (Gillon, 2000, 2002) shows that an extensive training of phonemic awareness in children of 5-7 years with SLI enhances not only phonemic awareness but also speech production skills, written word recognition and orthographic skills. In clinical practice, this is indeed what a number of professionals do when they use phonological awareness training, phonic methods for learning to read and programs that develop grapheme-phoneme conversions and decoding. Our results confirm the appropriateness of such methods and suggest using them more extensively in children with severe DLD. In the field of spelling and of learning correspondences between phonemes and graphemes, a new approach has recently been explored with encouraging results (Van Reybroeck & Michiels, 2018). This multiple single-case study suggests that finger-writing intervention (using finger-based exploration of the trajectory of handwritten grapheme production) is more effective than a control intervention, on learning phoneme-grapheme conversions in children with a DLD.

5. Conclusion

Based on the so-called "dual route" model, we analyzed the written word recognition of 19 French-speaking children with severe DLD (average age: 11.01 years) compared to 19 children of the same reading level (RC children, average age: 8.12 years), and to 19 children of the same chronological age (AC children, average age: 10.84 years). It was a visual lexical decision task with words and pseudowords associated with these words: pseudohomophones, pseudowords phonologically close but visually distant to the true words, visually close but phonologically distant pseudowords. The groups did not process the pseudowords in the same way. Children with severe DLD were less successful than AC children with each type of pseudowords. It is possible that their phonological difficulties hinder the development of their phonological reading route which, in turn, hinders the development of their orthographic route. Children with severe DLD were more successful than RC children for pseudohomophones, tended to be less successful for phonologically close and visually distant pseudowords, and were similarly successful for visually close and phonologically distant pseudowords. These results suggest that children with severe DLD do not simply present a homogeneous delay in their ability to recognize written words but rather a deviant development compared to RC children, with a greater reliance on the orthographic reading route rather than on the phonological route. Studies comparing the effectiveness of different types of interventions improving children's reading performance with a DLD are needed.

Acknowledgments

The authors are grateful to the Region of Hauts-de-France for the grant that made this study possible. They are also grateful to the children, their parents, their schools and institutions, in particular the Linselles ISETA and SESSD, the SESSADs of Ronchin IRPA and Arras, and the Liévin and Longuenesse CLIS-SESSADs. Thanks are also due to C. Dudenko and M. Gourdin for help in data collection, and to the multidisciplinary team of the Saint-Vincent neuropediatric department for lively discussions that enriched reflection about learning disorders. We sincerely thank three reviewers for their constructive suggestions on an earlier version of this manuscript, and M. Maher for proofreading it.

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Table 1. Chronological age, nonverbal intellectual abilities, spoken language and reading aloud skills of children with severe developmental language disorder (DLD), reading control (RC) children, and age control (AC) children.

Characteristics		Children with severe DLD (*n* = 19)	RC children (*n* = 19)	AC children (*n* = 19)	Differences between the groups		
		M (*SD*) Range	*M* (*SD*) Range	*M* (*SD*) Range	Children with severe DLD vs. RC children	Children with severe DLD vs. AC children	RC children vs. AC children
Chronological age	Years	11.01 (1.23) 9.24 – 12.90	8.12 (0.52) 7.34 – 9.53	10.84 (0.92) 9.35 – 12.32	$p < .01$ $d = 3.05$	$p = 1$	$p < .01$ $d = -3.64$
Nonverbal intellectual skills, Matrices, WNV	Accuracy (%)	47.63 (10.17) 39 – 78	43.90 (5.27) 37 – 54	51.99 (13.14) 34 – 88			
	z score	-0.16 (0.71) -1.20 – 1.60	0.38 (0.53) -0.50 – 1.40	0.22 (0.93) -1.20 – 2.60			
Pseudoword repetition, L2MA-2	Accuracy (%)	16.67 (12.56) 0 – 44	58.48 (9.86) 44 – 78	68.42 (10.15) 50 – 89	$p < .01$ $d = -3.70$	$p < .01$ $d = -4.53$	$p = .02$ $d = -0.99$
	z score	-3.34 (0.86) -4.48 – -1.71	-0.06 (0.58) -0.78 – 1.19	0.28 (0.62) -1.07 – 1.40			
Word comprehension, ELO	Accuracy (%)	79.21 (7.69) 65-95					
	z score	-1.62 (1.25) -4.17 – 0.83					
Word production, ELO	Accuracy (%)	56.84 (9.53) 44 – 72					
	z score	-1.42 (0.75) -2.63 – -0.25					
Sentence comprehension, ELO	Accuracy (%)	69.74 (16.47) 28 – 87					

	z score	-0.56 (1.60) -5.13 – 1.20					
Sentence completion, ELO	Accuracy (%)	55.58 (17.12) 12 – 76	73.89 (7.93) 60 – 88	87.79 (4.89) 80 – 100	$p < .01$ $d = -1.37$	$p < .01$ $d = -2.56$	$p = .01$ $d = -2.11$
	z score	-4.72 (2.07) -8.90 – -2.12	-0.13 (0.57) -1.04 – 0.92	-0.22 (0.63) -0.94 – 1.41			
Sentence repetition, L2MA-2	Accuracy (%)	60.90 (11.83) 36 – 78					
	z score	-3.72 (1.19) -6.50 – -1.82					
Alouette text, objective scoring of reading level	Years	7.47 (0.79) 6.50 – 9.08	7.82 (0.53) 7 – 9.17	11.09 (1.38) 9.08 – 13.25	$p = 1$	$p < .01$ $d = -3.22$	$p < .01$ $d = -3.13$
Alouette text, subjective scoring of reading level	Years	7.62 (0.86) 6.50 – 9.42	7.82 (0.53) 7 – 9.17	11.09 (1.38) 9.08 – 13.25	$p = 1$	$p < .01$ $d = -3.02$	$p < .01$ $d = -3.13$

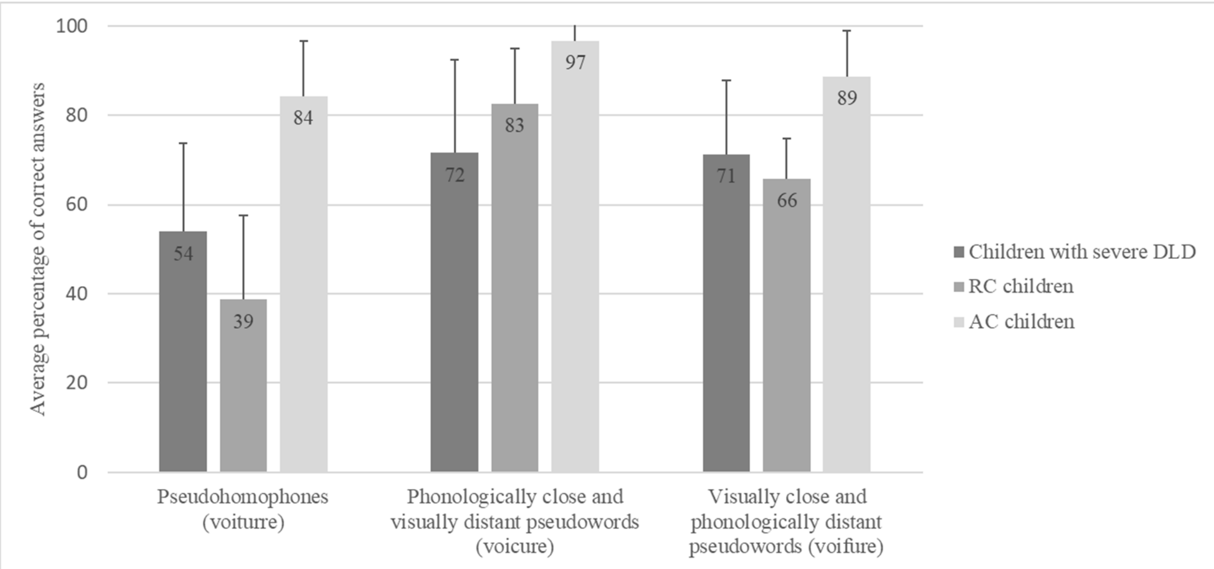
Note. Comparisons (children with severe DLD vs. RC children, children with severe DLD vs. AC children, RC children vs. AC children) were done using Bonferroni tests in a one-way ANOVA. DLD = developmental language disorder; RC = reading control; AC = age control; WNV = échelle non verbale d'intelligence de Wechsler [Wechsler Nonverbal Scale of Ability], Wechsler and Naglieri, 2009; L2MA-2 = langage oral, langage écrit, mémoire, attention, 2ème édition [Oral language, written language, memory, and attentional skills], (2nd ed.), Chevrie-Muller et al., 2010; ELO = évaluation du langage oral [Oral language assessment], Khomsi, 2001.

Table 2. Accuracy scores of words and pseudowords for the visual lexical decision task in children with severe developmental language disorder (DLD), reading control (RC) children, and age control (AC) children.

Visual lexical decision		Children with severe DLD (n = 19)	RC children (n = 19)	AC children (n = 19)	Differences between the groups		
		M (*SD*) Range	*M* (*SD*) Range	*M* (*SD*) Range	Children with severe DLD vs. RC children	Children with severe DLD vs. AC children	RC children vs. AC children
Word accuracy (%)	Targets plus fillers	89.21 (6.32) 78 – 97	89.21 (5.89) 77 – 97	95.26 (3.30) 87 – 100	$p = 1$	$p < .01$ $d = -1.20$	$p < .01$ $d = -1.27$
Pseudoword accuracy (%)	Pseudohomophones	53.95 (19.69) 15 – 90	38.68 (18.92) 10 – 80	84.21 (12.39) 60 – 100	$p = .03$ $d = 0.79$	$p < .01$ $d = -1.84$	$p < .01$ $d = -2.85$
	Phonologically close and visually distant	71.58 (20.89) 30 – 100	82.63 (12.18) 60 – 100	96.58 (5.79) 80 – 100	$p = .06$ $d = -0.65$	$p < .01$ $d = -1.63$	$p = .01$ $d = -1.46$
	Visually close and phonologically distant	71.32 (16.49) 40 – 90	76.05 (8.91) 65 – 95	88.68 (10.12) 60 – 100	$p = .72$	$p < .01$ $d = -1.27$	$p = .01$ $d = -1.33$

Note. Comparisons (children with severe DLD vs. RC children, children with severe DLD vs. AC children, RC children vs. AC children) were done using Bonferroni tests in a one-way ANOVA for words; and using Bonferroni tests in a repeated-measures ANOVA for the pseudowords. DLD = developmental language disorder; RC = reading control; AC = age control.

Figure 1. Percentages of correct answers for the pseudowords of the visual lexical decision task in children with severe developmental language disorder (DLD), reading control (RC) children, and age control (AC) children.



Appendix A. Stimuli for visual lexical decision task.

Words				Pseudowords		
Cumulative written frequency	Target words	Filler words		Pseudohomophones	Phonologically close pseudowords	Phonologically distant pseudowords
Very low (25-50 per million)	citron /sitʀɔ̃/ [lemon]	confiture [jam]	fatigue [tiredness]	sitron /sitʀɔ̃/	cidron /sidʀɔ̃/	citrou /sitʀu/
	ceinture /sɛ̃tyʀ/ [belt]	fraise [strawberry]	genou [knee]	cinture /sɛ̃tyʀ/	ceincure /sɛ̃kyʀ/	ceinfure /sɛ̃fyʀ/
	kangourou [kangaroo] /kɑ̃guʀu/	poulet [chicken]	septembre [September]	cangourou /kɑ̃guʀu/	kandourou /kɑ̃duʀu/	kaugourou /koguʀu/
	zéro /zeʀo/ [zero]	télé [TV]	zèbre [zebra]	zérau /zeʀo/	séro /seʀo/	zéra /zeʀa/
Low (50-75 per million)	camion /kamjɔ̃/ [truck]	cheminée [chimney]	chemise [shirt]	quamion /kamjɔ̃/	tamion /tamjɔ̃/	comion /komjɔ̃/
	cartable /kaʀtabl/ [schoolbag]	leçon [lesson]	mardi [Tuesday]	kartable /kaʀtabl/	carcable /kaʀkabl/	carfable /kaʀfabl/
	copain /kopɛ̃/ [friend]	orange [orange]	papillon [butterfly]	copin /kopɛ̃/	gopain /gopɛ̃/	capain /kapɛ̃/
	viande /vjɑ̃d/ [meat]	singe [monkey]	tenir [to hold]	viende /vjɑ̃d/	fiande /fjɑ̃d/	viaude /vjod/
Moderate (75-150 per million)	attendre /atɑ̃dʀ/ [to wait]	bébé [baby]	cadeau [gift]	atendre /atɑ̃dʀ/	attengre /atɑ̃gʀ/	atteudre /atədʀ/
	dimanche /dimɑ̃ʃ/ [Sunday]	canard [duck]	gentil [kind]	dimenche /dimɑ̃ʃ/	dimanje /dimɑ̃ʒ/	dimauche /dimoʃ/
	joli /ʒoli/ [lovely]	lecture [reading]	midi [noon]	jolli /ʒoli/	zoli /zoli/	joti /ʒoti/
	nuage /nɥaʒ/ [cloud]	sauter [to jump]	ventre [belly]	nuaje /nɥaʒ/	nuache /nɥaʃ/	nuoge /nɥɔʒ/
High (150-250 per million)	éléphant /elefɑ̃/ [elephant]	assez [enough]	blanche [white]	éléfant /elefɑ̃/	élévant /elevɑ̃/	étéphant /etefɑ̃/
	fenêtre /fənɛtʀ/ [window]	château [castle]	chocolat [chocolate]	fenaitre /fənɛtʀ/	senêtre /sənɛtʀ/	fenêfre /fənɛfʀ/
	journée /ʒuʀne/ [daytime]	demain [tomorrow]	musique [music]	journé /ʒuʀne/	chournée /ʃuʀne/	jouruée /ʒuʀɥe/
	sortir /sɔʀtiʀ/ [to go out]	numéro [number]	venir [to come]	sortire /sɔʀtiʀ/	fortir /fɔʀtiʀ/	sorfir /sɔʀfiʀ/
Very high (>250 per million)	beaucoup /boku/ [a lot]	après [after]	dessin [drawing]	beaucou /boku/	beautoup /botu/	heaucoup /oku/
	devant /dəvɑ̃/ [in front of]	histoire [story]	livre [book]	devan /dəvɑ̃/	tevant /təvɑ̃/	devaut /dəvo/
	partir /paʀtiʀ/ [to leave]	maison [house]	neige [snow]	partire /paʀtiʀ/	pardir /paʀdiʀ/	portir /pɔʀtiʀ/
	voiture /vwatyʀ/ [car]	petit [small]	table [table]	voiturre /vwatyʀ/	voicure /vwakyʀ/	voifure /vwafyʀ/