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Morphological awareness in dyslexic university students

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ABSTRACT
This research assessed phonological and morphological awareness in dyslexic university students. We tested 44 dyslexic university students in phonological and morphological awareness tasks and compared their performances to those of both matched chronological age and matched reading level controls. In the phonological awareness tests, the dyslexic university students performed at the same level as their reading level controls. In contrast, they systematically outperformed their reading level controls in the morphological awareness tasks and almost reached the proficiency level of the chronological age controls. The results show that dyslexic university students develop their morphological awareness more than their phonological awareness. These findings add to the evidence indicating that morphological awareness is not deficient in dyslexia and could instead play a beneficial role in the development of literacy skills in this population.

Identifying the deficits responsible for developmental dyslexia has been a central objective of reading research over the past decades. This research has pointed to a causal role of deficits in the phonological skills required for reading acquisition (for a review, see Vellutino, Fletcher, Snowling, & Scanlon, 2004). Dyslexic children perform poorly in comparison to reading level (RL) controls in tasks evaluating phonemic and phonological awareness,[1] phonological short-term memory, rapid access to phonological forms in the mental lexicon, and phoneme–grapheme conversion (for a review, see Snowling, 2001). Alternative explanations to the phonological deficit hypothesis have been proposed, implying the causal role of auditory (Tallal, 1980; Temple et al., 2000), visual/magnocellular (Stein, 2001) or cerebellar deficits (Nicolson, Fawcett, & Dean, 2001). There is nonetheless considerable agreement that phonological deficits constitute a primary cause of developmental dyslexia, and these other deficits are considered by most as being associated (Sprenger-Charolles, Colé, & Serniclaes, 2006).

Deficits in phonemic awareness also characterize dyslexic adults (Ben-Dror, Pollatsek, & Scarpati, 1991; Bruck, 1990, 1993; Chiappe, Stringer, Siegel, & Stanovich, 2002; Pennington, van Orden, Smith, Green, & Haith, 1990). Phonemic awareness in dyslexic readers does not appear to evolve across their lives. For example, Bruck (1992) demonstrated that dyslexic readers do not develop phonemic awareness in accordance with either their chronological age (CA) or their RL. Dyslexic readers apparently reach a level of phonemic awareness beyond which they can no longer improve (Miller-Shaul, 2005). In sum, phonological deficits are persistent and constitute the core characteristic of developmental dyslexia. However, the expression of the phonological awareness deficit may vary across orthographies (Vellutino et al., 2004; Ziegler & Goswami, 2005). While English dyslexic adults are outperformed by both CA and RL controls in phonological awareness tasks (Bruck, 1992, 1993; Chiappe et al., 2002; Pennington et al., 1990), French adult dyslexics are outperformed only by CA controls but not by RL controls (Martin et al., 2010).

MORPHOLOGICAL AWARENESS IN DYSLEXIC CHILDREN AND ADULTS

Whereas the role of phonemic awareness in reading development and in dyslexia has been clearly demonstrated, the role of another metalinguistic ability, that is, morphological awareness, is less well documented and understood. Morphological awareness is defined as the capacity to reflect on and explicitly manipulate orally the morphological structure of words (Carlisle, 1995). Because morphological awareness plays a role in reading acquisition (see, e.g., Carlisle, 1995; Roman, Kirby, Parrila, Wade-Woolley, & Deacon, 2009; Wolter, Wood, & D'Zatko, 2009), it is important to gain knowledge about its development in the dyslexic population. The goal of the present research is to evaluate morphological and phonological awareness in dyslexic university students with the objective of determining the level of development of these reading-related skills in this population. To situate the metalinguistic abilities of the dyslexic university students properly, we compare their performances with those of appropriate CA and RL controls. As proposed by Bryant and Bradley (1985), CA controls allow the performances of the dyslexic readers to be situated with respect to the RL normally expected on the basis of CA, and RL controls on the basis of RL. These comparisons have often been used in the study of dyslexic adults (e.g., Ben-Dror et al., 1991; Bruck, 1990; Chiappe et al., 2002; Martin et al., 2010; Pennington et al., 1990). Moreover, our study, like others in the literature, focused on derivational morphology, because this type of morphology plays a central role in word formation and visual word recognition (see, e.g., Rastle, Davis, Marslen-Wilson & Tyler, 2000). Because our study was conducted on a population reading a language with an alphabetic system (French), our literature review will only include studies concerned with derivational morphology in alphabetic systems (see Muter, Hulme, Snowling, & Stevenson, 2004, for a review on inflectional morphology).

Morphological awareness has been shown to be important in typical reading development and literacy acquisition (Carlisle, 1995; Casalis & Louis-Alexandre, 2000; Mahony, Singson, & Mann, 2000; Roman et al., 2009; Wolter et al., 2009).

Morphological awareness contributes to decoding skills, word recognition skills, and reading comprehension independently of phonological skills (Carlisle, 1995; Casalis & Louis-Alexandre, 2000; Deacon & Kirby, 2004; Mahony et al., 2000; Nagy, Berninger, & Abbott, 2006; Roman et al., 2009; Singson, Mahony, & Mann, 2000) and vocabulary (Casalis & Louis-Alexandre, 2000; Nagy et al., 2006; Singson et al., 2000). Some English regression studies have found that the contribution of morphological awareness to predicting word reading ability increases across the school years (Carlisle, 1995; Singson et al., 2000), while that of phonemic awareness decreases (Singson et al., 2000). However, more recently Roman et al. (2009) did not replicate this dissociation between phonological and morphological awareness with English-speaking children in Grades 4, 6, and 8. Rather, they observed a constant and specific contribution of both abilities across these grades.

Although studies of the development of morphological awareness in dyslexics are relatively rare, there are some findings that have compared the morphological awareness of dyslexic children with that of CA and RL controls. Dyslexic children have been shown to perform less well than CA controls on morphological awareness tasks involving derivational morphology, both in French (Casalis, Colé, & Sopo, 2004; Casalis, Mathiot, Bécavin, & Colé, 2003) and in English (Champion, 1997; Tsesmeli & Seymour, 2006). However, these studies also reported that dyslexic children performed equally well or even better than the RL controls. Taken together, these results indicate that, contrary to phonological awareness, dyslexic children develop morphological awareness to at least the level expected from their RL.

Data on the morphological awareness of dyslexic adults are even scarcer despite their obvious utility for understanding its development across the life span of dyslexic readers. Only a few studies of morphological awareness in dyslexic university students or adults in alphabetic languages have been conducted, and these have always been in English. Tractenberg (2002) found that reading-disabled university students performed worse than typical university students in morphological awareness tasks. Leong (1999) found that learning-disabled university students performed similarly to RL controls in terms of processing speed, but they were more accurate. Finally Rubin, Patterson, and Kantor (1991) found that English-speaking adults with literacy problems performed similarly to 7-year-old normal readers in morphological tasks. However, there are some shortcomings in these studies. In Tractenberg's (2002) study, the dyslexic university students and the typically reading university students were not matched by CA. In Leong's (1999) and Rubin et al.'s (1991) studies, the experimental groups, labelled "learning-disabled" and "poor readers," may have included participants who suffered from other deficits than developmental dyslexia. In addition, the tasks used by Leong and Tractenberg required participants to read, which could have affected negatively the performance of dyslexic readers. In these tasks, the reading difficulties of the dyslexic readers in Leong (1999) probably slowed down their stimulus identification and decreased the validity of the comparison of the level of morphological awareness with that of the control groups.

In sum, dyslexic children do not develop phonemic awareness to a level that might be expected on the basis of their RL. This deficit, which is assumed to be causally linked to their reading deficits, persists into adulthood. In contrast, dyslexic children develop morphological awareness to a level that is lower than that of their CA but that appears to correspond at least to their RL. These difficulties are assumed not to be responsible for their reading deficits. In dyslexic adults, the level of morphological awareness was seldom assessed, and the existing studies had methodological flaws that did not allow clear conclusions to be drawn. Thus, the question of whether morphological awareness difficulties persist into adulthood is still unanswered, and it should be addressed using a carefully designed methodology.

RELATION BETWEEN PHONOLOGICAL AND MORPHOLOGICAL AWARENESS

The relation between phonological and morphological awareness has been examined by several researchers, but no clear picture has yet emerged. In typically developing readers, performances in morphological and phonological awareness tasks are often correlated (Carlisle, 1995; Casalis & Louis-Alexandre, 2000; Colé, Royer, Leuwers, & Casalis, 2004; Roman et al., 2009). For example, Carlisle and Nomanbhoy (1993) showed that the performance of first graders in a phonological awareness task was correlated with that in morphological awareness tasks, suggesting that the developmental trajectory of the two abilities is related (or that they rely on some common processes). However, as we have stated above, morphological and phonological awareness generally contribute independently to reading ability. Thus, Casalis and Colé (2009) showed in a training study that while some processes are shared by both metalinguistic abilities, each appears to have its own specificity and may have partially independent developmental trajectories. It has been shown that the overall developmental trajectory of morphological awareness has a much longer span than that of phonological awareness (Berninger, Abbott, Nagy, & Carlisle, 2010).

Differences between phonological and morphological awareness were evidenced with dyslexic readers too. Dyslexic children who differ in their phonological skills do not differ in their morphological awareness skills, as long as phonological processing required in the morphological task is not too great (Casalis et al., 2004). Elbro and Arnbak (1996) also showed that after specific training on morphological awareness, dyslexic children improved more than controls on morphological awareness tasks but not on phonemic awareness tasks.

PRESENT STUDY

In this study of dyslexic university students, we expect the levels of phonological awareness and morphological awareness to differ. We expect morphological awareness to develop further as compared with phonological awareness, whose development is curtailed (Bruck, 1992; Miller-Shaul, 2005) in the dyslexic population. An explanation for these different developmental trajectories for the two kinds of metalinguistic abilities in our population may well lie in the semantic dimension of morphology. Morphemes convey meaning, and dyslexic readers do not suffer from semantic deficits (Vellutino, Scanlon, & Spearing, 1995). Dyslexic readers rely heavily on semantics when available, as has been demonstrated in word identification studies with dyslexic university students (Bruck, 1990). Thus, dyslexic readers may depend on the semantic dimension of morphology to develop their morphological awareness, which is obviously not possible for the development of phonological awareness. This hypothesis is further supported by a longitudinal study showing that derivational morphological awareness continues to develop after the fourth grade in typically developing readers (Berninger et al., 2010). Consequently, one can expect that dyslexic adults will show higher levels of morphological awareness compared with phonological awareness.

To test this hypothesis, we assessed the levels of phonological and morphological awareness in dyslexic adults with a high level of academic achievement. The dyslexic adults involved in our study were university students or had attended a university in the past. University students generally have considerable exposure to print and have read throughout their lives, which is likely to enhance the development of their metalinguistic skills. Moreover, several authors have suggested that dyslexic university students may have developed compensatory mechanisms to be able to pursue university studies despite their persistent reading difficulties. In particular, Elbro and Arnbak (1996) proposed that dyslexic readers may rely on their morphological skills to compensate for their reading difficulties. Dyslexic university students thus constitute a privileged population for identifying to which extent phonological and especially morphological awareness can develop in readers with dyslexia.

We compared the performance of these dyslexic university students with that of both CA and RL controls. The use of these two control groups allowed us to situate precisely the performance of the dyslexic students with respect to normal reading development and CA. Our study was conducted in French, a language for which the prevalence of dyslexia is not significantly different from that of English-speaking countries (i.e., 5% to 10%; INSERM, 2007).

Comparisons of the phonological awareness of dyslexic university students with that of both CA and RL controls have already been made in French (Martin et al., 2010). Because our phonological awareness tasks and group characteristics are largely comparable to those in Martin et al. (2010), we expect to replicate their results. That is, we expect dyslexic university students to exhibit poorer phonological awareness skills in comparison with their CA controls but to perform at the level of their RL controls.

Comparisons of the morphological awareness of dyslexic university students with that of carefully defined CA and RL control groups will be made for the first time in this study. Our goal is to determine to what extent dyslexic university students have developed morphological awareness. Following Elbro and Arnbak (1996), we expect dyslexic adults to show a more developed morphological awareness performance than predicted, based on their reading skills. Thus, we expect dyslexic university students to consistently outperform their RL controls in the morphological awareness tasks. On the comparison with CA controls, we can put forward two alternative hypotheses. First, we can assume that the semantic dimension of morphological knowledge leads dyslexic university students to develop their morphological awareness to a level equal to that of the CA controls. Second, the persistent phonological difficulties of dyslexics could limit their development of morphological awareness, so that dyslexic university students would be outperformed by their CA controls.

METHOD

Participants

Three groups of 44 participants took part in the present study: dyslexic university students, CA controls, and RL controls. All participants were native monolingual speakers of French and had a nonverbal IQ within the normal range (i.e., at least equal to or above the 10th percentile; Raven's matrices: Raven & Court, 1995; Raven's Coloured Progressive Matrices; Raven, Court, & Raven, 1998). The participants' nonverbal IQ ranged from the 10th to above the 95th percentile.

Dyslexic university students were recruited at the University of Geneva by means of posters, in the Geneva and Lausanne areas (Switzerland) by means of an advertisement in a free local newspaper, at the University of Savoie (Chambéry, France) by a public e-mail sent to all students, and at the Health Center of the University of Grenoble (Grenoble, France) by means of a letter sent to their dyslexic students. To be included in the study, dyslexic participants had to be current or past university students. They also had to (a) be native, monolingual speakers of French; (b) lack any known neurological/psychiatric disorders and report normal or corrected to normal hearing or vision; and (c) have a nonverbal IQ within the normal range (Raven's matrices; Raven & Court, 1995). The majority of our participants had been diagnosed as dyslexic by a speech therapist[2] in their childhood. Those with no diagnosis by a speech therapist[3] at the time of our study (6 out of the 44 participants) had to score 2 *SD* below the control mean on a reading task. We relied on this criterion (see Szenkovits & Ramus, 2005, with self-identified French dyslexic university students for a similar criterion) because no standardized reading test exists in French for adults older than 16 years. The dyslexic university students with no diagnosis by a speech therapist all reported major difficulties in learning to read in their childhood. Moreover, their reading age on the Alouette Test (see below) never exceeded 12 years and 2 months. Finally, on aloud reading of isolated pseudowords, the reading latencies of all these participants were 2 *SD* below the control mean.

Reading scores were obtained using the Alouette Test (Lefavrais, 1967),[4] a standardized French reading test employed in the study of developmental dyslexia in French (e.g., Bogliotti, Serniclaes, Messaoud-Galusi, & Sprenger-Charolles, 2008; Casalis et al., 2004; Martin et al., 2010; Sprenger-Charolles, Colé, Kipffer-Piquard, Pinton, & Billard, 2009; Ziegler et al., 2008; Ziegler, Pech-Georgel, George, & Lorenzi, 2009). This test requires participants to read aloud a meaningless text within a 3-min time limit. The text consists of real words in meaningless but grammatically correct sentences. Each participant's performance is converted into a reading age according to a standard procedure taking into account both the time taken to read and the number of errors. The Alouette test is standardized for the reading performance of children aged from 5 to 14, so the highest possible reading age is 14 (which was reached by the CA controls). So as to avoid ceiling effects, we calculated a composite score (called the "reading score") that took both accuracy and speed into account. To do so, for each participant, we calculated a z score for speed and a z score for accuracy, with CA controls as the reference group, and we then averaged these z scores. If the participant did not finish reading the text within the 3-min time limit, his/her raw performance in terms of speed and accuracy was adjusted to the whole text on the basis of the performance for the number of words read. Finally, the z scores signs were adjusted so that negative z scores correspond to a bad performance (higher number of errors or longer reading time).

The dyslexic university students were matched with two control groups, one of the same CA and the other of the same RL. In both control groups, the participants had normal literacy skills and no previous history of any learning disability. In addition, dyslexic participants were matched pairwise with both control groups by gender and country of education. All three groups were composed of 44 participants each (25 females, 19 males), of which 13 were educated in Switzerland and 31 in France. The CA controls were recruited from the university student bodies of the University of Geneva, the University of Savoie, and the University of Provence. The RL controls were recruited from elementary schools and middle schools in Geneva, Annemasse (France), and in the Academy of Aix-en-Provence (France).

The dyslexic participants were between the ages of 18 and 47 ($M = 25.56$, $SD = 6.91$). They all reported histories of reading difficulties, and their mean reading score was –3.38 ($SD = 2.12$), which corresponds to a mean reading age of 11.3 years. Twenty-seven had received a diagnosis of dyslexia during childhood and 11 after the age of 14.

The age of the CA controls ranged from 18 to 48 years ($M = 25.56$, $SD = 6.64$), and their mean reading score was 0.00 ($SD = 0.70$). The mean reading score of the dyslexic participants differed significantly from that of CA controls, t (86) = 10.03, $p < .001$, whereas the CA of the two groups did not, t (86) < 1, *ns*.

The age of the RL controls ranged from 7 to 15 years ($M = 11.40$ years, $SD = 1.75$). Their mean reading score was –3.48 ($SD = 2.49$), which did not differ significantly from the dyslexic participants' score, t (86) < 1, *ns*, whereas their CA did, t (86) = 13.18, $p < .001$.

Experimental tasks

We used three existing tasks to test phonological awareness, and we developed three new oral tasks to evaluate morphological awareness.

Tests of phonological awareness. Three tests were used to assess phonological awareness: the trisyllabic (TRISYL) test, the consonant–vowel–consonant (CVC) test, and the consonant–consonant–vowel (CCV) test. These were taken from EVALEC, a computerized battery of tests of reading and reading-related skills for French elementary school children (Sprenger-Charolles, Colé, Béchennec, & Kipffer-Piquard, 2005). All involved the deletion of the first part (syllable or phoneme) of a pseudoword and measured both accuracy and speed.

TRISYL TEST. In this test participants had to delete the first syllable of a trisyllabic pseudoword. This test includes 10 items with a simple syllabic structure (consonant–vowel; e.g., *povidu*). Items were prerecorded in order to ensure identical stimuli and to avoid lip-reading. They were presented to the participant through headphones. The test was computer driven, and each trial was carried out as follows: the experimenter clicked on the mouse to trigger the item presentation. As soon as the participant gave his/her answer, the experimenter clicked on the mouse again to stop the chronometer and measure response times. Before the experiment began, participants received one example and one training trial with feedback.

CVC TEST. In this second test participants had to delete the first phoneme of a pseudoword composed of three phonemes. This test included 12 items with a CVC structure (e.g., *puf*). The procedure was identical to the TRISYL test.

CCV TEST. This test was similar in all respects to the CVC test, except that the 12 pseudowords had a CCV structure (e.g., *klo*).

Tests of morphological awareness. We developed three computer-driven oral tasks to evaluate the morphological awareness of our participants: the suffixation decision task, the prefixed word detection task, and the suffixed word detection task. These tasks tested explicit morphological awareness[5] and measured the participants'performance in terms of accuracy and also in terms of speed for the suffixation decision task. They were designed to meet several criteria. First, we limited the phonological difficulty of these tasks, which is known to affect the dyslexics' performance in morphological awareness tasks (Casalis et al., 2004; Fowler & Liberman, 1995; Shankweiler et al., 1995). To do so, we limited to three the number of words the participants had to remember to perform the task. Second, we ensured that the participants' response could not be based exclusively on the form properties of the words. To do so, all the monomorphemic items we used were pseudoaffixed. Pseudoaffixed words contain affixlike sequences that are not actually suffixes, as in the case of pseudosuffixed words (e.g., *mistr<u>al</u>*), or not prefixes, as in the case of pseudoprefixed words (e.g., *<u>en</u>dive*).

The three morphological awareness tasks were always presented in the same order: first, the suffixation decision task; second, the prefixed word detection task; and third, the suffixed word detection task. Before testing the participants, the experimenter informed them of the definition of suffixes and prefixes and trained them on this distinction. No item was used in both the training and the experimental tasks.

MORPHOLOGICAL TRAINING. At the beginning, the experimenter gave a definition of an affix. He/she then gave an example of a suffixed and of a pseudosuffixed word, and explained each time why the word was suffixed or not. The same was done with a prefixed and a pseudoprefixed word. At the end of this training the experimenter asked the participant to decide whether a suffixed and a pseudosuffixed word were suffixed, and whether a prefixed and a pseudoprefixed word were prefixed. The experimenter gave feedback to the participants for each response, explaining if necessary why their answer was wrong. At the end of this training phase, the participants could start with the morphological awareness tasks.

SUFFIXATION DECISION TASK. In this task, participants made a speeded manual forced choice of words heard in isolation. In each trial, they had to decide whether the word they heard was suffixed or not. The material consisted of 24 bisyllabic and 24 trisyllabic words, half being suffixed (e.g., *frontal*) and half being pseudosuffixed (e.g., *mistral*) words. All the words were of low written ($M = 2.08$, $SD = 2.16$) and spoken frequency ($M = 0.94$, $SD = 1.26$) according to Lexique, a lexical database for adults in French (New, Pallier, Ferrand, & Matos, 2001). Suffixed and pseudosuffixed words were matched pairwise for word endings, number of syllables, and grammatical class, and did not differ in their oral frequency, t (46) < 1, *ns*, and written frequency, t (46) = 1.13, $p > .20$. Suffixed words had a root ranging from low to high frequency (range of occurrences per million: oral frequency = 2.46–570.67, written frequency = 0.88–105.61), with a greater majority of high-frequency roots (66% oral frequency and 92% written frequency). The frequency of the root was always higher than that of the derived form, in terms of either written or oral frequency. Because the pseudosuffixed words did not contain a root, it was not possible to match the suffixed and pseudosuffixed words based on this criteria.

Words were prerecorded and played through headphones. The task was computer driven, and the procedure was as follows: a cross appeared in the middle of the screen for 250 ms and then the participant heard the item. Participants were instructed to answer as accurately and as quickly as possible. Their response was given by pressing a green button if the item was suffixed and a red one if the item was not suffixed, the "suffix" reponse being given with the preferred hand. There was a 1100-ms intertrial interval separating the participant's response and the beginning of the next trial. The items were presented randomly, and both accuracy and reaction times were measured. The experiment was preceded by a training phase using eight items whose characteristics were similar to those of the target items.

PREFIXED WORD DETECTION TASK. In this task, participants heard triplets of words and had to indicate which of the three was prefixed. Twelve word triplets sharing the initial phonemes (e.g., *endive*, *envol*, and *enclume*) were selected, with 1 prefixed and 2 pseudoprefixed words. All the words were of low frequency according to both their spoken frequency ($M = 2.08$, $SD = 2.25$) and their written frequency ($M = 3.18$, $SD = 2.76$; New et al., 2001). Words within triplets were strictly matched by word onset, number of syllables, and grammatical class. Words were also matched by their spoken frequency, t (22) < 1, *ns*, for all comparisons; and written frequency, t (22) = 1.39, $p > .15$, for the comparison of the prefixed word and one pseudoprefixed word list, t (22) < 1, *ns*, for the remaining comparisons. Prefixed words had a root ranging from low to high frequency (range of occurences per million: oral frequency = 4.75–766.2; written frequency = 6.69–923.45), with a greater majority of high-frequency roots (83% in terms of oral frequency and 92% in terms of written frequency). The frequency of the root was always higher than that of the derived form, in terms of either written or oral frequency. Because the pseudoprefixed words did not contain a root, it was not possible to match the prefixed and pseudoprefixed words based on this criteria.

Words were prerecorded and played over headphones. The task was computer driven, and the procedure was as follows: participants first heard the three words in succession with a 750-ms pause between them. Immediately after the third word, a cross appeared in the middle of the screen. Participants were instructed to answer as quickly and as accurately as possible once the cross appeared on the screen. Participants responded by means of the response box, by pressing the left button to select the first word, the middle button to select the second word, and the right button to select the third word. The target prefixed words occupied each of the three positions in equal proportion. The order of words within the triplets was fixed across participants, but the triplets were presented randomly. There was a 1000-ms intertrial interval before the next trial began. The experiment was preceded by a training phase composed of three triplets of words whose characteristics closely matched those of the target item. Accuracy was measured.

SUFFIXED WORD DETECTION TASK. In this task, participants had to do the same as in the previous task, but this time with respect to the suffix (e.g., *lanière*, *tanière* and *glacière*). The 12 word triplets were made up of one suffixed word and two pseudosuffixed words. All the words were of low frequency according to both their spoken frequency ($M = 2.16$, $SD = 3.21$) and their written frequency ($M = 3.24$, $SD = 2.65$). Words within triplets were strictly matched by word-onset, number of syllables, and grammatical class. Words were also matched by their oral frequency t (22) < 1, *ns*, for all comparisons; and written frequency, t (22) = 1.39, $p > .20$, for the comparison of the suffixed word and one pseudosuffixed word list, t (22) = 1.15, $p > .20$, for the comparison of the two pseudosuffixed word lists, t (22) < 1, *ns*, for the remaining comparison. Suffixed words had a root ranging from low to high frequency (range of occurences per million: oral frequency = 1.27–605.75, written frequency = 15.61–923.45), with a greater majority of high-frequency roots (92% in terms of oral frequency and 100% in terms of written frequency). The frequency of the root was always higher than that of the derived form, in terms of either written or oral frequency. Because the pseudosuffixed words did not contain a root, it was not possible to match the suffixed and pseudosuffixed words based on this criteria. The procedure was the same as in the prefixed word detection task.

Statistical analyses

All results were analysed with the R software (R Development Core Team, 2007). We used mixed-effects regression models to run our analyses because they have many advantages for analyzing data with high inter- and intrasubject variability, such as that typically obtained with dyslexic adults or children (see Baayen, Davidson, & Bates, 2008; Goldstein, 1987, 1995; Quené & van den Bregh, 2008; Rasbash & Goldstein, 1994, for details on mixed-effects regression models applied to psycholinguistic data). As with simple linear regression, mixed-effects regression models allow us to test whether a standard fixed predictor accounts for the data. In addition, these models have the advantage of accounting simultaneously for the random variation induced by specific words and by specific participants. In this manner any data averaging across participants or items is avoided. Thus, in all our analyses, we entered both participants and items as random variables, which always significantly improved the final models according to likelihood ratio tests (all $ps < .001$).

To fullfill the aim of our study (i.e., situate the performance of the dyslexic university students compared to the CA and RL controls), we entered group as a predictor and compared the performance of the dyslexic university students to that of the CA and the RL controls. Because these two comparisons are nonorthogonal, we lowered the significance level to 0.025 following Bonferroni correction. The effect of group (and predictors in general) was tested by comparing the model with and without this predictor by means of likelihood ratio tests.

On the suffixation decision task, in addition to group, several relevant variables were included in the analysis to account for the data: the number of syllables (two vs. three), the type of item (suffixed vs. pseudosuffixed), the response time for responding correctly in the TRISYL task, the physical duration of the item, and the interaction between the type of item and the group. We tested the effect of these variables to ensure that any group effect would not be confounded with such effects. The number of syllables, the type of item, and the interaction between the type of item and the group were entered as categorical predictors for both accuracy and reaction times analyses. The response time for responding correctly in the TRISYL task was also entered as a covariate in both cases (centered), because the phonological difficulties of the dyslexic participants in these morphological awareness tasks may have prevented them from performing this task quickly and accurately.[6] Finally, the physical duration of the item was entered as a covariate for the analysis of reaction times (centered). Only factors that were significant were retained in the final models.

Accuracy analyses were realized by running generalized linear mixed-effects models underlied by a binomial distribution (statistical package lme4) on the data sets, with accuracy as a dependant variable. To analyze speed, we considered the response times for correct answers only. We removed short response times, which were likely to correspond to anticipated responses (8 datapoints below 750 ms in the suffixation decision task). Then we ensured that the reaction/response times followed a normal distribution. To do so, we performed a visual inspection of the reaction times. This inspection showed that the distribution was right skewed in all tasks. This skewness was removed by taking out the longest response times when necessary (TRISYL task: 7 points above 5000 ms; CCV task: 4 points above 7000 ms; suffixation decision task: 2 points above 15000 ms) and by performing a reciprocal transformation of the remaining data points (following the Box–Cox test; Box & Cox, 1964). In this manner, only a few data points were removed from the raw data, and participants were never eliminated from the sample. Mixed-effects models analyses (statistical package lme4) were run on these data sets with centered, reciprocally transformed reaction/response times as a dependent variable. Following Baayen et al. (2008), residuals having an absolute value higher than 2.5 were considered outliers and duly removed (comprising at most 2.56% of the data).

Table 1. *Mean (standard deviation) error percentages and response times related to phonological awareness on the TRISYL, CVC, and CCV tests*

	CA Controls	Dyslexic Adults	RL Controls
TRISYL			
Error (%)	1.03 (3.27)*	6.46 (13.33)	4.65 (9.15)
Response time (ms)	2116 (205)***	2827 (971)	2795 (457)
CVC			
Error (%)	0.78 (3.05)	0.97 (2.70)	2.52 (5.31)
Response time (ms)	1659 (164)***	2043 (345)	2042 (434)
CCV			
Error (%)	7.74 (9.27)**	16.27 (17.26)	18.85 (19.48)
Response time (ms)	1837 (225)***	2521 (465)	2580 (811)

Note: TRISYL, trisyllabic; CVC, consonant–vowel–consonant; CCV, consonant–consonant–vowel; CA, chronological age; RL; reading level.
$^*p < .025$. $^{**}p < .01$. $^{***}p < .001$.

To sum up, we relied on mixed-effects regression models to run our analyses. For each model, both participants and items were entered as random variables, and group was entered as a categorical predictor. In this manner, we tested the effect of the group while accounting simultaneously for the random variation induced by each item and by each participant. Precision analyses relied upon generalized linear mixed-effects models with accuracy as a dependent variable. Speed analyses used mixed-effects models analyses with centered, reciprocally transformed reaction/response times as a dependent variable.

RESULTS

Phonological awareness

On the phonological awareness tasks, data were missing for one RL control. Data from this participant and the matching dyslexic and CA controls were removed from the data sets. The results (mean scores and standard deviations) of the three reading groups in the phonological awareness tasks are presented in Table 1.

Reliability. Cronbach alphas were calculated to measure reliability. When Cronbach alphas did not reach high values, we dropped problematic items to improve reliability. All reliability scores exceed 0.60. On the TRISYL task, one item was dropped to improve reliability, which reached 0.88 and 0.62 for response time and accuracy, respectively. On the CVC task, the Cronbach α was 0.94 for response times (analyses were not conducted on accuracy because participants reached performances at ceiling). On the CCV task, Cronbach αs were 0.86 and 0.72 for response times and accuracy, respectively.

TRISYL test. Group was a significant predictor of accuracy, χ^2 (2, 5) = 9.83, $p <$ .01, and the probability of answering correctly was higher in CA controls than in dyslexic university students ($\beta = 1.97$, $z = 2.51$, $p = .012$), but it did not differ between dyslexic university students and RL controls ($\beta = 0.37$, $z < 1$, *ns*). In response times, group was a significant predictor, χ^2 (2, 6) = 65.75, $p < .0001$, with the dyslexics being slower than the CA controls ($\beta = –0.08$, $t = –7.16$, $p <$ .0001), but not differing from the RL controls ($\beta = 0.02$, $t = 1.34$, $p > .15$).

CVC test. Because all groups performed at ceiling, only analyses of response times for correct answers were carried out. Group was a significant predictor, χ^2 (2, 6) = 40.81, $p < .0001$, with the dyslexics being slower than the CA controls ($\beta = –0.10$, $t = –5.96$, $p < .0001$), but not differing from the RL controls ($\beta =$ –0.00, $t < 1$, *ns*).

CCV test. On the CCV task, reaction times were missing for one RL control. Data from this participant and the matching dyslexic university student and CA controls were removed from data sets. Accuracy was predicted significantly by group, χ^2 (2, 5) = 11.33, $p < .001$, with the dyslexics being less accurate than the CA controls ($\beta = 1.08$, $z = 2.73$, $p < .01$), but not differing from the RL controls ($\beta = –0.22$, $z < 1$, *ns*). For response times, group was a significant predictor, χ^2 (2, 6) = 76.88, $p < .0001$, with the dyslexics being slower than the CA controls ($\beta = –0.14$, $t = –8.96$, $p < .001$) but not differing from the RL controls ($\beta = –0.00$, $t < 1$, *ns*).

In sum, in phonological awareness tasks, the dyslexic university students were less accurate than their CA controls in both the TRISYL and the CCV tasks, and all groups performed at ceiling in the CVC task. For response times, dyslexic university students were slower than their CA controls in all tasks. The performance of the dyslexic university students never differed from that of their RL controls for the three tasks, neither for accuracy nor speed. In sum, dyslexic university students were outperformed by their CA controls but performed like their RL controls, both in terms of speed and accuracy.

Morphological awareness

Reliability. Cronbach alphas were again calculated to measure reliability; when the alphas did not reach high values, we dropped problematic items to improve reliability. All reliability scores exceed 0.60. On the suffixation decision task, Cronbach αs were 0.91 and 0.69 for response times and accuracy, respectively. On the prefixed word detection task, two items were dropped to improve reliability, which reached 0.69. On the suffixed word detection task, one item was dropped to improve reliability, which reached 0.60.

Suffixation decision task. Concerning accuracy, the type of item was a significant predictor, χ^2 (1, 6) = 13.21, $p < .001$, with participants responding more accurately to pseudosuffixed words as compared to suffixed words. Accuracy was also significantly predicted by group, χ^2 (2, 6) = 30.48, $p < .0001$. Dyslexics did not

Table 2. *Mean (standard deviation) error percentages and response times related to morphological awareness on the suffixation decision task, detection of prefixed words, and detection of suffixed words*

	CA Controls	Dyslexic Adults	RL Controls
Suffixation decision task			
Error (%)	22.49 (8.45)	23.58 (7.81)	32.67 (10.34)***
Reaction time (ms)	1876 (729)***	2316 (500)	2751 (1013)*
Detection of prefixed word			
Error (%)	6.14 (9.93)†	10.23 (11.71)	19.77 (20.63)**
Detection of suffixed word			
Error (%)	13.84 (10.83)	16.94 (11.02)	30.17 (19.68)***

Note: CA, chronological age; RL; reading level.
†$p < .05$ (marginal). **$p < .01$. ***$p < .001$.

differ from CA controls ($\beta = 0.08$, $z < 1$, *ns*), but they were more accurate than RL controls ($\beta = -0.59$, $z = -4.70$, $p < .001$).

Concerning reaction times, the duration of the item was a marginal predictor, χ^2 (1, 7) = 3.60, $p = .06$. Group was a significant predictor of reaction times, χ^2 (2, 7) = 42.48, $p < .0001$, with dyslexic participants being slower than CA controls ($\beta = -0.11$, $t = -4.55$, $p < .001$) but faster than RL controls ($\beta = 0.06$, $t = 2.36$, $p < .025$).

Detection of prefixed word. Accuracy was significantly predicted by group, χ^2 (2, 5) = 21.56, $p < .0001$. The dyslexic university students were marginally less accurate than the CA controls ($\beta = 0.78$, $z = 1.96$, $p = .05$) and were more accurate than the RL controls ($\beta = -1.00$, $z = -2.87$, $p < .01$).

Detection of suffixed word. Accuracy was significantly predicted by group, χ^2 (2, 5) = 28.90, $p < .0001$. The dyslexic university students did not differ from the CA controls ($\beta = 0.34$, $z = 1.25$, *ns*) and were more accurate than the RL controls ($\beta = -1.07$, $z = -4.18$, $p < .001$).

In sum, in the morphological awareness tasks (Table 2), dyslexic university students did not differ in accuracy from their CA controls in either the suffixation decision task or the detection of suffixed word task. They were marginally less accurate than their CA controls in the detection of prefixed word task and slower than their CA controls in the suffixation decision task. The dyslexic students always outperformed their RL controls, both in terms of speed and accuracy.

DISCUSSION

In this study, we evaluated the levels of phonological and morphological awareness in French-speaking dyslexic university students. We employed two control groups, CA controls and RL controls, to accurately assess the performance of the dyslexic university students in each of these abilities. In the phonological awareness tasks, dyslexic students were outperformed by their CA controls and performed at the level of their RL controls. In contrast, in the morphological awareness tasks, dyslexic students clearly outperformed their RL controls and almost reached the proficiency level of their CA controls. These results have several implications that are discussed below.

Concerning phonological awareness, as expected, we have replicated Martin et al.'s (2010) results using a similar population and similar phonological awareness tasks. In phonological awareness tasks, French-speaking dyslexic university students appeared to perform better than their English-speaking counterparts, who were outperformed by their RL controls in such tasks (Bruck, 1992, 1993; Chiappe et al., 2002; Pennington et al., 1990). To explain these differences, Martin et al. (2010) proposed that the relative orthographic transparency of the two languages played a role. From the point of view of reading, French orthography is more transparent than English orthography (Peereman & Content, 1998; Peereman, Lété, & Sprenger-Charolles, 2007). Consistent correspondences between graphemes and phonemes may facilitate the development of phonemic awareness, particularly for dyslexics. A good example of the positive effect of orthographic consistency can be found in German, which is considered to have a transparent orthography. Studies by Wimmer (1993, 1996) with German dyslexic children across several grades showed that only in first grade did the children have trouble with their phonemic awareness, which was no longer observed by the end of fourth grade. In a similar fashion, the relative transparency of French orthography might have helped the dyslexic participants to develop phonemic awareness, although this development remained limited.

Concerning morphological awareness, our results indicate that dyslexic university students can develop far better morphological awareness than that which might be expected from their RLs. This finding for dyslexic university students mirrors what has been previously observed in French dyslexic children (Casalis et al., 2004). It adds to the evidence suggesting that the development of morphological awareness is unlikely to be deficient in French dyslexic university students. Several hypotheses can be proposed to explain how morphological awareness could have developed so well in our population.

As we proposed in the introductory section, because the semantic abilities of people with dyslexia are not deficient (Vellutino et al., 1995), this population could probably rely on the semantic dimension of morphology to develop morphological awareness. Some studies also reported a relationship between morphological awareness and vocabulary knowledge in normally developing readers (Carlisle & Fleming, 2003; Colé et al., 2004; Kirby, Derochers, Roth, & Lai, 2008). However, the exact nature of this relationship is still under discussion. A vocabulary measure was not included in our study, but it would be useful in future studies to test if the level of morphological awareness is related to that of vocabulary knowledge.

That morphology is encoded in the orthography could also be important for the development of morphological awareness. In French, as described by Jaffré (2006), morphemes are systematically encoded in print, even though they are frequently not fully pronounced. For example, morphograms (letters or groups of letters at the end of words) that often encode morphological relations establish a visible link between different words sharing a morphological relationship, but they are not always pronounced.[7] Morphograms are likely to help French readers to grasp the morphological relations between words and to develop awareness of the morphological structure of the language. Moreover, although morphograms introduce inconsistencies at the graphophonological level, they represent consistencies at a graphosemantic level, which could be particularly relevant for dyslexic readers. This hypothesis about the role of orthography in the development of morphological awareness is not limited to French because alphabetic languages all encode morphology in print to some extent. Across such languages, there are nonetheless differences in consistency between speech and print in morphological encoding. The involvement of orthography in the development of morphological awareness across languages may depend precisely upon these differences in consistency. More generally, the involvement of orthography in the development of morphological awareness is supported by the fact that dyslexic readers appear to be sensitive to the morphological information contained in written language. The few studies conducted on alphabetic orthographies with dyslexic children and teenagers show that they process the morphological structure of the written language in word identification and that this processing does not seem to be deficient (Burani, Marcolini, De Luca, & Zoccolotti, 2008; Carlisle et al., 2001; Elbro & Arnbak, 1996; but see Deacon, Parrila, & Kirby, 2006, for contrary results with dyslexic university students; see also Deacon, Parrila, & Kirby, 2008, for a literature review of morphological processing by dyslexic readers).

That our target population consisted of university students must also be taken into account when interpreting the high degree of morphological awareness we observed. First, dyslexic university students are not representative of dyslexic adults. Data indicate that university students with learning disabilities (including dyslexia and other learning disabilities) represent less than 2% of the student body (Horn & Berktold, 1999), which contrasts with the prevalence of dyslexia in the general population (5% to 10%; INSERM, 2007). Second, several authors propose that dyslexic university students develop compensatory strategies to be able to pursue university studies despite their persistent reading difficulties. Elbro & Arnbak (1996) suggested that morphological knowledge may support one such compensatory reading mechanism. The level of morphological awareness of our target population, which is better than expected from their RL, is consistent with the idea that this skill does play a compensatory role in reading. Unfortunately, our study was not designed to test for the existence of a compensatory mechanism, which would have required other experimental conditions. Moreover, this level of morphological awareness is not specific to dyslexic university students because it has also been observed in dyslexic children (Casalis et al., 2004). Whether these children also possess compensatory reading strategies remains an open question. In sum, the low representativity of our population and the possibility that morphological awareness has a specific compensatory function in this population make it difficult to generalize our results to the entire population of dyslexic adults. However, our results raise the very interesting possibility that morphological awareness may play a specific compensatory role in our population.

Third, the comparison of phonological and morphological awareness in our target population, using RL controls as a baseline, showed differences between these two skills, with an advantage in favor of morphological awareness. The level of morphological awareness of the dyslexic university students clearly surpassed that which was expected from their RL. In contrast, their level of phonological awareness corresponded to that which was expected from their RL. One could argue that, in morphological awareness tasks, dyslexic university students were faster than their RL controls because they were much older and thus benefited from an advantage in their motor and cognitive development (rapidity of processing and response). However, if it were the case, this should also have been true for phonological awareness tasks. In phonological awareness tasks, the dyslexics were never faster than their RL controls. Thus, the dyslexic university students were genuinely more proficient in completing morphological awareness tasks than their RL controls, and this effect could not be attributed to differences in their general level of cognitive and motor development. The higher level of morphological awareness, as opposed to phonological awareness, observed in our dyslexic university students adds to the body of evidence that suggests that these two metalinguistic abilities can, to a certain extent, develop independently.

In conclusion, the present study has allowed us to show that French-speaking dyslexic university students exhibit higher levels of morphological awareness than phonological awareness by using CA and RL controls as a baseline. Future studies should clarify the role of semantics, vocabulary, and orthography in the development of morphological awareness in dyslexic population. Moreover, it would be essential to understand if the level of morphological awareness demonstrated by our university student population is also found in dyslexic adults in general or if it is somewhat exceptional. It would also be crucial to establish if it constitutes a specific compensatory mechanism. It is important to identify the abilities and procedures that can improve reading in dyslexic readers, especially because they could provide a solid basis for intervention. It is likely that morphological instruction could be beneficial to dyslexic readers because it has already proved to be beneficial to learners, and in particular to poor readers (see Bowers, Kirby, & Deacon, 2010, for a review of the literature, and Goodwin & Ahn, 2010, for a meta-analysis).

NOTES

1. Phonemic awareness refers to the ability of individuals to identify and manipulate phonemes consciously, whereas phonological awareness refers more generally to this metalinguistic awareness of phonological units of different sizes (syllables, rimes, and phonemes, for example).
2. In France and in Switzerland, to diagnose developmental dyslexia, speech therapists first exclude any possible trouble due to hearing, visual, or neurological/psychiatric disorders or to a deficient nonverbal IQ (using the CIM-10 criteria). Reading is evaluated through standardized tests of reading isolated regular and irregular words, of decoding pseudowords, and of reading texts. Phonological awareness is tested, and standardized spelling tests and standardized evaluation of the oral language are used to detect comorbidities and to exclude differential diagnoses.
3. We included university students who were not diagnosed as dyslexics by a speech therapist in their childhood because, at that time, developmental dyslexia was less

well known and many children probably have missed being diagnosed. Including only students who had been diagnosed as dyslexics would have biased our sample toward those individuals who were most strongly affected or possibly those from higher socioeconomic backgrounds.

4. The Alouette-R (Lefavrais, 2005) has been standardized for pupils up to 16 years old. However, the groups used for this standardization were fairly small (on average 36 children per level), and we favored the use of the original version.
5. Explicit morphological awareness refers to the use of morphological knowledge that the child manipulates intentionally. It contrasts with implicit morphological awareness, for which the manipulation of knowledge is rather automatic and executed without focusing attention (Colé et al., 2004). For example, extracting the base from a derived word presented in isolation (e.g., *breakable . . . break*) taps into explicit morphological awareness, whereas the sentence completion task with the derived form of a root word (e.g., *something that can break is. . . breakable*) taps into implicit morphological awareness.
6. Note that the results of the group comparisons are exactly the same without this covariate, for both accuracy and response times.
7. By way of illustration, the “t” morphogram at the end of the word *lait* (milk), which is not pronounced in spoken French, can also be found (and heard) in the derived words *laitier* (milkman), *laitage* (dairy product), *laiteux* (milky), *allaiter* (to nurse or breastfeed), *allaitement* (breastfeeding), and so on.

REFERENCES

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*, 390–412.

Ben-Dror, I., Pollatsek, A., & Scarpati, S. (1991). Word identification in isolation and in context by college dyslexic students. *Brain and Language*, *40*, 471–490.

Berninger, V. W., Abbott, R. D., Nagy, W., & Carlisle, J. (2010). Growth in phonological, orthographic, and morphological awareness in grades 1 to 6. *Journal of Psycholinguist Research*, *39*, 141–163.

Bogliotti, C., Serniclaes, W., Messaoud-Galusi, S., & Sprenger-Charolles, L. (2008). Discrimination of speech sounds by children with dyslexia: Comparisons with chronological age and reading level controls. *Journal of Experimental Child Psychology*, *101*, 137–155.

Bowers, P. N., Kirby, J. R., & Deacon, S. H. (2010). The effects of morphological instruction on literacy skills: A systematic review of the literature. *Review of Educational Research*, *80*, 144–179.

Box, G. E. P., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society*, *26B*, 211–252.

Bruck, M. (1990). Word-recognition skills of adults with childhood diagnoses of dyslexia. *Developmental Psychology*, *26*, 439–454.

Bruck, M. (1992). Persistence of dyslexics’ phonological awareness deficits. *Developmental Psychology*, *28*, 874–886.

Bruck, M. (1993). Word recognition and component phonological processing skills of adults with childhood diagnosis of dyslexia. *Developmental Review*, *13*, 258–268.

Bryant, P. E., & Bradley, L. (1985). *Children’s reading problems: Psychology and education*. Oxford: Blackwell.

Burani, C., Marcolini, S., De Luca, M., & Zoccolotti, P. (2008). Morpheme-based reading aloud: Evidence from dyslexic and skilled Italian readers. *Cognition*, *108*, 243–262.

Carlisle, J. F. (1995). Morphological awareness and early reading achievement. In L. B. Feldman (Ed.), *Morphological aspects of language processing* (pp. 189–209). Hillsdale, NJ: Erlbaum.

Carlisle, J. F., & Fleming, J. (2003). Lexical processing of morphologically complex words in the elementary years. *Scientific Studies of Reading*, *7*, 239–253.

Carlisle, J. F., & Nomanbhoy, D. M. (1993). Phonological and morphological awareness in first graders. *Applied Psycholinguistics*, *14*, 177–195.

Carlisle, J. F., Stone, C. A., & Katz, L. (2001). The effects of phonological transparency on reading derived words. *Annals of Dyslexia*, *51*, 249–274.

Casalis, S., & Colé, P. (2009). On the relationship between morphological and phonological awareness: Effects of training in kindergarten and in first-grade reading. *First Language*, *29*, 113–142.

Casalis, S., Colé, P., & Sopo, D. (2004). Morphological awareness in developmental dyslexia. *Annals of Dyslexia*, *54*, 114–138.

Casalis, S., & Louis-Alexandre, M.-F. (2000). Morphological analysis, phonological analysis and learning to read French: A longitudinal study. *Reading and Writing*, *12*, 303–335.

Casalis, S., Mathiot, E., Bécavin, A. S., & Colé, P. (2003). Conscience morphologique chez des lecteurs tout venant et en difficultés. *Silexicales*, *3*, 57–66.

Champion, A. (1997). Knowledge of suffixed words: A comparison of reading disabled and nondisabled readers. *Annals of Dyslexia*, *47*, 29–55.

Chiappe, P., Stringer, R., Siegel, L. S., & Stanovich, K. E. (2002). Why the timing deficit hypothesis does not explain reading disability in adults. *Reading and Writing*, *15*, 73–107.

Colé, P., Royer, C., Leuwers, C., & Casalis, S. (2004). Les connaissances morphologiques dérivationnelles et l'apprentissage de la lecture chez l'apprenti-lecteur français du CP au CE2. *L'Année Psychologique*, *104*, 701–750.

Deacon, S., & Kirby, J. R. (2004). Morphological awareness: Just "more phonological"? The roles of morphological and phonological awareness in reading development. *Applied Psycholinguistics*, *25*, 223–238.

Deacon, S., Parrila, R., & Kirby, J. R. (2006). Processing of derived forms in high-functioning dyslexics. *Annals of Dyslexia*, *56*, 103–128.

Deacon, S., Parrila, R., & Kirby, J. R. (2008). A review of the evidence on morphological processing in dyslexics and poor readers: A strength or weakness? In G. Reid, A. Fawcett, F. Manis, & L. Siegel (Eds.), *The Sage handbook of dyslexia* (pp. 212–237). London: Sage.

Elbro, C., & Arnbak, E. (1996). The role of morpheme recognition and morphological awareness in dyslexia. *Annals of Dyslexia*, *46*, 209–240.

Fowler, A. E., & Liberman, I. Y. (1995). The role of phonology and orthography in morphological awareness. In Laurie Beth Feldman (Ed.), *Morphological aspects of language processing* (pp. 157–188). Hillsdale, NJ: Erlbaum.

Goldstein, H. (1987). *Multilevel models in educational and social research*. London: Griffin.

Goldstein, H. (1995). Hierarchical data modeling in the social sciences. *Journal of Educational and Behavioral Statistics*, *20*, 201–204.

Goodwin, A. P., & Ahn, S. (2010). A meta-analysis of morphological interventions: Effects on literacy achievement of children with literacy difficulties. *Annals of Dyslexia*, *60*, 183–208.

Horn, L. J., & Berktold, J. (1999). *Students with disabilities in postsecondary education: A profile of preparation, participation, and outcomes* (Report No. NCES 1999–187). Washington, DC: Department of Education, National Center for Education Statistics.

INSERM (Ed.). (2007). *Dyslexie, dysorthographie, dyscalculie: Bilan des données scientifiques*. Paris: Editions INSERM.

Jaffré, J.-P. (2006). Pourquoi distinguer les homophones? *Langue Française*, *151*, 25–40.

Kirby, J. R., Derochers, A., Roth, L., & Lai, S.V.S. (2008). Longitudinal predictors of word reading development. *Canadian Psychology*, *49*, 103–110.

Lefavrais, P. (1967). *Test de l'Alouette*. Paris: Editions du Centre de Psychologie Appliquée.

Lefavrais, P. (2005). *Test de l'Alouette Révisé*. Paris: Editions du Centre de Psychologie Appliquée.

Leong, C. K. (1999). Phonological and morphological processing in adult students with learning/reading disabilities. *Journal of Learning Disabilities*, *32*, 224–238.

Mahony, D., Singson, M., & Mann, V. (2000). Reading ability and sensitivity to morphological relations. *Reading and Writing*, *12*, 191–218.

Martin, J., Colé, P., Leuwers, C., Casalis, S., Zorman, M., & Sprenger-Charolles, L. (2010). Reading in French-speaking adults with dyslexia. *Annals of Dyslexia*, *60*, 238–264.

Miller-Shaul, S. (2005). The characteristics of young and adult dyslexics readers on reading and reading-related cognitive tasks as compared to normal readers. *Dyslexia*, *11*, 132–151.

Muter, V., Hulme, C., Snowling, M., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: Evidence from a longitudinal study. *Developmental Psychology*, *40*, 665–681.

Nagy, W., Berninger, V., & Abbott, R. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology*, *98*, 134–147.

New, B., Pallier, C., Ferrand, L., & Matos, R. (2001). Une base de données lexicales du français contemporain sur internet : LEXIQUE. *L'année psychologique*, *101*, 447–462.

Nicolson, R. I., Fawcett, A. J., & Dean, P. (2001). Developmental dyslexia: The cerebellar deficit hypothesis. *Trends in Neurosciences*, *24*, 508–511.

Peereman, R., & Content, A. (1998). Is perception a two-way street? The case of feedback consistency in visual word recognition. *Journal of Memory and Language*, *39*, 151–174.

Peereman, R., Lété, B., & Sprenger-Charolles, L. (2007). Manulex-infra: Distributional characteristics of grapheme–phoneme mappings, and infralexical and lexical units in child-directed written material. *Behavior Research Methods*, *36*, 156–166.

Pennington, B. F., van Orden, G. C., Smith, S. D., Green, P. A., & Haith, M. M. (1990). Phonological processing skills and deficits in adult dyslexics. *Child Development*, *61*, 1753–1778.

Quené, H., & van den Bergh, H. (2008). Examples of mixed-effects modeling with crossed random effects and with binomial data. *Journal of Memory and Language*, *59*, 413–425.

Rasbash, J., & Goldstein, H. (1994). Efficient analysis of mixed hierarchical and cross-classified random structures using a multilevel model. *Journal of Educational and Behavioral Statistics*, *19*, 337–350.

Rastle, K., Davis, M. H., Marslen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, *15*, 507–537.

Raven, J., & Court, J. (1995). *Standard Progressive Matrices Series A, B, C, D, E* (Révision 1956). Paris: Editions techniques et psychotechniques.

Raven, J. C., Court, J., & Raven, J. (1998). *Progressives Matrices Couleur*. Paris: EAP.

R Development Core Team. (2007). *R: A language and environment for statistical computing*. Vienna: Author.

Roman, A. A., Kirby, J. R., Parrila, R., Wade-Woolley, L., & Deacon, S. (2009). Toward a comprehensive view of the skills involved in word reading in grades 4, 6, and 8. *Journal of Experimental Child Psychology*, *102*, 96–113.

Rubin, H., Patterson, P. A., & Kantor, M. (1991). Morphological development and writing ability in children and adults. *Language, Speech, and Hearing Services in Schools*, *22*, 228–235.

Shankweiler, D., Crain, S., Katz, L., Fowler, A. E., Liberman, A. M., Brady, S. A., et al. (1995). Cognitive profiles of reading-disabled children: Comparison of language skills in phonology, morphology, and syntax. *Psychological Science*, *6*, 149–156.

Singson, M., Mahony, D., & Mann, V. (2000). The relation between reading ability and morphological skills: Evidence from derivational suffixes. *Reading and Writing*, *12*, 219–252.

Snowling, M. J. (2001). From language to reading and dyslexia. *Dyslexia*, *7*, 37–46.

Sprenger-Charolles, L., Colé, P., Béchennec, D., & Kipffer-Piquard, A. (2005). Lecture et compétences reliées: Données normatives pour la fin de la 1ère, 2nde, 3ème et 4ème année du primaire issues d'une nouvelle batterie de tests, EVALEC. *European Review of Applied Psychology/Revue Europeenne de Psychologie Appliquee*, *55*, 157–186.

Sprenger-Charolles, L., Colé, P., Kipffer-Piquard, A., Pinton, F., & Billard, C. (2009). Reliability and prevalence of an atypical development of phonological skills in French-speaking dyslexics. *Reading and Writing*, *22*, 811–842.

Sprenger-Charolles, L., Colé, P., & Serniclaes, W. (2006). *Reading acquisition and developmental dyslexia (essays in developmental psychology)*. Hove: Psychology Press.

Stein, J. (2001). The magnocellular theory of developmental dyslexia. *Dyslexia*, *7*, 12–36.

Szenkovits, G., & Ramus, F. (2005). Exploring dyslexics' phonological deficit I: Lexical vs sub-lexical and input vs output processes. *Dyslexia*, *11*, 253–268.

Tallal, P. (1980). Language and reading: Some perceptual prerequisites. *Annals of Dyslexia*, *30*, 170–178.

Temple, E., Poldrack, R. A., Protopapas, A., Nagarajan, S., Salz, T., Tallal, P., et al. (2000). Disruption of the neural response to rapid acoustic stimuli in dyslexia: Evidence from functional MRI.

Proceedings of the National Academy of Sciences of the United States of America, *97*, 13907–13912.
Tractenberg, R. E. (2002). Exploring hypotheses about phonological awareness, memory, and reading achievement. *Journal of Learning Disabilities*, *35*, 407–424.
Tsesmeli, S., & Seymour, P. (2006). Derivational morphology and spelling in dyslexia. *Reading and Writing*, *19*, 587–625.
Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, *45*, 2–40.
Vellutino, F. R., Scanlon, D. M., & Spearing, D. (1995). Semantic and phonological coding in poor and normal readers. *Journal of Experimental Child Psychology*, *59*, 76–123.
Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics*, *14*, 1–33.
Wimmer, H. (1996). The nonword reading deficit in developmental dyslexia: Evidence from children learning to read German. *Journal of Experimental Child Psychology*, *61*, 80–90.
Wolter, J. A., Wood, A., & D'Zatko, K. W. (2009). The influence of morphological awareness on the literacy development of first-grade children. *Language, Speech and Hearing Services in Schools*, *40*, 286–298.
Ziegler, J. C., Castel, C., Pech-Georgel, C., George, F., Alario, F. X., & Perry, C. (2008). Developmental dyslexia and the dual route model of reading: Simulating individual differences and subtypes. *Cognition*, *107*, 151–178.
Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, *131*, 3–29.
Ziegler, J. C., Pech-Georgel, C., George, F., & Lorenzi, C. (2009). Speech-perception-in-noise deficits in dyslexia. *Developmental Science*, *15*, 732–745.