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Phonemic – Morphemic dissociation in university students with dyslexia: An index of reading compensation?

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Abstract

A phonological deficit constitutes a primary cause of developmental dyslexia, which persists into adulthood and can explain some aspects of their reading impairment. Nevertheless, some dyslexic adults successfully manage to study at university level, although very little is currently known about how they achieve this. The present study investigated at both the individual and group level, whether the development of another oral language skill, namely, morphological knowledge can be preserved and dissociated from the development of phonological knowledge. Reading, phonological and morphological abilities were measured in 20 dyslexic and 20 non-dyslexic university students. The results confirmed the persistence of deficits in phonological but not morphological abilities, thereby revealing a dissociation in the development of these two skills. Moreover, the magnitude of the dissociation correlated with reading level. The outcome supports the claim that university students with dyslexia may compensate for phonological weaknesses by drawing on morphological knowledge in reading.

Keywords: University students with dyslexia, phoneme awareness, morpheme awareness, dissociation.

Phonological and morphological knowledge in dyslexic students

Developmental dyslexia (hereafter, dyslexia) is currently characterized in the DSM-5 (2013) by poor development of effective word decoding strategies, low level of reading fluency and poor spelling performance. It is now well established that dyslexia is a neurological disorder (Shaywitz et al., 2001; Shaywitz, 2005; Sprenger-Charolles & Colé, 2013), principally characterized by a phonological deficit (Lyon, Shaywitz, & Shaywitz, 2003; Shaywitz, Mody, & Shaywitz, 2006), but also by difficulties with verbal learning at the lexical/word level (Di Betta & Romani, 2006; Romani, Di Betta, & Tsouknida, 2008; Litt & Nation, 2014). The multiple case study conducted by Ramus et al., (2003) with university students with dyslexia confirmed that a phonological deficit is at the core of dyslexia. A number of other studies also support the view that a phonological deficit is persistent in adults with dyslexia and, thus, does not represent a transient "developmental lag" (Bruck, 1992, Shaywitz & Shaywitz, 2005). Moreover, while it is well known that reading difficulties are sensitive to orthographic depth, adults with dyslexia still show deficits in reading speed in orthographic systems that are more transparent than English such as Italian (Re, Tressoldi, Cornoldi & Lucangeli, 2011), Spanish (Suárez-Coalla & Cuetos, 2015), Dutch (Callens, Tops, & Brysbaert, 2012) and Polish (Reid, Szczerbinski, Iskierka-Kasperek, & Hansen, 2006), suggesting that reading deficits in adults with dyslexia are persistent in both deep and shallow orthographic systems. Despite their high levels of educational attainment, adults with dyslexia show word recognition deficits and they fail to achieve the phonological awareness level of both chronological-age (CA) and reading level (RL) controls (Bruck, 1993; Martin, Colé, Leuwers, Casalis, Zorman, & Sprenger-Charolles, 2010). Indeed, most studies of adults with dyslexia have found that performance on assessments of phonological awareness – i.e. the ability to identify and to manipulate the phonological units in spoken words – (Gombert, 1990), is a good marker of dyslexia (Swanson & Hsieh, 2009). In addition, recent studies show that university students with dyslexia tend to perform worse than controls on tests such as word reading, word spelling, visual memory and arithmetic (Callens et al., 2012; Callens, Tops, Stevens, & Brysbaert, 2014), while performing equally well on text comprehension tests (see also Swanson, 2012, for a meta-analysis in adults with dyslexia).

The majority of studies of adults with dyslexia have shown persistent deficits in several forms of phonological processing involved in reading (see Swanson and Hsieh, 2009 for a meta-analysis based on behavioral measures; and Richlan, Kronbichler, and Wimmer, 2011 for a meta-analysis based on neuroimaging results). Nearly all of these studies evaluated university students with dyslexia who despite poor phonological and reading skills studied towards a university degree. It remains to be understood how these dyslexic individuals managed to cope with the intensive exposure to written language required in obtaining a university degree. One can make the assumption that they have built a compensatory reading system using other, fully intact, language and possibly cognitive abilities. This approach is innovative compared to the majority of studies which describe only deficits among these students (but see Cavalli, Casalis, El Ahmadi, Zira, Poracchia-George, and Colé, 2016, for vocabulary skills; Law, Wouters, and Ghesquière, 2015 and Leong, 1999, for morphological knowledge; and Romani et al., 2008, for verbal learning).

Very few hypotheses have been made about how dyslexics read despite their deficits. Elbro and Arnbak (1996) have argued that adolescents with dyslexia use the identification of morphemes – i.e. the smallest unit of meaning – as a compensatory strategy for reading. They suggest that written morpheme recognition might allow dyslexic readers to compensate for their basic phonological difficulties while reading meaningful text. Moreover, they examined whether it would be possible to develop dyslexics' morphological awareness and whether such training would have a positive effect on reading abilities (Arnbak & Elbro, 2000). Significant gains in word reading speed and in spelling were observed after training and it was proposed that these findings constituted evidence for an alternative encoding strategy based on morpheme units. In keeping with this hypothesis, we assume in the present study that university students with dyslexia may rely on their intact morphological awareness skills to compensate for their reading difficulties and that this population might capitalize on the semantic dimension of morphology to acquire morphological knowledge and support reading comprehension (for a recent review of morphological and semantic skills among dyslexics, see Deacon, Tong, and Mimeau, in press).

Morphological awareness reflects the ability to manipulate morphemes explicitly and to analyze words into smaller meaningful parts such as roots and affixes (Carlisle, 1995). Currently, an increasing body of evidence suggests that morphological awareness is associated with both visual word recognition and text reading comprehension skills during literacy acquisition (Deacon & Kirby, 2004; Nagy, Berninger, & Abott, 2006). The majority of studies of the relationship between morphological awareness and dyslexia focus mainly on children. The results appear to depend on the kind of control group with which the dyslexics have been compared (chronological-age (CA) control or reading-level (RL) control) and the morphological awareness tasks used. Most studies have shown that children with dyslexia perform less well than their CA controls on morphological awareness tasks involving derivational morphology (Casalis, Colé, & Sopo, 2004; Casalis, Mathiot, Bécavin, & Colé, 2003; Tsesmeli & Seymour, 2006), especially when there is a phonological and/or orthographic change in the derived form (Fowler & Liberman, 1995; Leong, 1989). However, previous studies also report that children with dyslexia perform as well as RL controls in tasks involving the production of word derivations in a sentence context (Fowler & Liberman, 1995) or the production of derived, inflected and compound forms of pseudowords (Elbro, 1989). These findings suggest that unlike phonological awareness, morphological awareness can be developed by children with dyslexia at least to the level expected from their reading ability – and that any weaknesses in morphological awareness may be a consequence of poor phonological abilities and/or lack of reading experience.

Data on morphological awareness in adults with dyslexia are relatively rare, although the importance of this skill in reading performance is well-established, notably among skilled adult readers (Guo, Roehrig, & Williams, 2011). Thus, few studies have been conducted on morphological knowledge (using both explicit morphological awareness tasks and implicit morphological processing tasks) among university students with dyslexia and even fewer have investigated morphological awareness specifically. To our knowledge, only two of the existing studies were conducted in an alphabetic writing system (for the English orthography, see Law, Wouters, and Ghesquière, 2015; for the French orthography, see Martin, Frauenfelder, and Colé, 2013), and two examined Hebrew-speaking university students with dyslexia (Leikin & Zur Hagit, 2006; Schiff & Raveh, 2007). Furthermore, although some other studies have assessed morphological awareness in English (e.g., Tractenberg, 2002; Leong, 1999), these studies examined populations with learning disabilities, including participants who presented with deficits other than developmental dyslexia.

In the Hebrew writing system, the morphemic units in words are not concatenated as is the case in English or French. Most content words can be broken down further into two basic components, root and pattern, which convey semantic information about the word (see Leikin et al., 2006 and Schiff et al., 2006, for a detailed presentation of Hebrew morphology). The main characteristic of the morphological structure of words is that phonology and morphology are generally not dissociable. Although Schiff and Raveh (2007) found some weakness in morphological awareness in dyslexic students in Hebrew, Leiken and Zur Hagit (2006) showed that the contribution of morphological awareness to decoding was significant even after phonological processing was partialled out, suggesting that morphological awareness is an important factor in addition to phonological skills for successful word decoding.

In Indo-European languages with alphabetic writing systems like English and French, morphologically complex words are frequently formed by the combination of a root and an affix situated at the beginning and/or at the end of the word. For instance, in French, the word *travailleur* [worker], is composed of a stem *travail* [work] and a suffix *-eur* [-er, "someone who ..."]. The meaning of the whole word is a product of the combination of the morphemes. Derivational morphology is very important in French because of the Latin origins. Indeed, words are frequently spelled in ways that are governed by morphology rather than phonology alone; for example, *lait* [milk] is spelled with a silent *t* in analogy with the spelling of the morpheme in derived words like *laitier* [dairy]. As pointed out by Duncan, Casalis, and Colé (2009), derivation is less prevalent and less productive in English than in French. As a result, metamorphological development appears to be slightly accelerated in French relative to English (Duncan et al., 2009).

In contrast to Hebrew, in which written phonological and morphological units are notably difficult to dissociate, the linguistic border between phonological and morphological units is clear in French (e.g., *chaton* [kitten], which is composed of the base *chat* [cat] and the suffix *-on*). Therefore, in French, dyslexic adult readers may take full advantage of the semantic information conveyed by morphemes and strongly activate morphological knowledge while reading words. To our knowledge, only one study has evaluated the morphological awareness of French university students with dyslexia (Martin et al., 2013). These authors investigated the level of oral morphological and phonological awareness among university students with dyslexia in comparison to both CA and RL controls. With phonological awareness tasks, the results showed that dyslexic readers were significantly outperformed by their CA controls but performed similarly to their RL controls, in terms of both speed and accuracy. In contrast, with morphological awareness tasks, the dyslexics systematically outperformed their RL controls and almost reached the proficiency level of the CA controls. Contrary to observations of phonological skills, this study indicates that university students with dyslexia may have developed far better morphological awareness than would be expected from their reading level. The authors discussed the role of the transparent French orthography in the development of morphological awareness and explained these results in terms of the semantic dimension of morphology, which was probably preserved among the dyslexic readers, in line with Elbro and Arnbak (1996).

More recently, Law et al. (2015) found that English-speaking university students with dyslexia were impaired in morphological awareness tasks. However, while Martin et al. (2013) used oral tasks to measure morphological awareness, Law et al. used written tasks (i.e., paper-and-pencil word and nonword sentence completion tasks), potentially confounding a predictor of reading (i.e., morphological awareness) with reading itself. Thus, the possibility cannot be excluded that the weakness that the authors observed in morphological awareness among the dyslexic sample was due not to a deficit in morphological awareness *per se* but to the acknowledged deficit in reading. Nevertheless, this study also showed a larger interaction between morphological awareness and word reading skill in adults with dyslexia when compared with the control group, as morphology accounted for 16.7% of the variance in word reading for the dyslexic readers but did not account for any significant variance for the control readers. Interestingly, when the dyslexic sample was divided into "compensated dyslexics" (those whose reading scores were no longer found to be deviant) and "non-compensated dyslexics" (those whose reading scores were still deviant), the morphological awareness of the compensated dyslexics did not differ significantly from that of the CA controls. However, they did differ significantly from the performance of the non-compensated dyslexics in tests of morphological awareness, after controls for vocabulary and phonology. Therefore, these results suggest that intact morphological awareness contributes to the level of compensation achieved by university students with dyslexia.

Thus, morphological analysis may be an important component of reading compensation for individuals with dyslexia. Support for this possibility comes from studies that have assessed implicit morphological skills and shown that morphological processing does not seem to be deficient for children (Quémart & Casalis, 2013), adolescents (Elbro & Arnbak, 1996) or adults with dyslexia (Leiken & Zur Hagit, 2006). However, Deacon, Parrila and Kirby (2006) found contrasting results with English university students with dyslexia. These differing findings across languages may be related to the orthographic transparency of the French writing system relative to English, and to the fact that metamorphological development is accelerated in French relative to English (Duncan, Casalis, & Colé, 2009), thus counteracting the effect of phonological impairments in the development of morphological knowledge. These results are important and allow us to consider the use of morphological skills as a compensatory reading strategy among students with dyslexia.

The present study

Most studies of adults with dyslexia have focused on identifying the deficits responsible for the persistent impairment in visual word recognition and have included phonological awareness tasks because phonological impairments are considered to be a primary cause of dyslexia. In order to understand which language abilities dyslexics may rely on to compensate for their deficits, it is also fundamental to establish dissociations, which can be done at the individual level then confirmed at the group level to establish stability and generalizability to the population from which the samples were selected. However, morphological awareness has rarely been systematically assessed despite the studies of children and adults which have suggested that morphological awareness may be preserved in dyslexia.

With respect to the only comparison of dyslexic phonological and morphological awareness in French by Martin and al. (2013), some methodological limitations need to be addressed. First, given the heterogeneity within both the dyslexic and CA control groups and the size of both samples, it appears necessary to apply more strict matching criteria, particularly with regard to educational level (e.g. number of years of higher education) because it is well known that educational level influences the development of cognitive skills such as vocabulary and morphological awareness (Anglin, 1993; Carlisle, 1987). Second, vocabulary was not taken into account or controlled in Martin et al.'s study, although a relationship is known to exist between vocabulary and morphological awareness among skilled readers (Guo et al., 2011). In the present study, the participant's vocabulary knowledge was carefully controlled.

Thus, the main goal of the present study was to compare the development of both phonological and morphological awareness between French university students with dyslexia and chronological-age controls (with groups matched on gender, nonverbal IQ, educational level, and vocabulary). The hypothesis we tested was that, unlike phonological awareness, morphological awareness would be well-developed in university students with dyslexia.

For this purpose, we have employed two statistical methodologies to investigate whether a dissociation exists between these two reading-related skills: the first approach is based on an individual level of analysis using a single case study methodology (Crawford & Garthwaite, 2005; Crawford, Garthwaite, & Porter, 2010) and the second approach is based on a classical group analysis.

The single case methodology allowed us to analyze the performance of one subject in two tasks, in comparison with a representative sample of the population. Generally, the aim of this type of methodology is to determine if a patient exhibits a statistically significant deficit and to compare the difference between a patient's performances on two or more tasks using z scores. However, this criterion for dissociation is not sufficiently rigorous. This is why Crawford and Garthwaite (2005a; 2005b) proposed an additional criterion, namely, that the patient's standardized difference on the two tasks should differ from the distribution of differences in controls. They developed a method to test for a difference between a case's score on two tasks and to obtain a point estimate of the effect size and interval estimates of the abnormality of the case's difference (for a mathematical explanation, see Crawford et al., 2005, 2010).

The first objective of this study was to investigate whether phonological and morphological awareness are dissociable among dyslexic university student using two tasks which involve a decomposition procedure, the phonological consonant-consonant-vowel task and the morphological suffixation decision task. In the morphological awareness task, the boundary between the stem and the suffix is phonological as well as semantic because the stem and suffix in morphologically complex words are both morphemes which convey meaning. Therefore, we hypothesized that morphological but not phonological decomposition will be preserved among French university students with dyslexia and that these decomposition processes will be independent from each other as demonstrated by evidence of dissociation at the individual level. The second objective was to confirm the dissociation hypothesis at the group level in order to test whether the results could be generalized to the population of university students. We expected to find an interaction between groups and tasks (phonological versus morphological awareness) on the efficiency scores taken with each task. Finally, the third objective was to find evidence for a link between the magnitude of the dissociation and the reading level of university students with dyslexia, which would offer empirical support for the compensation hypothesis based on morphology (Elbro & Arnbak, 1996). Thus, we hypothesized that if morphological awareness is preserved in adults with dyslexia while phonological awareness is impaired, then we would expect that the magnitude of the dissociation would be related to their reading level.

Method

Participants

Forty participants agreed to participate in the present study. Twenty university students with dyslexia and 20 skilled readers matched on gender (each group was composed of 14 women and 6 men), chronological age ($t(38) = 0.40$, $p > .80$), educational level ($t(38) = 0.11$, $p > .90$), vocabulary ($t(38) = 0.08$, $p > .90$; as measured by the EVIP scale (Dunn, Thieriault-Whalen, & Dunn,1993), the French adaptation of the Peabody Picture Vocabulary Test-Revised, PPVT-R (Dunn & Dunn, 1981)) and nonverbal IQ ($t(38) = 0.38$, $p > .90$). The two groups differ significantly on mean reading score ($t(38) = -10.9$, $p < 0.001$). These results are shown in Table 1.

(Insert Table 1 about here)

Reading scores (CTL indicator) were obtained using the "Alouette" test (Lefavrais, 2005), a standardized French assessment of reading level. Participants have to read 265 words as rapidly and as accurately as possible within a 3-minute time limit. The text includes rare words and some spelling traps, and the characteristics of this test prevent impaired readers from compensating for their written word recognition difficulties via the use of contextual guessing. We used the CTL score which takes both accuracy and speed into account ($\text{CTL} = \frac{C \times 180}{TL}$; with C = the number of words correctly read, and TL = the reading time; max = 180s).

Both groups were recruited at Aix-Marseille University (France) from a wide variety of academic programs (e.g., Psychology, Law, Medicine, Neurosciences, Pharmacy, Economy, Archeology, Mathematics, and Physics). Note that in France, unlike many other countries, there is no selection process for entry to university (any holder of a high school diploma is admitted). University students with dyslexia were recruited following a diagnosis of dyslexia established by CERTA (Centre de Référence des Troubles d’Apprentissages [Center for the diagnosis of learning disabilities] – Hôpital Salvator, Marseille). The dyslexics had been diagnosed during primary school and 90% of them had received remedial teaching for an average of 5.44 years (SD = .31). Moreover, all dyslexics reported having experienced major difficulties in learning to read in childhood. They also had to: (1) be monolingual native speakers of French, (2) lack any known neurological/psychiatric disorders and report normal or corrected-to-normal hearing or vision, (3) have a nonverbal IQ within the normal range (that is, above 25th centile, Raven's matrices; Raven, Court, & Raven, 1995), and (4) present a reading score 2 SD below the mean of the control group. In the control group, students had typical literacy skills with no previous history of any learning disability and they also had non-verbal IQ in the normal range.

Experimental tasks

For the phonological assessments, we administered pseudoword reading, phonological awareness (i.e., phonemic awareness) and phonological short-term memory tasks 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). In France, there are no such computerized tests for adults (see Martin et al., 2010; 2013).

Pseudoword reading. This task assessed the efficiency (time and accuracy) of the sublexical decoding procedure using 20 pseudowords, ten short and ten long (mean pseudoword lengths: 4.4 and 7.8 letters, respectively).

Phonemic awareness. The test involved the deletion of the first phoneme of a pseudoword composed of three phonemes. There were 12 items with a consonant-consonant-vowel structure (CCV, e.g., *spo*). The subjects heard the items one by one through headphones and had to repeat each item without the first phoneme as accurately as possible. The time taken to complete each task (response time) and accuracy were measured. The experimental items were preceded by a practice session in which participants received five training trials with feedback. No item was used in both the training and the experimental tasks.

Phonological short term memory. This task consisted of repeating 24 pseudowords from three to six syllables long (e.g., *moukola*). Pseudowords were presented in order of increasing syllable length, with six items for each length. The time taken to perform the whole task (response time) and accuracy were measured.

Then, to assess morphological knowledge, we administered two computer-driven oral tasks developed by Martin et al. (2013) to measure performance speed and accuracy. These tasks have been designed to require a minimum of phonological analysis (i.e., the level of phonological difficulty was low) and all of the monomorphemic items used were composed of a suffix-like ending (e.g., *mistral [mistral], bretelle [strap]*).

S*uffixation decision.* The stimuli in this task consisted of 24 bisyllabic and 24 trisyllabic words, half being genuinely suffixed (*e.g., pendulette, [little clock]*) and half containing a suffix-like ending (*e.g., renard, [fox]*). Words were prerecorded and played through headphones. In this task, participants made a speeded manual forced choice about words heard in isolation after a fixation cross that appeared for 250 ms in the middle of the screen. For each trial, they had to decide whether the word that they heard was suffixed or not. The intertrial interval was 1100 ms.

S*uffixed word detection.* In this test, participants heard triplets of words sharing final phonemes with a 750 ms pause between them, followed by a fixation cross in the middle of the screen. Participants had to indicate which of the three was suffixed (e*.g., lanière, tanière and glacière; [strap, den, cooler]*). There was a 1000 ms intertrial interval. The 12 word triplets were made up of one suffixed word and two non-suffixed words.

In both morphological awareness tasks, the psycholinguistic properties of the materials were controlled for written and spoken frequency according to the Lexique database (New, Pallier, Ferrand, & Matos, 2001), and also for word endings, number of syllables and grammatical class (see Martin et al. (2013) for further information about the stimuli and the experimental procedure). Prior to testing, the experimenter informed participants about the definition of suffixes and trained them on the distinction between suffixed and non-suffixed word using five practice items for each category with feedback. No item was used in both the training and the experimental tasks.

Results

The mean scores of the dyslexics and skilled readers in these tasks are given in Table 2. Both accuracy and response time scores are reported for all tasks and we additionally report efficiency scores for the phonological awareness task and for the two morphological awareness tasks, which were calculated as the number of correct responses given per second. Efficiency scores were used for two reasons. Firstly, they were not subject to ceiling effects (unlike the control group accuracy scores in the phoneme awareness task). Secondly, efficiency scores have an advantage over separate accuracy and speed scores in that they are not influenced by individual variability in emphasis on precision versus speed. Some participants may place an emphasis on being correct rather than fast, whereas others would place emphasis on speed. This variability was of minor importance to the study.

(Insert Table 2 about here)

On the set of phonological assessments (reading pseudowords, phonemic awareness, phonological short-term memory), the university students with dyslexia performed significantly more slowly and less accurately than the skilled readers (all p values < .001). Results also showed a significant difference between groups concerning efficiency on phonemic awareness (t (38) =10.5, p < .001).

On the morphological awareness tasks, there was no significant difference between dyslexic and skilled readers on accuracy (t < 1) in either task. Concerning response times, there was no significant difference for the suffixation decision task ($t(38) = 1.17$, $p = 0.20$), but the dyslexic group was significantly slower than the skilled readers in the suffixed word detection task ($t(38) = 2.3$, $p < .05$). The results showed no difference between groups with regard to efficiency in either morphological awareness task ($t < 1$).

Finally, we calculated the correlation between the two measures of morphological awareness efficiency, which was significant ($r(38) = .68$, $p < .001$) showing a lower bound estimate of the reliability of the measures.

Multiple-case studies: method and dissociation results

To compare the level of development of phonological and morphological awareness in each group, we have selected only the phonemic awareness and suffixation decision tasks because the format of item presentation is comparable. To examine the dissociation between phonological and morphological awareness on both accuracy and speed, we used the "Dissocs_EX.exe" program (Crawford et al., 2010) to test whether a single case meets the criteria for dissociation. This upgraded version now offers the option of using a one-tailed test when testing for a difference between a case's X and Y scores. Crucially, this method provides point and interval estimates of the effect size for the difference between case and controls. More precisely, this dissociation measure refers to an index that compares the difference between tasks observed for the single case with the differences observed for controls. The formula for obtaining the point estimate of the effect size when testing for dissociation is described by Crawford et al. (2010, pp. 254): "*the case's scores on the two tasks are converted to z scores based on the control means (M) and standard deviations (S) for the two tasks and their difference divided by the standard deviation of the difference between two nonindependent z scores; this produces a z score for the difference. We denote this index as Z_{DCC}. The formula for the index is:*

$$ZDCC = \frac{[(x - Mx)/Sx] - [(y - My)/Sy]}{\sqrt{2 - 2Rxy}} = \frac{Zx - Zy}{\sqrt{2 - 2Rxy}}$$

Where R_{xy} corresponds to the correlation between the two tasks in the control sample, and all other terms are obvious".

Tables 3 and 4 present the statistical results for dissociation analyses on accuracy and response times between phonological and morphological awareness. Each table presents the number of subjects, the estimated effect size (Z_{CC}; the subscript $_{CC}$ representing "case-control") with the 95% confidence interval for both phonological and morphological tasks, the point and estimates of effect size for the dissociation (Z_{DCC}) and the significance test *t* with *p* values. Note that the mean difference between standardized scores in controls is necessarily zero.

Table 3 shows that 14 dyslexics exhibited a significant dissociation between the phonological and morphological tasks on accuracy scores (see the last column of table), indicating that their phonological scores are inferior to those of the controls and their morphological scores are at least equal to or higher than those of the controls. Moreover, the table provides the effect size for the dissociation (Z_{DCC}) and the 95% confidence interval, which together allow us to identify a trend (when the Z_{DCC} is close to 0, there is no dissociation). Thus, we can see that the point estimated effect-size (Z_{DCC}) and 95% confidence interval are very low for only 2 of the dyslexic cases (*Subjects 4, 18*), and performances on both tasks are close to those of the control group. All other cases obtained a Z_{DCC} and confidence interval greater than the controls (i.e. the difference between a Z_{CC} for the X and Y tasks is large enough to consider a dissociation or a trend of dissociation). Figure 1 summarizes the dissociation analyses for accuracy scores by submitting the point estimates of Z_{CC} for both phonological and morphological tasks compared to the mean standardized scores of the control group. Note that in this figure the control group scores (aligned with the zero value) correspond to the mean standardized score for both the phonological and morphological tasks.

(Insert Table 3 about here)

(Insert Figure 1 about here)

In the same way, Table 4 shows that 12 dyslexics exhibited a significant dissociation in response time between the phonological and morphological tasks. Moreover, the point estimated effect-size (Z_{DCC}) and 95% confidence interval were very close to 0 for only 1 dyslexic case (*Subject 17)*. All other dyslexics obtained a Z_{DCC} and confidence interval greater than the controls. Figure 2 summarizes the dissociation analysis for response times in the same way as Figure 1. Taken together, these findings show a clear dissociation for 18 dyslexics on at least one indicator (accuracy or speed), with 8 of these cases presenting a dissociation in both accuracy and response time. Note that Subjects 4 and 18, who did not exhibit a dissociation for accuracy, do show a significant dissociation for response time. Subject 17 who showed a significant dissociation for accuracy did not show a dissociation for response time, and this was also true for Subjects 5, 10, 12 and 13 suggesting a speed-accuracy tradeoff strategy (for a review, see Bogacz, Wagenmakers, Forstmann, and Nieuwenhuis, 2010; and see Kunert and Scheepers, 2014, for a recent study on the speed and accuracy of adult dyslexic word recognition).

(Insert Table 4 about here)

(Insert Figure 2 about here)

One of the typical reasons for looking at dissociations is to explore whether there are different patterns of performance within subgroups of dyslexics. Here, we observed a relatively homogenous pattern among dyslexic participants on these dissociation measures. At present, the implication is that dyslexics in general might be able to compensate for poor phonological abilities via morphological knowledge although a few students (only two in this study) do not show the dissociation. Since some dyslexics had better phonological abilities than others, we would not expect a clear correlation between morphological processing and reading. In fact, dyslexics with very poor phonological abilities would have to have very good morphological abilities to compensate, and those with better phonological abilities would not need (or use) morphological abilities to the same extent. Hence, we do not predict a strong correlation between morphological abilities and reading but rather we expect to find that it is the magnitude of the dissociation between morphological and phonological abilities that correlates with reading performance.

Prior to that, we worked to make sure that there were no significant correlations between performances on the phonological and morphological awareness tasks for accuracy ($r(18) = 0.101$; $p = 0.67$) or response times ($r(18) = 0.109$; $p = 0.647$) in the dyslexic group. Concerning the magnitude of the dissociation for response times, we found a positive correlation with reading as measured by the Alouette test ($r(18) = 0.45$; $p < .05$). Concerning the magnitude of the dissociation for accuracy, we found a marginal correlation with reading ($r(18) = 0.34$; $p = .10$). This shows that reading performance is related to the presence of a dissociation, particularly for response times. Indeed, when the dissociation is strong and in favor of morphological awareness skill, dyslexics have better reading scores.

Group level analyses

In order to confirm and generalize the dissociation between phonological and morphological awareness evident in the dyslexic group at the individual level, we conducted a group level analysis on efficiency scores. As mentioned above, the efficiency scores have the advantage of being free from ceiling effects with respect to accuracy and insensitive to individual tradeoffs between accuracy and speed.

A group (dyslexic vs. control) × 2 condition (phoneme vs. morpheme) mixed design ANOVA yielded a main effect of group ($F(1,28) = 12.20$, $p < .001$), no effect of condition, and a significant interaction between group and condition ($F(1,28) = 6.10$, $p < .02$). The interaction effect indicates the relative independence between phonological (phoneme) and morphological (suffix) awareness as illustrated in Figure 3. While the two groups were not significantly different in morpheme detection efficiency, the two groups were virtually non-overlapping in phonemic awareness.

(Insert Figure 3 about here)

Discussion

The main objective of this study was to evaluate and compare the development of two language skills involved in reading, namely phonological and morphological awareness, among dyslexic and non-dyslexic university students in France. In doing so, our aim was to establish whether or not dyslexic morphological awareness is well-developed relative to phonological awareness by applying methodologies to establish dissociation between measures of these skills at both the individual (Crawford et al., 2005; 2010) and group levels. Our other objective was to determine whether the magnitude of the dissociation was related to reading level among these dyslexic readers.

Our study of French university students with dyslexia confirms the persistence of deficits in reading (as assessed by the Alouette test), in pseudoword reading, and also in phonological reading-related skills (phonological awareness and short-term memory), both in terms of accuracy and speed (Martin et al., 2010). It is widely acknowledged that phonological deficits constitute the core characteristic of dyslexic readers, who cannot easily access or use phonological representations for decoding or retrieving the meaning of written words (see Boets et al., 2013).

Concerning morphological awareness, our results suggest that university students with dyslexia perform on a par with non-dyslexic controls, partially confirming the findings of Martin et al. (2013). However, we failed to replicate Martin et al.'s observation that the dyslexic group was slower than CA controls in the suffixation decision task. This discrepancy between the studies could be due to controlling for the effects of both educational and vocabulary levels across the participant groups in the present study, which was not the case in Martin et al's study. In our study, we also measured response times for the suffixed word detection task, which indicated that dyslexic readers were slower than CA controls. This might best be explained as a task effect because in the suffixed word detection task, participants identify which of three words is the target suffixed word, while in the suffixation decision task, participants only make a decision about one word. Thus, in the former task, there is a greater involvement of executive function, especially inhibitory processes and working memory, which could increase the level of difficulty of the task, especially for dyslexic readers (see Corkett and Parrila, 2008).

One possible limitation of the study is the lack of a reading-level (RL) control group. Both RL and CA controls are important in the search for causes of reading difficulties (e.g., Goswami & Bryant, 1989). Goswami and Bryant further suggested that "*a combination of positive results in a CA match and negative results in a RL match should be treated with great caution*" (p.418). However, in Martin's et al. (2013) study the performance of the dyslexic group was compared with those of both CA and RL match controls using exactly the same tasks. While the dyslexics performed at the same level as their RL controls in the phonological awareness tasks, they systematically outperformed their RL controls in the morphological awareness tasks. These results support the view that university students with dyslexia can develop far better morphological awareness than would be expected from their reading level, which is in line with previous results from French dyslexic children (see Casalis, Colé, and Sopo, 2004).

We then compared levels of morphological awareness with levels of phonological awareness to examine whether a dissociation was present between these two forms of reading-related knowledge among our university students with dyslexia. Using the single-case method, we observed that the vast majority of dyslexic participants did exhibit such a dissociation. More precisely, 14 dyslexics exhibited a significant dissociation for accuracy and 12 dyslexics showed a dissociation for response time. Taken together, these findings provide evidence of a dissociation for 18 dyslexics (*90%*) on at least one indicator (accuracy or speed) and, for 8 dyslexics (*44%*), a dissociation on both indicators. However, it should be noted that some participants (*38%*) who displayed a clear dissociation on one indicator did so as a result of using a speed-accuracy trade off in order to make more accurate responses. Using the group level analysis based on efficiency scores, we showed an interaction between group and type of unit to be manipulated in the awareness tasks (phoneme/morpheme). This interaction arose because phonological (phoneme) awareness was affected in the dyslexic sample while morphological (suffix) awareness remained unaffected.

In order to argue for a compensation hypothesis based on morphological skills in university students with dyslexia, we provided evidence of a link between the magnitude of the dissociation and reading level. Our findings reveal a positive correlation, indicating that the higher the quality of morphological awareness as compared to phonological awareness, the more efficient the reading of the dyslexic individual. This result can be linked to those obtained by Elbro (1986), who showed that a high degree of morpho-semantic analysis in decoding single written words was associated with higher reading speeds in a sample of teenagers with severe dyslexia. This set of findings is critical and supports the compensation hypothesis based on preserved morphemic skills in Danish adolescents with dyslexia (Elbro &

Arnbak, 1996; Arnbak & Elbro, 2000). Thus, our findings indicate that morphological awareness is not deficient among university students with dyslexia and importantly, that the development of their phonological and morphological awareness seems at least partly independent.

Several hypotheses could be proposed to explain: (1) how morphological awareness was able to be well-developed in this population; and (2) why the development of morphological awareness can be dissociated from phonological awareness in this population. Firstly, the fact that morphology is systematically encoded in the French orthography (but very rarely in phonology) might be important for the development of morphological knowledge as a compensatory strategy (see Martin et al., 2013). At the level of the word form, morphology is important for spelling and decoding because the French writing system is largely morphologically-based (Rey-Debove, 1984). As morphemes appear very frequently in words and are systematically associated with meaning, they may act as functional reading units facilitating the rapid decoding of written words and access to word meaning. In addition, university students with dyslexia encounter reading material very frequently, they may benefit from repeated presentations of morphemes, leading them to develop strong connections between orthographic representations, word identification and access to the meaning. Our hypothesis that adults with dyslexia can use their knowledge about the internal structure of words (frequent orthographic units such as morphemes) as a compensatory reading procedure is also in line with the orthographic lexical-learning hypothesis (Di Betta et al., 2006; Romani et al., 2008) defined as the capacity to form new representations by recombining the units of a restricted set. A few, but nevertheless crucial studies have already demonstrated that children and adolescents with dyslexia rely on morphological processing (i.e., implicit morphological knowledge) during visual word recognition (Elbro & Arnbak, 1996, Quémart & Casalis, 2013). This set of findings points to the conclusion that dyslexics have preserved morphological knowledge and use their knowledge to support a compensatory strategy. Nevertheless, insights into developmental issues need to be supported by further investigations using longitudinal designs.

Secondly, since the semantic knowledge associated with words seems to be preserved both in children (Vellutino et al., 1995) and adults (Cavalli et al., 2016; Elbro et al., 1994) with dyslexia, and since neuroimaging studies show no differences between the spatial distribution of the brain areas involved in semantic processing by dyslexic and skilled readers (Helenius, Salmelin, Service, & Connolly, 1999; Rüsseler, Becker, Johannes, & Münte, 2007), we assume that dyslexics are likely to capitalize on the semantic dimension of morphology to develop morphological knowledge. In accordance with this hypothesis, a recent study conducted in Dutch showed that in the context of a productive dictation task, university students with dyslexia made slightly fewer grammatical errors and proportionally more phonological and orthographic errors than their control peers in spelling words and sentences to dictation. This suggests that students with dyslexia are able to use morpho-syntactic rules and can profit from morphological knowledge in production tasks (Tops, Callens, Bijn, & Brysbaert, 2013). However, the difference between morphology-related spelling errors and phonology-related spelling errors found in the Tops et al. study was smaller than the dissociation reported in the present study. This suggests a difference between both perception and production tasks, where morphology is more helpful in the oral modality than in the written modality, although difficulties in phonology are still present in both modalities. These results allow us to assume that university students with dyslexia have developed other reading-related skills to offset their poor reading, mainly by using their unimpaired oral language skills (for a recent discussion, see Haft, Myers, and Hoeft, 2016).

In the case of morphological skills, it will be necessary to replicate the results of the present study in future studies. However, as stated by Deacon et al. (in press), there is recent evidence from several alphabetic orthographies that morpheme analysis might offer a compensatory route to reading for dyslexics. The evidence for such a compensatory route has emerged from studies in both shallow (phonologically transparent) orthographies like Dutch (Tops et al., 2012), and Italian (e.g., Burani, Marcolini, De Luca, & Zoccolotti, 2008) – and in deeper orthographies like Danish (Elbro & Arnbak, 1996) and English, (e.g., Elbro, King, Rown, & Oakhill, 2016; Law et al., 2015). All of these studies have found that morphological skills (i.e., implicit or explicit morphological knowledge) seem to be preserved in dyslexia.

Finally, some additional evidence regarding the role of morphological skills in dyslexic students' reading derives from morphological intervention studies. The small number of studies of this type show that morphological interventions might offer a compensatory strategy for several reading skills such as spelling, vocabulary, word reading, reading comprehension and inferring the meaning of morphologically complex words (Casalis et al., 2004; Elbro & Arnbak, 1996, Goodwin & Ahn, 2010). Interestingly, the large majority of our dyslexic sample received remedial teaching during primary school for an average of 5.4 years. Although training in grammar and morpho-syntax is only one part of French remediation programs, which mainly target phonological and decoding training, the relatively good development of morphological awareness in university students with dyslexia might reflect the effectiveness of such training, leading us to consider morphological training as worthy of interest. However, we cannot exclude the possibility that morphological awareness can develop spontaneously in readers with dyslexia because of its semantic dimension. Further study should therefore investigate whether adults with dyslexia may benefit from morphologically-based instruction about the semantic dimension of language. The evidence presented here of a dissociation between phonological and morphological awareness certainly suggests that morphological skills might offset some of the phonological processing challenges that continue to trouble dyslexic readers into adulthood (Elbro & Arnbak, 1996; Fowler & Liberman, 1995).

Conclusion

According to Elbro and Arnbak (1996), the type of persistent difficulties in the activation of phonological codes shown by university students with dyslexia in the present study will encourage the development of alternative reading strategies, particularly strategies based on morphology. Our observation of a dissociation between (poor) phonological awareness and (good) morphological awareness among dyslexic students is consistent with this hypothesis. In order to validate these findings, further studies of morphological processing in the reading of adults with dyslexia are needed. The results will be very important for improving the diagnosis of dyslexia, especially in adulthood, because morphological awareness may act as a positive marker of this population. In relation to remediation programs, preserved morphological skills could provide an important basis for developing compensatory strategies in reading as is suggested by preliminary results using “MORPHOREM” (Colé, Casalis, & Dufayard, 2012), a computer tool based on morphological analysis for the remediation of dyslexic students’ reading.

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Table 1. *Means (and standard deviations) for university students with dyslexia (DYS group) and CA controls (CA group), for chronological age, educational level, vocabulary, Raven's Matrices, and reading score.*

	DYS group (N=20)		CA group (N=20)
Chronological age	23.76 (4.37)		24.1 (4.26)
Education level	3.00 (1.41)		3.05 (1.39)
EVIP Vocabulary (standard score)	116.3 (7.6)		115.7 (6.5)
Raven's Matrices (max = 58)	48.55 (4.17)		49.05 (4.07)
Reading score	314.86 (63.58)	***	508.17 (46.31)

*** $p < .001$

Table 2. *Mean scores (and standard deviations) for university students with dyslexia (DYS group) and CA controls (CA group) on tests of reading pseudowords, phonological awareness, phonological short term memory, and morphological awareness (suffixation decision, suffixed word detection).*

		DYS group		CA group
Pseudowords	Accuracy (%)	90.2 (6.9)	***	97.7 (2.4)
	Response Time (ms)	1308 (419)	***	631 (118)
Phonological awareness (CCV)	Accuracy (%)	86.6 (8.28)	***	98.7 (3)
	Response Time (s)	31.0 (7)	***	16.1 (4)
	Efficiency	0.34 (0.08)	***	0.76 (0.15)
Phonological STM	Accuracy (span)	4.5 (0.8)	***	5.3 (0.5)
	Response Time (s)	60 (13)	***	46 (4)
Suffixation decision	Accuracy (%)	78.02 (7.72)		76.56 (6.37)
	Response Time (ms)	3072 (719)		2767 (909)
	Efficiency	0.27 (0.08)		0.30 (0.08)
Suffixed word detection	Accuracy (%)	79.58 (11.30)		77.50 (9.40)
	Response Time (ms)	2818 (1607)	*	1783 (1183)
	Efficiency	0.49 (0.52)		0.58 (0.31)

*$p < .05$; ** $p < .01$, *** $p < .001$

Table 3. *Dissociation between phonological (X task) and morphological (Y task) awareness on accuracy (% of correct responses) following the dissocs_ES.exe program. The CA control group mean on the phonological task (M = 98.7; SD = 3), on the morphological task (M = 76.56; SD = 6.37), and the correlation between both tasks (r = 0.059) have been entered into the program.*

	Effect size (Z-CC) for X task		*Effect size (Z-CC) for Y task*		*Effect size (Z-DCC) for dissociation*		*Dissociation*	
Subject	*Point*	*95 % (CI)*	*Point*	*95 % (CI)*	*Point*	*95% (CI)*	*t*	*p-values*
Subject 1	-5.123	(-6.79 to -3.44)	-1.23	(-1.8 to -0.63)	-2.83	(-4.38 to -1.51)	2.6	0.01
Subject 2	-2.343	(-3.19 to -1.47)	2.377	(-1.5 to 3.23)	-3.44	(-4.67 to -2.32)	3.2	0.004
Subject 3	-2.343	(-3.19 to -1.47)	2.049	(1.25 to 2.82)	-3.20	(-4.36 to -2.15)	3.0	0.006
Subject 4	0.433	(-0.03 to 0.88)	0.082	(-0.35 to 0.52)	0.25	(-0.19 to 0.71)	0.2	0.81
Subject 5	-2.343	(-3.19 to -1.47)	-0.246	(-0.68 to 0.20)	-1.52	(-2.34 to -0.79)	1.4	0.16
Subject 6	-5.123	(-6.79 to -3.44)	0.082	(-0.38 to 0.52)	-3.79	(-5.43 to -2.39)	3.5	0.001
Subject 7	-5.113	(-6.77 to -3.43)	-0.574	(-1.04 to -0.09)	-3.30	(-4.89 to -1.96)	3.1	0.005
Subject 8	-2.343	(-3.19 to -1.47)	1.066	(0.50 to 1.60)	-2.48	(-3.45 to -1.60)	2.3	0.02
Subject 9	-5.123	(-6.79 to -3.44)	2.377	(1.5 to 3.23)	-5.46	(-7.42 to -3.73)	5.1	0.000
Subject 10	-5.123	(-6.79 to -3.44)	-2.213	(-3.02 to -1.38)	-2.12	(-3.65 to -0.78)	2.0	0.059
Subject 11	-7.9	(-10.42 to -5.36)	-0.574	(-1.04 to -0.09)	-5.34	(-7.75 to -3.30)	5.0	0.000
Subject 12	-2.343	(-3.19 to -1.47)	-0.246	(-0.68 to 0.20)	-1.52	(-2.34 to -0.79)	1.4	0.16
Subject 13	-2.343	(-3.19 to -1.47)	-0.902	(-1.41 to -0.37)	-1.05	(-1.85 to -0.32)	0.9	0.33
Subject 14	-7.9	(-10.42 to -5.36)	0.41	(-0.05 to 0.86)	-6.05	(-8.55 to -3.92)	5.6	0.000
Subject 15	-2.343	(-3.19 to -1.47)	1.393	(0.76 to 2.0)	-2.72	(-3.75 to -1.79)	2.5	0.01
Subject 16	-10.677	(-14.06 to -7.27)	-0.574	(-1.04 to -0.09)	-7.36	(-10.61 to -4.62)	6.8	0.000
Subject 17	-5.123	(-6.79 to -3.44)	1.066	(0.50 to 1.60)	-4.51	(-6.26 to -2.99)	4.2	0.000
Subject 18	0.433	(-0.03 to 0.88)	-0.574	(-1.04 to -0.09)	0.73	(0.24 to 1.23)	0.69	0.49
Subject 19	-2.343	(-3.19 to -1.47)	0.738	(0.23 to 1.22)	-2.24	(-3.16 to -1.41)	2.12	0.04
Subject 20	-5.123	(-6.79 to -3.44)	0.082	(-0.38 to 0.52)	-3.79	(-5.43 to -2.39)	3.5	0.001

Table 4. *Dissociation between phonological (X task) and morphological (Y task) awareness on response times following the dissocs_ES.exe program. The CA control group mean on the phonological task (M = 16.1; SD = 4), on the morphological task (M = 27.67; SD = 909), and the correlation between both tasks (r = 0.31) have been entered into the program.*

	Effect size (Z-CC) for X task		*Effect size (Z-CC) for Y task*		*Effect size (Z-DCC) for dissociation*		*Dissociation*	
Subject	*Point*	*95 % (CI)*	*Point*	*95 % (CI)*	*Point*	*95 % (CI)*	*t*	*p-values*
Subject 1	-3	(-4.03 to -1.95)	-0.769	(-1.26 to -0.26)	-1.91	(-2.98 to -0.96)	1.7	0.08
Subject 2	-4.175	(-5.55 to -2.78)	0.444	(0.02 to 0.89)	-3.95	(-5.55 to -2.57)	3.6	0.001
Subject 3	-4.7	(-6.23 to -3.14)	-0.16	(-0.59 to 0.28)	-3.88	(-5.57 to -2.43)	3.6	0.001
Subject 4	-2.725	(-3.68 to -1.75)	-0.343	(-0.79 to 0.11)	-2.03	(-3.05 to -1.14)	1.9	0.07
Subject 5	-4.525	(-6.01 to -3.02)	-0.782	(-1.27 to -0.27)	-3.20	(-4.77 to -1.85)	3.0	0.007
Subject 6	-5.375	(-7.12 to -3.62)	0.583	(0.10 to -1.05)	-5.10	(-7.12 to -3.35)	4.7	0.000
Subject 7	-6.95	(-9.17 to -4.71)	-0.691	(-1.17 to -0.19)	-5.35	(-7.76 to -3.30)	4.9	0.000
Subject 8	-1.325	(-1.92 to -0.71)	0.395	(-0.06 to 0.84)	-1.47	(-2.16 to -0.83)	1.3	0.18
Subject 9	-2.725	(-3.68 to -1.75)	1.072	(0.50 to 1.61)	-3.25	(-4.48 to -2.16)	3.0	0.006
Subject 10	-4.625	(-6.14 to -3.09)	-2.023	(-2.78 to -1.24)	-2.22	(-3.77 to -0.85)	2.0	0.05
Subject 11	-6.2	(-8.19 to -4.19)	-0.442	(-0.89 to 0.02)	-4.93	(-7.10 to -3.07)	4.5	0.000
Subject 12	-4.325	(-5.75 to -2.88)	-0.56	(-1.02 to -0.08)	-3.22	(-4.74 to -1.91)	3.0	0.007
Subject 13	-2.875	(-3.87 to -1.86)	1.05	(0.49 to 1.59)	-3.36	(-4.63 to -2.24)	3.1	0.005
Subject 14	-2.35	(-3.20 to -1.48)	-0.134	(-0.57 to 0.30)	-1.89	(-2.81 to -1.07)	1.7	0.09
Subject 15	-1.95	(-2.69 to -1.18)	-0.336	(-0.78 to 0.12)	-1.38	(-2.16 to -0.67)	1.3	0.20
Subject 16	-4.35	(-5.78 to -2.90)	0.023	(-0.41 to 0.46)	-3.74	(-5.33 to -2.36)	3.5	0.002
Subject 17	-1.425	(-2.04 to -0.78)	-1.077	(-1.62 to -0.51)	-0.29	(-0.94 to 0.33)	0.2	0.78
Subject 18	-3.325	(-4.45 to -2.18)	-0.988	(-1.51 to -0.44)	-2.00	(-3.16 to -0.97)	1.8	0.07
Subject 19	-2.95	(-3.97 to -1.91)	-1.525	(-2.16 to -0.86)	-1.22	(-2.26 to -0.26)	1.1	0.26
Subject 20	-9.275	(-12.22 to -6.31)	-0.451	(-0.90 to 0.01)	-7.55	(-10.79 to -4.79)	6.9	0.000

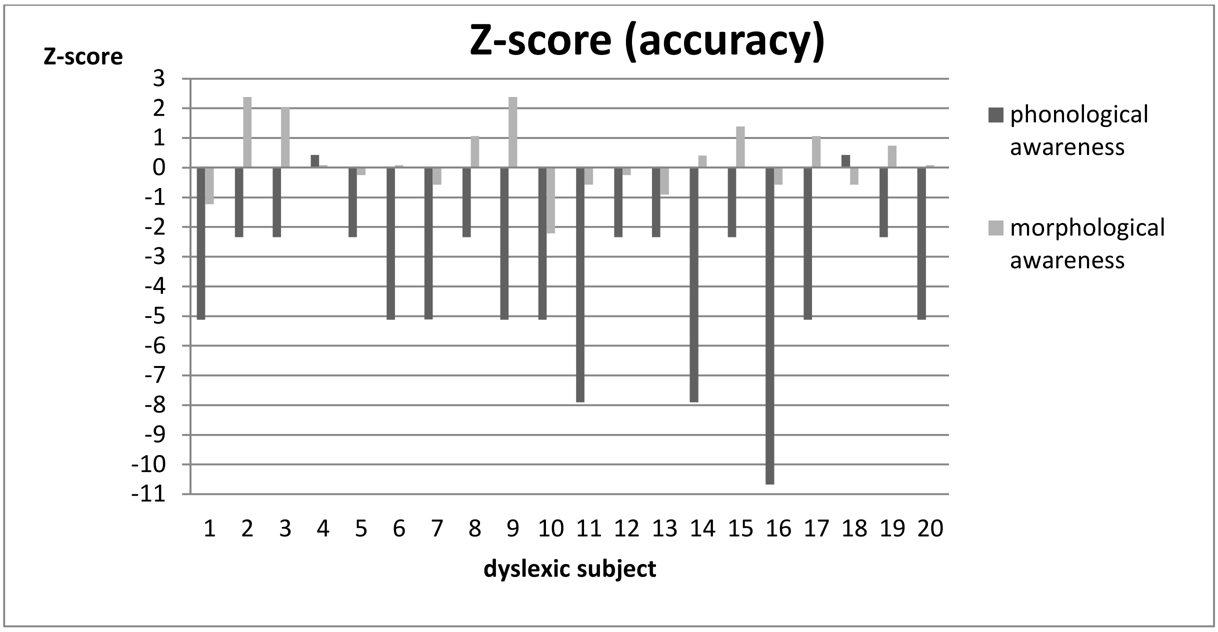

Figure 1. *Z* score (accuracy) on both phonological and morphological tasks comparing a single-case to controls. The baseline (aligned with the zero value) corresponds to the control mean.

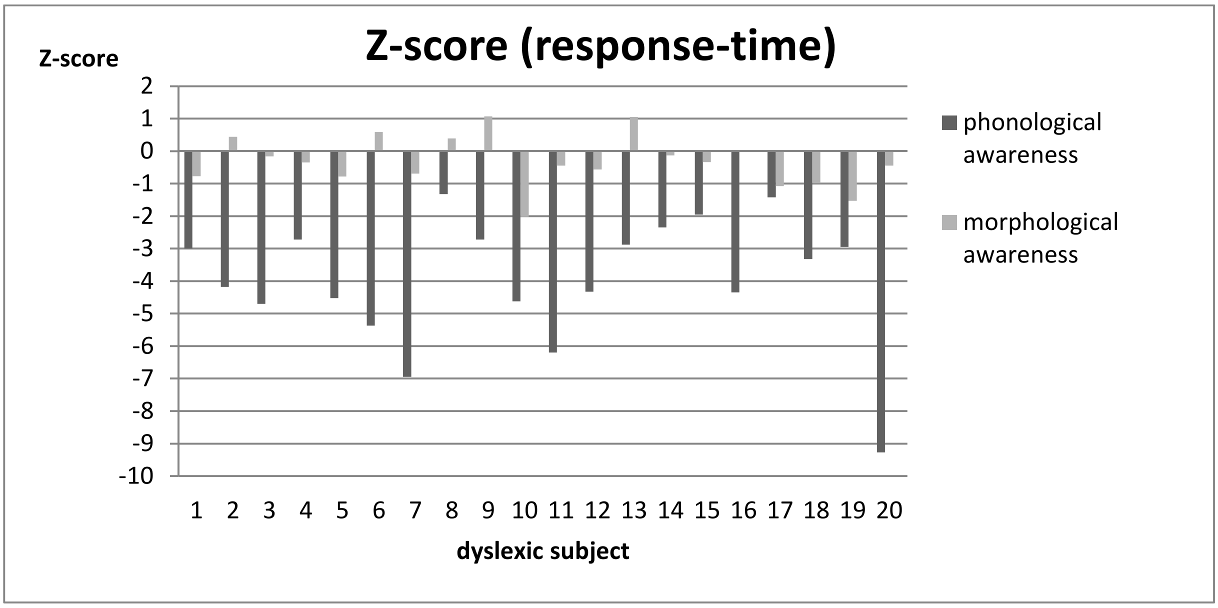

Figure 2. *Z* score (response times) on both phonological and morphological tasks comparing a single-case to controls. The baseline (aligned with the zero value) corresponds to the control mean

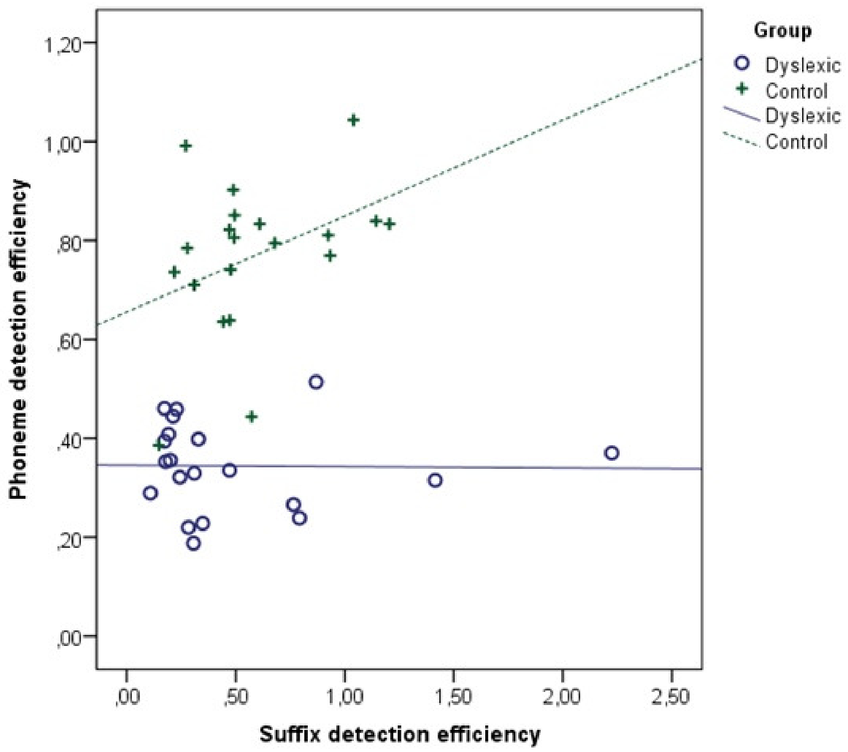

Figure 3. Phonological (phoneme) versus morphological (suffix) detection efficiency (number correct per second) in dyslexic and control university students.