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Centro de Neurociencias (Cuba)

Learning to read is one of the most important cognitive milestones in the human social environment. One of the most accepted models explaining such process is the Double-Route Cascaded Model. It suggests the existence of two reading strategies: lexical and sublexical. In the Spanish language there are some contradictions about how these strategies are applied for reading. In addition, there are only a few studies dealing with the analysis of shifts between them, achieving a fluent reading process. In this paper we use a reading task including words and pseudowords for characterizing the cost of shifting between reading strategies in children with developmental dyslexia and normal controls. Our results suggest the presence of both strategies in these two experimental groups. In controls, both strategies become more efficient in correspondence to the increased exposition to written material. However, in children with developmental dyslexia only the lexical strategy exhibits such improvement. Their also point to a low cost for shifting between strategies in controls and a much more significant one in children with developmental dyslexia, differentiating subgroups with distinct shifting patterns.

Keywords: reading strategies, shifts, Spanish, dyslexic children.

El aprendizaje de la lectura constituye uno de los hitos cognitivos más importantes del entorno social humano. Uno de los modelos de lectura más aceptados ha sido el Modelo de Doble Ruta en Cascada que sugiere la existencia de dos estrategias de lectura: lexical y sublexical. En el idioma español existen datos contradictorios acerca de cómo se aplican estas estrategias y no hay estudios que describan cómo se realizan los cambios de una a otra para lograr una lectura fluida. En este trabajo utilizamos una tarea de lectura de palabras y pseudopalabras para caracterizar el costo de cambio de una a otra estrategia en niños buenos lectores y niños con dislexia del desarrollo. Nuestros resultados sugieren la presencia de ambas estrategias en los dos grupos. En los niños buenos lectores ambas estrategias se hacen más eficientes con el grado de exposición a la lectura. Sin embargo, en los niños disléxicos esto solo ocurre en la estrategia lexical. Además, indican que los niños buenos lectores desarrollan un bajo costo en el cambio de estrategia de lectura mientras que un subgrupo de niños disléxicos presenta un costo mayor, conformándose subgrupos con patrones diferentes de afectación selectiva.

Palabras clave: estrategias de lectura, cambio, español, niños disléxicos.
The acquisition of reading skills is one human learning process that has played an extensive role in the cultural evolution of the species. It consists of learning to codify oral language into a new form of representation: written word. Among the models proposed for the study of reading processing is the dual route cascade model (Coltheart, 2006; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; Houghton & Zorzi, 2003; Jackson & Coltheart, 2001). According to this model, there exist two different, yet interacting pathways, or strategies, to accessing the semantic lexicon (a type of mental dictionary where each word is represented as an entry). These are: the lexical (visual, direct), and the sublexical. Ergo, words can either be read via the lexical path, which is faster, through direct, orthographic representations, or via the sublexical path, which is slower, and based on a process of grapheme-phoneme decoding. The latter strategy (sublexical) is the only means to reading words that are not represented in an individual’s lexicon, and it is also the only way to read pseudowords (artificially constructed stimuli that are pronounceable, but meaningless) (Castles & Holmes, 1996; Price & Mechelli, 2005; Rastle & Coltheart, 1998). The dual route cascade model has been applied to study the system of information processing used in reading and spelling, and it has been confirmed for readers of various languages, including English (Coltheart, Curtis, Atkins & Haller, 1993; Coltheart & Rastle, 1994; Rastle & Coltheart, 1998, 1999a, 1999b), Spanish (Defior, Justicia & Matos, 1996; García-Albea, Sánchez-Casas & Viso, 1982; Valle-Arroyo, 1996; de Vega & Carreiras, 1989; de Vega, Carreiras, Gutiérrez & Alonso-Quecuty, 1990) and German (Ziegler, Perry & Coltheart, 2000), among others.

A psycholinguistic marker known as the "lexical effect" has been utilized in order to reveal the presence of those two strategies of reading processing (Monsell, Patterson, Graham, Hughes & Milroy, 1992; Nergard-Nilssen, 2006; Ziegler, Perry, Wyatt, Ladner & Korne, 2003). The effect is based on the respective velocities of reading words versus pseudowords; reading actual words is faster (Baron, 1979; Boder, 1973; Castles & Coltheart, 1993; Hernández, Pérez, Morgades, Reigosa, Galán & Santos, 2007; Jiménez, Hernández & Conforti, 2006; Jiménez & Ramírez, 2002; Mitterer, 1982; Moll, Hutzelr & Wimmer, 2005; Temple & Marshall, 1983; Treitman, 1984). The differing reading velocities stand as evidence that words and pseudowords are read using different strategies (Nergard-Nilssen, 2006). This effect becomes especially evident during tasks in which a subject reads a list that includes a mixture of both words and pseudowords. From this we may infer that subjects utilize two different strategies.

Spanish-language studies directed at revealing the presence of two distinct reading strategies have demonstrated that Spanish-speaking children start to read at the basic level using graphetic-phonetic mapping strategies (Valle-Arroyo, 1996) and achieve a high level of reading competency more quickly than children who read languages with opaque orthographies (Aro & Wimmer, 2003). Due to the nature of this mechanism, children learning to read Spanish make greater use of the sublexical pathway than expert readers do; experts tend to utilize the lexical pathway the majority of the time (Dominguez & Cuertos, 1992). The existence of both strategies has even been found in dyslexic, Spanish-speaking children (Jiménez & Ramírez, 2002). Developmental dyslexia is defined as a specific learning disorder that pertains to reading, and that develops despite the presence of normal intelligence and available, adequate educational and socioeconomic resources, and also despite the absence of any obvious sensory deficit (Snowling, 2001). From a cognitive perspective, it is explained as a phonological deficit, independent of the language one speaks, and it has universal, neural basis (Paulesu, Demonet, Fazio, McCrory, Chanoine, Brunswick et al., 2001). Authors who postulate the phonological hypothesis propose that retardation in phonological development affects the construction of adequate phonological representations. These deficient representations do not create a solid base for the subsequent development of orthographic understanding (Metsala, 1997; Snowling & Hulme, 1994).

Although the importance of the sublexical strategy may seem so clear as to be universal, the role of the language itself in the selection and application of a strategy for reading comprehension is central to the debate. The use of one strategy over another seems to depend on the orthographic characteristics of the language at hand (Frost, Katz & Bentin, 1987; Wydell, Butterworth & Patterson, 1995; Ziegler et al., 2003; Ziegler & Goswami, 2005). Especially crucial are the properties of regularity/consistency in orthographic and phonological mapping (the extent to which an orthographic unit maintains the same pronunciation across words, and to which a phonological unit has a single, unique spelling across words). Along those lines, there is clearly a wide variety of orthographic systems. On one extreme end of the spectrum are languages that have a high level of orthographic transparency, where mapping between graphemes and phonemes is highly consistent (German, Spanish, Italian), and on the other end of that spectrum are languages with opaque orthographies (English, French, Arabic), which show very little consistency between corresponding graphemes and phonemes (Aro & Wimmer, 2003; Davis, 2005; Ellis & Hopper, 2001; Seymour, Aro & Erskine, 2003; Ziegler, Stone & Jacobs, 1997). In the case of opaque languages, both reading strategies are completely necessary in order to read without error because irregular words may only be read correctly using the direct strategy. In transparent orthographies such as that of Spanish, on the other hand, various authors have suggested a greater use of the sublexical strategy, since irregular words are minimal or do not exist at all, and since they can all be read correctly using this strategy (Ardila, 1998; Cozzi, Gugliotta & Marshall, 1995; Davis, 2005; Frith, Wimmer, & Landerl, 1998; Goswami, Gombert & Barrera, 1998;
Goswami, Ziegler, Dalton, & Schneider, 2001; Jiménez & Guzmán, 2003; Signorini & Borzone, 2003; Thorstad, 1991; Wimmer & Goswami, 1994).

Goswami, Ziegler, Dalton and Schneider (2003) conducted a cross-cultural study that compared German and English children in order to determine the relative importance of each reading strategy during the acquisition of reading comprehension in languages with differing levels of consistency between its graphemes and phonemes. In this study, lists of pseudowords were composed, and the list items were of differing types. Some could be read using a sublexical strategy (processing letter by letter, graphhetic/phonetic conversion), while others required a more lexical strategy in order to be read; they required one to break the pseudowords down into larger fragments (combinations of various letters). The different types of pseudowords were presented in various lists, at times mixed together and at times separate. The underlying hypothesis was that languages with little graphetic-phonetic consistency would require more time to read the mixed list because they would be forced to switch back and forth between strategies. Meanwhile, it was hypothesized that children who speak a language with transparent orthography would use only one strategy, the sublexical, and thus there would be no difference in the time it takes them to read the two lists. The results showed that the reading times of the English children were indeed affected by mixing the two types of stimuli, while that change yielded no effect for the German children that participated. According to the author of that study, children who speak transparent languages utilize small orthographic units, or in other words orthographic representations that codify phonology on a small scale (into graphemes and phonemes) (Goswami et al., 2003), in which case the sublexical strategy would be sufficient for them independent of context. A flexible strategy (as was employed by the English children) would be characterized by different reading times of the same stimulus depending on the context in which that stimulus is presented, which reflects an altogether different balance in the use of the two strategies.

In another study, by Goswami et al., (2003), only pseudowords were used. However, the experimental design was limiting; it did not allow them to explain what actually occurs when an individual reads known words in a transparent language, nor did it allow the researchers to make use of the lexical effect as a marker. The very fact that the stimuli used in the experiment were pseudowords would lead the participants to use a sublexical strategy, which is quite comfortable for people who speak a transparent language. This study did not show what happens when pseudowords are mixed with words from one’s own language that could be read using either strategy.

Those studies did not take into account that if one uses both strategies, changing from one to the other probably incurs a cognitive cost, it might take additional time. If this is true, then a mixed list should be read more slowly than a list composed only of words, or only of pseudowords. The flexibility with which one adjusts their strategies may be modulated by the language being read (Goswami et al., 2003), and probably, too, by the extent of one’s exposure to reading. If an equal number of words and pseudowords are mixed together in a list, given the transparent nature of the Spanish language, one of two alternatives could be expected. First, if an exclusively sublexical strategy is employed, no lexical effect would be obtained while reading the stimuli, and there would be no cognitive cost to passing from one item to the next. The second alternative implies both strategies are used. In this case, a reader would need to check his or her orthographic lexicon to determine whether or not the stimulus was present. Thereupon, he or she would decide if the word should be read in terms of its lexical information. If the list item is unknown, better put, if it is not represented in the lexicon, it would be necessary to decode it according to its graphemes and phonemes. In this case, we might expect the lexical effect to appear, and with it a cognitive cost upon switching strategies.

The present study has two primary objectives. The first is to reveal, through the lexical effect and the cognitive cost incurred upon switching strategies, that reading a list of words and pseudowords requires alternative changes in strategy even for children who read the Spanish language well. The second objective is to determine whether the cognitive cost of switching strategies varies as a function of one’s level of dominance over reading strategies by comparing children of different ages, some who are good readers and some who are dyslexic.

Our hypotheses are based on the results of a group of authors (Acha & Perea, 2008; Cuetos, 1989; Signorini & Piacente, 2001; Valle-Arroyo, 1989) that referred to the precedence of the sublexical strategy during reading skills acquisition. Even if in the Spanish language, the reading strategies are not formed simultaneously during the early years of schooling, at least at first, it is to be expected that children change from one strategy to another as they read different types of stimuli, resulting in a cognitive cost. Next, it may be expected that as one matures, the cost incurred in switching from one strategy to the other ought to diminish. This may be due to the fact that the strategies become automatic, or because strategies are created where both sublexical and lexical strategies occur simultaneously. Last, it may be supposed that dyslexic children, given their initial phonological deficit (Goswami, 2002; Paulesu et al., 2001; Ziegler, 2006), display a different pattern of maturation than their peers (delayed maturation). For them, this may imply a high cognitive cost to switch from one strategy to another, independently of the subtype of dyslexia they exhibit. These results may be relevant to the analysis of serial processing versus parallel processing in today’s models of reading. They may be of additional interest in analyzing the models for adult reading, in that it could explain what occurs during the process of acquiring and developing reading competency.
From a practical point of view, it is not unusual that school-age children find words in a text that are unknown to them, and that therefore require a sublexical reading (Bowey & Underwood, 1996; Coltheart & Leahy, 1992; Goswami, 2002; Hagliassias, Pratt & Johnston, 2006; Martin, Pratt & Fraser, 2000; Signorini & Borzone, 2003). If this is true, then the speed at which one switches strategies could be a factor influencing efficiency; this factor is not presently taken into account in the context of pedagogy (Jenkins, Zumeta & Dupree, 2005; Roman, Kirby, Parrila, Wade-Woolley & Deacon, 2009; Sears, Siakaluk, Chow & Buchanan, 2008).

Participants and Methods

Participants

The present study's sample consisted of 1,127 participants, all school-age children, and all belonging to the primary education system in the Republic of Cuba, in the third and sixth grades, hailing from all 14 provinces of the country. Informed consent was solicited in writing from participants' parents or tutors prior to participation. All participants had normal or corrected vision, and no history of neurological or psychiatric disorders. Table 1 displays the distribution of students according to group, grade, sex, age and score obtained on the Raven's Color Matrices test (Raven, Court & Raven, 1986). All children included in the study sample had normal IQs (above the 50th percentile) according to the Chilean scale (Ivanovic, Forno, Durán, Hazbún, Castro & Ivanovic, 2003).

The groups were composed according to the results of word and pseudoword reading tasks (included in the Mini-Battery for Reading Disorders (Mini-Batería para los Trastornos de la Lectura, MiniBTL), and in accordance with the criteria outlined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (APA, 1994). Inclusion in a given group was determined in the following way: children who were good readers (GR) met the criteria of efficiently reading both words and pseudowords ($Z < 1.96$), having a normal IQ, and having scored in the expected range for their age and grade in school on a standardized test of academic achievement (Bernabeu & León, 2003). Children with developmental dyslexia (DD) scored more than two levels below their peers on a standardized test of word and pseudoword reading efficiency, and scored below what would be expected given their age and grade in school on a standardized test of academic achievement, yet they had normal IQs (Bernabeu & León, 2003).

Procedure

The children completed a reading task of both words and pseudowords, a subtest called the Mini B.T.L., which belongs to a standardized battery of computerized tasks for cognitive exploration in Reading (B.T.L.) (Reigosa, Pérez-Abalo, Manzano & Antelo, 1994), programmed in Borland Delphi (Borland Software Corporation, EUA) for the Windows platform. This task is designed to evaluate the mechanisms involved in decoding written words that are specific to reading. This type of task has generated the majority of the existing classifications of reading disabilities we know of (Baron, 1979; Boder, 1973; Castles & Coltheart, 1993; Mitterer, 1982, Treiman, 1984; Temple & Marshall, 1983). All stimuli had three syllables, and included between 6 and 7 letters in total. The frequency of words was controlled. In order to select the words, a frequency of use dictionary was utilized (Piñeiro, Reigosa & Manzano, 1999). 15 high-frequency words (greater than or equal to 10) and 15 low-frequency words (less than or equal to 2) were chosen and nouns, adjectives and verbs were homogeneously distributed (10 stimuli were chosen from each category). The pseudowords were constructed using the aforementioned words, but the positions of all the vowels within each one were changed while

<table>
<thead>
<tr>
<th>SUBGROUPS</th>
<th>GRADE</th>
<th>n</th>
<th>SEX</th>
<th>AGE</th>
<th>RAW IQ SCORES</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR</td>
<td>3rd</td>
<td>336</td>
<td>F:148</td>
<td>8.33</td>
<td>21.36</td>
</tr>
<tr>
<td></td>
<td>M:188</td>
<td></td>
<td>(0.43)</td>
<td></td>
<td>(4.58)</td>
</tr>
<tr>
<td></td>
<td>6th</td>
<td>487</td>
<td>F:202</td>
<td>11.36</td>
<td>25.61</td>
</tr>
<tr>
<td></td>
<td>M:285</td>
<td></td>
<td>(0.59)</td>
<td></td>
<td>(4.09)</td>
</tr>
<tr>
<td>DD</td>
<td>3rd</td>
<td>122</td>
<td>F:39</td>
<td>8.52</td>
<td>20.31</td>
</tr>
<tr>
<td></td>
<td>M:83</td>
<td></td>
<td>(0.68)</td>
<td></td>
<td>(4.17)</td>
</tr>
<tr>
<td></td>
<td>6th</td>
<td>182</td>
<td>F:57</td>
<td>11.46</td>
<td>24.94</td>
</tr>
<tr>
<td></td>
<td>M:125</td>
<td></td>
<td>(0.53)</td>
<td></td>
<td>(4.369)</td>
</tr>
</tbody>
</table>

Table 1

Characterization of the groups of children according to the classifications of the Mini B.T.L. by sex (F: female, M: male), age (average and (standard deviation)) and raw score on the intelligence test (average and (standard deviation)).
maintaining the order of the consonants and not altering the orthographic structure of the original word (for example, bonita-binato, batido-bitoda). All the pseudowords used were legal; they complied with the criteria listed above. The stimuli were presented in a central part of the computer screen, one at a time, for a maximum time of 5000 ms. During that time, the children read the stimuli aloud through a microphone that was connected to the sound card of the computer. Once a given stimulus was read, the experimenter qualified the answer as either correct or incorrect by pressing the keys marked “B” or “M,” respectively, on the computer keyboard. Once the answer had been evaluated, the presentation would move on to the next stimulus. When the maximum time passed in presenting a stimulus to a participant, without any response from that participant, the program automatically moved on to the next item, and the non-response was counted as a reading error by omission. The lists of words and pseudowords presented were randomly mixed. The average reading time was calculated, as was the proportion of errors for each type of stimulus (words and pseudowords).

Each child was evaluated on an individual basis in well-lit places with a low level of noise toward the end of the school year. The tests were performed over the course of two sessions of approximately 20 and 25 minutes, respectively.

Data Analysis

From the randomized list of words and pseudowords used in the Mini B.T.L., four conditions were defined, paying special attention to the preceding stimulus in order to analyze the influence of strategy shifting:

Conditions without change of stimulus:
1. Reaction time (RT) in reading words preceded by other words (word-word)
2. RT in reading pseudowords preceded by other pseudowords (pseudoword-pseudoword).

Conditions with change of stimulus:
3. RT reading words preceded by pseudowords (word-pseudoword).
4. RT reading pseudowords preceded by words (pseudoword-word).

In each condition, the mean RT was computed whenever both the stimulus and the preceding stimulus had been read correctly.

The cost of switching between words and pseudowords was computed by taking the difference between the conditions with and without changing the stimulus (Formulas 1 and 2). Please note that the aforementioned subtraction was necessary in order to eliminate the actual reading time of each stimulus.

(1) TCWord = RT (word/word) – RT (pseudoword/word)
Where:
TCWord: Time it takes to change to a word stimulus
RT(word/word): Reaction time to reading a word when it is preceded by another word.
RT(pseudoword/word): Reaction time to reading a word when it is preceded by a pseudoword.

(2) TCPseudo = RT (pseudoword/pseudoword) – RT (word/pseudoword)
Where:
TCPseudo: Time it takes to change to a pseudoword stimulus.
RT(pseudoword/pseudoword): Reaction time to reading a pseudoword when it is preceded by another pseudoword.
RT(word/pseudoword): Reaction time to reading a pseudoword when it is preceded by a word.

The values obtained from the above calculations will be negative whenever the reaction times in the conditions where the stimulus type switches exceed the reaction times when the stimulus type remains stable.

The data were processed using the STATISTICA package, version 6.1 (StatSoft, EUA). The data were analyzed using repeated measures ANOVAs, and the within-subjects factors were: TYPE OF STIMULUS (words and pseudowords) and PRECEDING STIMULUS (words and pseudowords). Meanwhile, the between-subjects factors were: CLASSIFICATION (control or dyslexic) and GROUP (3rd or 6th grade). A cluster analysis was also performed by calculating the Mahalanobis distance, taking into account the variables that described changes in reading strategy. The Mahalanobis distance was useful in that it determines similarity between two random, multidimensional variables, differing from Euclidean distance in that it takes into account the correlation between those random variables. In this way, it was possible to separate out independent groups from a sample without needing to assume any slant or other type of information ahead of time, such as its MiniBTL classification.

Results

The participants (when both groups were collapsed) read words more quickly than pseudowords (see Table 2 for details, means and standard deviations for the reading reaction times) \(F(1, 1123) = 898.93, p = .001\) and in general, the third graders read more slowly than the sixth graders \(F(1, 1123) = 17.612, p = .001\). Also note that dyslexic participants read more slowly than the control group did \(F(1, 1123) = 734.77, p = .001\). In addition, an interaction between the type of stimulus and participants’ year in school was also recorded. The difference between the reading reaction times for words and the reading reaction times for pseudowords was greater for the sixth
graders than it was for the third graders ($F(1, 1123) = 86.198, p = .001$) due to an increased speed of reading words ($p = .001$). The two groups, third graders and sixth graders, read pseudowords with a similar velocity ($p = .831$). It is also of note that the difference between the reading times for words and pseudowords was similar in dyslexic and control group participants ($F(1, 1123) = 2.1784, p = .140$). Nevertheless, dyslexic participants read both types of stimuli more slowly than the control group ($p = .001$ for words and pseudowords equally). The interaction between the lexical effect, one’s grade in school, and the classification of children in the sample became an interesting aspect of analysis ($F(1, 1123) = 19.095, p = .001$) (Figure 1). Control group (Figure 1b) participants in both third and sixth grade read words more quickly than pseudowords ($p = .001$ for words and pseudowords equally). Dyslexic participants, on the other hand (Figure 1a), exhibit similar behavior when reading words ($p = .001$) but when they read pseudowords, there is much less difference between the third and sixth graders ($p = .040$). This markedly sets them apart from the control group.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>RT Words (ms)</th>
<th>RT Pseudowords (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd grade</td>
<td>1663.07 (18.96)</td>
<td>1993.66 (31.01)</td>
</tr>
<tr>
<td>6th grade</td>
<td>1405.17 (15.75)</td>
<td>1873.49 (25.76)</td>
</tr>
<tr>
<td><strong>Dyslexic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd grade</td>
<td>2423.14 (31.46)</td>
<td>2672.63 (51.46)</td>
</tr>
<tr>
<td>6th grade</td>
<td>2177.24 (25.76)</td>
<td>2809.38 (42.14)</td>
</tr>
</tbody>
</table>

Figure 1. Reaction time for reading words and pseudowords in a) dyslexic children, and b) children who read well, pertaining to two different grades in school (3rd and 6th) in the Cuban education system.
On another note, the proportion of errors was very low in both groups of children. However, the kids made more errors when reading pseudowords than they did when reading words (see Table 3 for details, means and standard deviations of the proportions of errors) \((F(1, 1123) = 1015.8, p = .001)\). Generally speaking, the kids in sixth grade were more precise than those in third grade \((F(1, 1123) = 69.320, p = .001)\) and dyslexic children made more errors than participants in the control group did \((F(1, 1123) = 165.13, p = .001)\). In our analysis, it was found that children from both grades exhibited similar differences in accuracy between words and pseudowords \((F(1, 1123) = 1.1286, p = .288)\). Nevertheless, there was a greater difference between the accuracy of reading words and reading pseudowords among the dyslexic children, as compared to the control group \((F(1, 1123) = 49.731, p = .001)\).

In order to analyze the variable cost of switching between words and pseudowords, and in light of the need to establish behavioral patterns, Mahalanobis distances were calculated. On the whole, children in third grade exhibited a greater
cost upon switching reading strategies than did their sixth grade counterparts \( F(1, 1119) = 5.0322, p = .025 \). No differences were found, however, between changing to words versus changing to pseudowords \( F(1, 1119) = 3.6639, p = .056 \) and this behavior was stable independent of the participants’ year in school \( F(1, 1119) = .41202, p = .521 \). Finally, it was most interesting to analyze the interaction between the cost of switching reading strategies and the classification performed according to Mahalanobis distances \( F(3, 1119) = 12.236, p = .001 \). The results of this analysis are shown in Figure 2.

A group of 1,036 children (group 1) switched from reading words and switched from reading pseudowords with the same velocities as one another (means: \(-22.07\) ms. and \(56.78\) ms., respectively) \( p = .001 \). Another group of 35 children (group 2) behaved similarly to group 1 when they switched to reading words (mean: \(-27.11\) ms) \( p = .939 \), but were significantly slower than group 1 when they switched to reading pseudowords (mean: \(-302.77\) ms) \( p = .001 \). A third group of 35 children (group 3) exhibited behavior opposite to that of group 2. The speed at which they switched to reading pseudowords was similar to that of group 1 (mean: \(17.49\) ms) \( p = .678 \), yet they switched to reading words significantly more slowly than group 1 did (mean: \(-676.77\) ms) \( p = .001 \). Lastly, a fourth group of 21 children (group 4) was slower during both types of switches, to words and to pseudowords, in comparison to group 1 (means: \(-198.91\) ms, \( p = .037 \); \(-290.95\) ms, \( p = .004 \)). These results suggest opposite patterns in the switching time to words or pseudowords. In Table IV, the composition of the groups described above is shown in terms of subclassification on the MiniBTL instrument.

The majority of children in both the control group and the dyslexic group were included in group 1 (98% and 75 %, respectively). The other 25% of the dyslexics and 2% of participants in the control group were distributed into the other 3 groups defined by their Mahalanobis distances. Specifically, when the time it takes to switch strategy is considered, groups 2 and 3 display opposite behavioral patterns, independent of their classifications within the subtypes of dyslexia.

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### Table 4

**Composition of the groups defined by calculating the Mahalanobis distance according to the subclassification system of the MiniBTL instrument.**

<table>
<thead>
<tr>
<th>Mahalanobis Classification</th>
<th>Controls</th>
<th>Phonological Dyslexics</th>
<th>Superficial Dyslexics</th>
<th>Mixed Dyslexics</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>807</td>
<td>22</td>
<td>142</td>
<td>65</td>
<td>1036</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>4</td>
<td>6</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>2</td>
<td>17</td>
<td>11</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>Totals</td>
<td>823</td>
<td>29</td>
<td>172</td>
<td>103</td>
<td>1127</td>
</tr>
</tbody>
</table>

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**Discussion**

The lexical effect found in the sample of children used in the present study suggests clearly that from the first moments of reading skill acquisition, it is possible to ascertain the existence of two reading strategies in the Spanish language. Given the regularity of Spanish, and the presence of both words and pseudowords in the list of stimuli, we were able to assume that all the stimuli used in our experiment could be read correctly through a sublexical strategy. That being said, our results provide evidence for the employment of a lexical strategy for reading words. These data do not, however, support the hypothesis that there is a greater use of the sublexical strategy for readers of languages that are orthographically consistent (Frith, Wimmer & Landerl, 1998; Goswami et al., 1998; Goswami et al., 2001; Goswami, Porpodas & Wheelwright, 1997; Landerl, Wimmer & Frith, 1997; Wimmer & Goswami, 1994).

As may have been expected, children from the control group display a quicker use of both strategies with age, which is probably due to the fact that with age, one is increasingly exposed to written material. Particularly, the lexical strategy is benefited the most by the advancement of age. This may be explained by the fact that the phonological method produces very early training in graphetic-phonetic decoding, and that reaches a plateau in the first years of life (Signorini & Borzone, 2003; Ziegler & Goswami, 2006). These results confirm that development toward efficient reading (in terms of increased velocity) depends on one’s training in the lexical strategy (Acha & Perea, 2008). Nevertheless, it would be necessary to confirm this hypothesis in adult readers that have already achieved a high level of reading efficacy.

Similar to the control group, our results demonstrate the presence of both strategies (lexical effect) among dyslexic children. The behavioral manifestations of deficit are expressed as a diminished reading velocity for both strategies. This confirms the findings of prior studies about the characteristics of the disorder in the context of languages with transparent orthographies (Holapainen, Ahonen & Lyytinen, 2001; Muller & Brady, 2001; Wimmer, 1996),
such as a slight increase in the rate of error. The detriment associated with dyslexia is accentuated when one reads pseudowords, which one would assume to be read through a sublexical strategy. This confirms the theory that developmental dyslexia involves a universal, phonological deficit. However, the most interesting of the results resides in the analysis of how reading strategies evolve with age for dyslexic children. Although the reading times were longer than those of the control group, the lexical strategy experiences a noticeable improvement as one is increasingly exposed to written material. On the other hand, the sublexical strategy is not benefited by increased exposure to written material. This suggests that the difficulty reading is probably the consequence of a deficit in the phonological decoding mechanisms that operate in series as one reads, and extremely slowly in the case of dyslexics (Ramus, 2003; Ramus, Rosen, Dakin, Day, Castelletto, White, et al., 2003). Our results provide behavioral evidence in line with recent studies (Paulus, et al., 2001) that suggest some common biological basis as the origin of dyslexia in different languages.

The use of the two strategies while performing a reading task of words and pseudowords implies that subjects should change their way of reading as they pass from one type of stimulus to another in order to adjust to the material they read. Our findings confirm that this transition does generate a certain cost in terms of mode-switching time. This process is similar to the one used by children from an early age to read texts where familiar words and totally new vocabulary are mixed on a regular basis. It is on this point that the important role of the preceding stimulus comes into play.

When only the time taken to change from one strategy to another (switching cost) is taken into account, 4 different groups may be identified according to switching velocity (Figure 2). The majority of children, especially the good readers, exhibit a low cost when they switch strategy, and the direction of the switch does not matter. An analysis of the cost of switching does not reveal the distinction between children who read well and dyslexic children. This is due to the fact that the traditional classification of dyslexia is constructed upon other criteria, such as the velocity at which stimuli are read, and the rate of error. In spite of this, 25% of dyslexic children in our study exhibited a significant strategy switching cost, as opposed to the good readers, for whom this cost was only present in 2% of the total sample.

Of particular interest is the presence of opposite patterns of strategy switching cost (Figure 2) that selectively affects the transition into one strategy or another. If that cost were produced by the deficiencies of a more general, cognitive mechanism such as, for example, attentional change, the magnitude of the cost would always be the same, regardless of the direction of that change. However, our results show that there are groups of children who experience high cognitive costs to switch to one strategy, while the inverse change is completed with a velocity similar to that of children who read well. This suggests that the cost of switching strategies is produced during the actual process of selecting a reading strategy.

The presence of the two strategies seen in the lexical effect, as well as the existence of a cognitive cost to switching strategies, do not guarantee the theory that there are “mixed” strategies, at least for the age group studied, that simultaneously involve both lexical and sublexical components. This evidence poses a challenge to the information codifying schemas that have defined computational reading models. In the literature on the subject there are numerous models that attempt to explain how exactly a word is read. The models that explain it in terms of parallel architecture (the interactive activation model, for example, (Rumelhart & McClelland, 1982) and derivatives of them (the dual route cascade model (Coltheart, Rastle, Perry, Ziegler, & Langdon, 2001) as well as the Multiple Read-Out Model (Grainger & Jacobs, 1996), and more recent theories that determine serial processing based on new entry schemas for the visual recognition of a word (the SERIOL model, for example) (Whitney, 2001), the SOLAR model (Davis, 1999), the open diagram model (Grainger & van Heuven, 2003), and the superposition model (Gómez, Perea & Ratcliff, 2003) all attempt to describe the way in which different orthographic patterns are decoded. Although the majority of these models explain the lexical effect, they fall short of modeling how passing from one word to another occurs. In other words, there is an influence from the activated components of the preceding word over the following word. The modeling of what happens once reading a word has been completed and the next word begins to be read, could begin to explain why in our results different patterns of strategy switching costs were found for a group of dyslexic children. It seems that, for them, reading a word selectively depends upon the previous stimulus, while for other children the preceding element did not appear to be important. To model the transition from one word to another could create a link to help build a theoretical continuity between models of how words and texts are read, which remain disconnected in the literature on the subject at this time.

Even though the experimental design of the present study allows us to determine the general behavior of the strategy-switching cost for a group of children, it falls short of clarifying whether or not there are interferences between those strategies during the transitions. This could pose a possible interference between strategies, or alternately, it could allow them to be applied with greater flexibility. If the design called for the same stimuli to be presented in pure and mixed blocks, it could identify which of the hypotheses is sustained by the behavioral results. This process could study any modifications that occur as necessary to maintaining efficient reading even when there are variations on the written material, and even if those modifications...
depend on one’s dominance of reading. Also, it would be useful to characterize the evolution of these reading processes from the earliest stages of childhood through their optimal development for adult readers. Another useful factor in characterizing this evolution would be the strategy switching cost, as is suggested by the diminished cost found among third and sixth graders in our study. That factor could reflect reading maturation processes, which occur spontaneously, such that adult readers exhibit a very minimal transition from one strategy to another. Our hypothesis would either be that as both strategies become automatic, they reach a level at which the switching cost ceases to be apparent in subjects’ behavioral registry, or that over the course of development, mixed reading strategies are formed that combine elements from both lexical and sublexical strategies.

The presence of the two reading strategies, demonstrated by the lexical effect beginning in the early stages of learning, and the existence of a variable strategy switching cost, both in children from the control group and in dyslexic children, should be a warning call to the systems of teaching that are applied in actuality. Many languages with transparent orthographies, including Spanish, emphasize methods of teaching that are based on sublexical strategies, considering it most acceptable for a reader to primarily attend to the facility generated by a high graphetic-phonetic correspondence (Caravolas, 2006; Genard, Álgebra, Leybaert, Mousty & Defior, 2005; Goswami, 2002; Ziegler & Goswami, 2006). To fail to include the lexical strategy deliberately in this process is to underestimate a tool that evolves naturally and that also seems to be related to the reading fluency that expert readers achieve (Fuchs, Fuchs, Hops & Jenkins, 2001; Chard, Vaughn & Tyler, 2002; Jenkins, Fuchs, van der Broek, Espin & Deno, 2003; Rahbani & Sénéchal, 2009). This aspect could have repercussions for dyslexic children in particular because, while both strategies are affected for children who read well, the lexical strategy has been shown to become increasingly efficient with age. However, when the system teaches reading by emphasizing phonological methods and the sublexical strategy, and it is applied to these children, consider that dyslexics maintain a deficit throughout years of exposure to reading, despite the exposure. It is for that reason that it would be desirable to incorporate tools that train children in both strategies into the existing systems to teach reading. Training children to switch between the strategies would facilitate a quicker and more efficient means to teach them to read with fluidity. What that means for dyslexics is that those changes would allow them to minimize the impact of their phonological deficit as much as possible and would offer them an alternative, a process to learn to read based on the development of reading skills through a lexical strategy. In this way, strategy switching should come to be considered a crucial part of the discourse, and should be taken into consideration when analyzing the subtypes of developmental dyslexia because it could be either intensifying or attenuating the behavioral manifestations that are observed through the existing diagnostic instruments. This means that the instruments used to classify the subtypes of dyslexia based on the use of lists that mix words and pseudowords could be generating imprecise diagnoses by failing to distinguish between two processes that do not necessarily have the same impact (speed, errors in reading the stimuli, and ease of switching between reading strategies).

Conclusions

In the present study, we demonstrated the use of both reading strategies described in the Dual Route Cascade (DRC) model, in children who read well and also in dyslexic children. For children who read well, both strategies (sublexical and lexical) become more efficient as they are increasingly exposed to reading material. Dyslexics, on the contrary, only evolve their lexical strategy, which is consistent with the data on primary phonological deficit. Children who read well exhibit a small cost upon switching from one strategy to another, yet for dyslexic children, that cost was significantly greater and in some cases, selective. The importance of this finding bears on the strategies used to teach reading in the Spanish language, and calls for a review of said techniques, as well as methods of intervention/treatment for Developmental Dyslexia. Also, it is necessary to conduct more studies on the nature of strategy switching and the impact of orthographic context on the reading competency of school-aged children.

References


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