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Children Like Dense Neighborhoods: Orthographic Neighborhood Density Effects in Novel Readers

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Previous evidence with English beginning readers suggests that some orthographic effects, such as the orthographic neighborhood density effects, could be stronger for children than for adults. Particularly, children respond more accurately to words with many orthographic neighbors than to words with few neighbors. The magnitude of the effects for children is much higher than for adults, and some researchers have proposed that these effects could be progressively modulated according to reading expertise. The present paper explores in depth how children from 1st to 6th grade perform a lexical decision with words that are from dense or sparse orthographic neighborhoods, attending not only to accuracy measures, but also to response latencies, through a computer-controlled task. Our results reveal that children (like adults) show clear neighborhood density effects, and that these effects do not seem to depend on reading expertise. Contrarily to previous claims, the present work shows that orthographic neighborhood effects are not progressively modulated by reading skill. Further, these data strongly support the idea of a general language-independent preference for using the lexical route instead of grapheme-to-phoneme conversions, even in beginning readers. The implications of these results for developmental models in reading and for models in visual word recognition and orthographic encoding are discussed.

Keywords: lexical access; reading development; orthographic neighborhood; density effect

La investigación previa con lectores principiantes de ingles sugiere que algunos efectos ortográficos, tales como los efectos de la densidad (vecindad ortográfica), podrían ser más fuertes para los niños que para los adultos. En especial, los niños responden con mayor precisión a las palabras con muchos vecinos ortográficos que a las palabras con pocos vecinos. La magnitud de los efectos para los niños es mucho más alta que para los adultos, y algunos investigadores han propuesto que estos efectos podrían modularse progresivamente en función de la competencia lectora. Este estudio explora en profundidad cómo los niños de 1º a 6º curso llevan a cabo una decisión léxica con las palabras procedentes de vecindades ortográficas densas o escasas, atendiendo no sólo a las medidas de precisión sino también a las latencias de respuesta, mediante una tarea controlada por ordenador. Nuestros resultados revelan que los niños (como los adultos) muestran claros efectos de densidad (vecindad ortográfica), y que dichos efectos no parecen depender de la competencia lectora. Al contrario de observaciones previas, el trabajo actual muestra que los efectos de vecindad ortográfica no se modulan progresivamente según la competencia lectora. Además, estos datos claramente apoyan la idea de la preferencia por la ruta léxica, que no depende del lenguaje, en vez de las conversiones grafema-a-fonema, incluso en lectores principiantes. Se comentan las implicaciones de estos resultados para los modelos evolutivos de la lectura y para los modelos de reconocimiento visual de las palabras y la codificación ortográfica.

Palabras clave: acceso léxico, evolución lectora, vecindad ortográfica, efecto de densidad

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How does a reader access the meaning of a visually presented single word? For decades, researchers in psycholinguistics have been attempting to shed light on this issue. By now, what seems clear is that there are various processes that occur (or co-occur) when a reader faces a printed word: Letter position and identity encoding (e.g., Grainger, Granier, Farioli, Van Assche, & van Heuven, 2006), affix stripping and morphological decomposition (e.g., Duñabeitia, Perea, & Carreiras, 2007; Frost, Kugler, Deustch, & Forster, 2005), lexeme processing (e.g., Pollatsek, Hyönä, & Bertram, 2000) and semantic integration (e.g., Shelton & Martin, 1992), among others. However, it still unknown to what extent orthographic processes interact with morphological or semantic processes. Several models and theories support a localist approach, whereas others support fully distributed frameworks (for a recent review see Page, 2000). It is now known that even though a single word is presented, and the reader may effectively achieve its meaning, many other forms and meanings are activated while processing the target word. The present paper is centered on one specific orthographic relationship between word forms, which has been a focus of debate in recent decades: the orthographic neighborhood.

Coltheart, Davelaar, Jonasson, and Besner (1977) characterized the orthographic neighborhood of a given word (referred to as N) as all the existing words that could be created by replacing one of its letters by another different one. For example, the word *SAND* is said to have 11 orthographic neighbors, since there are 11 words that share with it 3 letters in the same position (e.g., *land*, *hand*, *band*, *send*, *said*, *sang* …). There is robust evidence from diverse experimental tasks and paradigms showing that the presentation of *SAND* activates the orthographic, lexical and even the semantic representations of its neighbors (see Siakaluk, Sears, & Lupker, 2002, for a review; also Duñabeitia, Carreiras, & Perea, in press, or Forster & Hector, 2002, for semantic activation of neighbors). Further, recent evidence has revealed that not only are these orthographic neighbors activated while accessing a word, but also other types of neighbors, such as addition or deletion neighbors, or the neighbors by transpositions. Davis and Taft (2005; also Davis & Perea, 2007) showed that words created by adding or deleting a letter from a base word are also activated during lexical retrieval (e.g., *stand* and *sad* are addition/deletion neighbors from *SAND*). Moreover, there is evidence in favor of a co-activation, not only of words that share all letters but one in the same position, but also of words that share all letters but in different positions, like the transposed-letter neighbors (e.g. *trial* and *trail*; see Andrews, 1996; Chambers, 1979). Therefore, the general term 'orthographic neighbor' introduced by Coltheart and colleagues, has been harmonized with a more detailed classification, depending on the overlap between the words: substitution neighbors (e.g., *sand-land*), addition/deletion neighbors (e.g., *sad-sand-stand*) or transposition-letter neighbors (e.g., *trial-trail*). Substitution neighbors are the ones that have been studied in more depth, and we will focus on them in the present research.

Substitution Neighborhood Density Effects

The index N is typically used to refer to the number of substitution neighbors of a given word (see Coltheart et al., 1977; Andrews, 1989, 1992). Words vary widely in the number of substitution neighbors that can be created by changing a single letter. On the one hand, there are words with dense neighborhoods such as the word *SAND*, which has many substitution neighbors. On the other hand, there are words with sparse neighborhoods, such as *BOTTLE*, which only has the word *battle* as a substitution neighbor. Laxon, Coltheart, and Keating (1988) designed them as 'friendly' words (the firsts) and 'unfriendly' words (the latter). Finally, one can also find words with no substitution neighbors, called 'hermits' (e.g., *LYNX*).

Generally, it has been assumed that the higher the density of N is for a word, the faster a response is given on that word, and the greater the accuracy (Andrews, 1989; Perea, 1998; Pollatsek, Perea, & Binder, 1999; see Siakaluk, Sears, & Lupker, 2002, for a review). This facilitation is generally obtained only in lexical decision tasks, and changing the task sometimes implies a reversal of the effect, becoming inhibitory instead of facilitative. For example, words with dense neighborhoods tend to be recognized slower in progressive demasking tasks (Carreiras, Perea, & Grainger, 1997; Grainger & Segui, 1990), speeded lexical decision tasks and perceptual identification tasks (Snodgrass & Mintzer, 1993), in on-line sentence reading monitored by eye-tracking systems (Pollatsek, Perea, & Binder, 1999), and even when electrophysiological measures are considered (see Holcomb, Grainger, & O'Rourke, 2002, for a larger amplitude of the N400 for words with high N density). Carreiras and colleagues (1997) explained these cross-task differences in N density effects in the following way: "Effects on orthographic neighborhood in the various tasks can vary from being facilitative to being inhibitory as a function of the extent to which participants base their responses on unique word identification" (p. 868).

Recently Lavidor, Johnston and Snowling (2006) compiled the most robust previous data in this line, and gave theoretical explanations for the (sometimes) facilitative effect of substitution neighbor density in lexical decision tasks. They argued that both the Interactive Activation frameworks (e.g., McClelland & Rumelhart, 1981) and the Multiple Read Out model (Grainger & Jacobs, 1996) could readily account for these data. Firstly, the Interactive Activation models assume that feedback activation from word to letter level facilitates processing, and therefore, the more activated candidates in the lexicon (namely neighbors), the more top-down feedback activation could be expected (see Andrews, 1989, 1997, for a similar approach). Secondly, the Multiple Read Out model accounts for this facilitative effect in terms of the increased lexical activation that helps the decision stage in the lexical decision task: “words with a large N lead to the partial activation of a large number of word representations in memory” (Holcomb, Grainger, & O’Rourke, 2002, p. 939). This last view is totally in line with explanations of how lexical decisions are carried out, based on the summed activation of all positively activated word representations (see Balota & Chumbley, 1984). Other models of word recognition, however, have more difficulties in accounting for the N density effect in lexical decision tasks. For example, the Search model (Forster, 1976) and the Activation-Verification framework (Paap et al., 1982), predict that having many substitution neighbors should increase reaction times (but see Forster & Shen, 1996, and Paap & Johansen, 1993).

Lavidor and colleagues (2006) also reviewed the evidence regarding the hemispheric distribution of the N effects. Recent data have shown that the N effect is more robust in the left visual field than in the right visual field (note that the left visual field relies on the right hemisphere, whereas the right visual field relies on the left hemisphere; see Rubinstein, Henik, & Dronkers, 2001; also Lavidor & Walsh, 2003). This lateralized effect perfectly matches Coltheart’s right hemisphere reading hypothesis (1980, 2000), and has been explained by the poorer resolution and focusing of the right hemisphere, that relies more on supra-letter units. The repercussion of this lateralization effect has been huge, and recent models on letter encoding have echoed it (SERIOL model by Whitney, 2001; Split-Fovea model by Shillcock, Ellison, & Monaghan, 2000).

N Effects in Special Populations

The theoretical implications of a well-defined N density effect are noteworthy, as are the applied educational implications of this effect. Curiously, however, N density effects have been typically studied in adult normal reader populations, and only a few studies have concentrated their efforts on uncovering how children or older adults reflect these effects. To our knowledge, only one study focused on neighborhood density effects and their relation with aging, demonstrating that older adults do not show them (Spieler & Balota, 2000). Rather more copious is the evidence about children’s orthographic processing and N effects. For instance, Laxon, Coltheart and Keating (1988) presented a list of words and nonwords of dense and sparse neighborhoods to children in a naming and in a lexical decision task. Correct responses on the items were measured for a group of children from 2nd and 3rd grade. Their results showed that ‘friendly’ words were read more accurately than ‘unfriendly’ words, both in naming and lexical decision (with more than a 10% accuracy difference in both cases). In a subsequent study, Laxon, Gallagher and Masterson (2002) studied children from 5 to 7 years old in a naming task, and partially replicated the previous results, showing that children were less accurate with words from sparse neighborhoods (see their Experiment 2 notwithstanding).

The fact that children do show robust N density effects was explained in terms of an early preference of beginning readers to use a lexical route, avoiding grapheme-to-phoneme conversion by using cues of orthographic segments (see Frith, 1980, 1985). In fact, other researchers have reached similar conclusions when attending to different orthographic effects in children. Perea and Estévez (2008) showed that beginning readers tend to commit more lexicalizations than adult readers in a naming task where nonwords created by letter transpositions were involved (e.g., *CHOLOCATE*; see Perea & Fraga, 2006, or Perea & Lupker, 2003, for a review on transposed-letter effects). Second grade children lexicalized more nonwords than 4th grade students (e.g., pronounced *CHOCOLATE* when visually presented *CHOLOCATE*), and the latter group lexicalized much more than a group formed by college students (percentages of lexicalizations were 45%, 39% and 30%, respectively). Sebastián-Gallés and Parreño (1995) also found a similar pattern of orthographic effects in children. These authors showed that at an early reading stage novel readers tend to [over] use a lexical route, as deduced from the lexicalization errors they committed when reading nonwords like *ABOGEDO*, which they articulated as *ABOGADO* (the Spanish word for *lawyer*).

However, it has been recently proposed that the use of the grapheme-to-phoneme conversion rules and the use of lexical direct routes may vary from language to language. Specifically, it has been said that beginning readers from transparent languages where the grapheme-phoneme correspondence is carried out almost in a one-to-one fashion might preferably use this mechanism rather than a lexical route, whereas novel readers from more opaque orthography-to-phonology conversions might develop preferences for using the lexical pathway (Ziegler & Goswami, 2006). These authors propose that “children who are learning to read more orthographically consistent languages, such as Greek, German, Spanish or Italian, rely heavily on grapheme-phoneme recording strategies because grapheme-phoneme correspondences are relatively consistent” (p.431). There is a clear discrepancy between this assumption and the previous data in favor of lexical route predominance in young readers from transparent/consistent languages (Perea & Estévez, 2008; Sebastián-Gallés & Parreño, 1995). The present work will try to shed some light on this debate.

This study was conducted in order to explore the scope of the substitution neighborhood density effects in children. There is previous evidence revealing that beginning readers do show great N effects (Laxon et al., 1988; Laxon, Masterson, & Moran, 1994), but there is still a gap to be filled regarding the gradation of these effects, if there is some. While Laxon and colleagues only tested 2nd and 3rd grade students, the present paper reports evidence with groups of children from all the six grades of Primary School. It is extremely important to uncover if beginning readers and skilled readers do show different patterns in the magnitude of N effects, because, if so, models of reading development and models of orthographic encoding should echo these differences.

Regarding the experimental paradigms used in the previous studies, the present study has a clear advantage in comparison with them. While Laxon and collaborators restricted their analyses to the accuracy data, in the present study we report analyses of both reaction time measures and accuracy measures. It is a fact that in many studies with adult samples, the N density effects only show up when measuring response latencies, and that accuracy data do not always reveal the same effects (Carreiras et al., 1997; Pollatsek et al., 1999; Sears, Hino, & Lupker, 1995). Moreover, with the appropriate analyses, reaction times with children can be very informative, as they are for adults (Perea & Algarabel, 1999).

In Laxon's studies, children were presented with strings of letters printed on cards, and they had to either pronounce them, or to make a lexical judgment about them. The experiment that we report was conducted using an automatized computer-controlled random presentation of the stimuli, instead of using more course presentation methods that could be influenced by and confounded with context-dependent factors. The present study focuses on real word processing and on how the orthographic overlap between words interferes with lexical access, and therefore no specific manipulations were carried out on the nonwords. We decided to avoid nonword manipulations also because, as stated earlier, there is previous evidence showing that the existence of the N density effect is sometimes constrained to specific manipulations on nonwords.

Method

Participants

Two hundred and sixty-two children from primary schools in Valencia took part in the present data collection. All of them had either normal or corrected-to-normal vision, and were native Spanish speakers. None of the participants had learning disabilities, or any remarkable reading difficulty. The sample included children from all levels of primary school: 28 students from 1st grade, 33 from 2nd, 45 from 3rd, 40 from 4th, 60 from 5th, and 56 from 6th. They were all tested at the end of their current course.

Materials

The experimental set comprised a block of 44 Spanish words taken from the LEXESP database (Sebastián-Gallés, Martí, Carreiras, & Cuetos, 2000). These words were analyzed using the B-PAL software (Davis & Perea, 2005) that provides the most common psycholinguistic indexes. Twenty two of these words had a dense neighborhood, whereas the other 22 had a sparse neighborhood. Words in the dense neighborhood condition had a mean frequency of 94.4 appearances per million words (standard deviation: 131.9), and a mean number of 4.8 letters (± 1.5). Their bigram token frequency was 770.1 (± 555.7), and their bigram type frequency was 37.5 (± 35.6). The mean number of neighbors of these words was 5.6 (range: 2-11). For example, the Spanish word *MENTA* (meaning *mint*) has 8 different orthographic neighbors that can be created just by changing one of the letters from the original string (i.e., *__l__enta*, *__r__enta*, *m__a__nta*, *__v__enta*, or *ment__e__*, translated as *slow*, *rent*, *blanket, sale* and *mind*, respectively). On the other hand, words in the sparse neighborhood condition had a mean frequency of 88.1 (± 92.9) appearances per million words, and a mean length of 5.8 letters (± 1). Their mean bigram token frequency was 726.2 (± 369.7) and their mean bigram type frequency was 48.5 (± 26.5). The mean number of orthographic neighbors of these words was 0.5 (range: 0-1). An example from this subset of words is *RURAL*, that only has one orthographic neighbor (*__m__ural*). As can be seen, the two sets were closely matched in all statistics except for orthographic neighborhood, as this is the critical manipulation in the current experiment. We conducted *t*-tests to compare the statistics of the different frequency measures for words in the sparse and dense neighborhood conditions and all the comparisons resulted non-significant (all *p*s > .12). However, the critical comparison between the two subsets of words, namely the difference in the number of orthographic neighbors, resulted significant ($t = 8.88$, $p < .01$). Moreover, words in the dense neighborhood and in the sparse neighborhood conditions had similar syllabic structures. These two subsets of words formed an item block, which was included in a list with another 31 Spanish words with similar frequencies and length, and a neutral number of neighbors (approximately 3), that were used for a reading test standardization purpose (Duñabeitia, Vidal-Abarca, & Izquierdo, 2008). In order to make the lexical decision possible, a set of 75 nonwords matched in length to the words was also included. These nonwords were all pronounceable, and did not comprise any illegal bigram or trigram (e.g., *JUENO*). All the stimuli were inserted in a single list, and were randomly presented to the participants, so that no order repetition effects could be expectable.

Procedure

Participants were tested individually, in a silent and well-lit room. All the data collection was carried out during school hours, with permission from parents and teachers. The list of items was presented on a laptop computer with a LCD monitor. The responses were recorded using the DMDX software for stimuli presentation and data collection

(Forster & Forster, 2003). All the stimuli were presented in the centre of the screen, in uppercase white 12 pt. Courier New font, with a black background. Each trial consisted in the appearance of a fixation point ('+++') for 1200 ms, followed by the presentation of the target word, displayed for 5000 ms, or until a response was made by the participant. Participants were instructed to decide if the string presented in the screen was, or was not, a legal Spanish word, by pressing one of the two buttons. They were also told to do so as fast and as accurately as possible. Participants' response latencies were measured from the target string's onset to the button pressing. Responses were made by pressing 'Z' or 'M' buttons, labeled as 'YES' and 'NO' respectively. Although no more buttons were labeled, those buttons surrounding the critical 'Z' and 'M' in the qwerty keyboard were also programmed for collecting responses (e.g., the 'A', 'S' and 'X' buttons for 'NO' responses, and the 'N', 'J' and 'K' buttons for 'YES' responses). This was done because our previous experience with very young children strongly ensures that many incorrect responses in lexical decision experiments are due to errors in button pressing. At the beginning of the experiment, a trained experimenter carefully read and explained the instructions to the participants. All the participants carried out a practice with a list of 6 stimuli (3 words and 3 nonwords), in order to get them used to the experimental procedure.

Results

Incorrect or null responses (YES responses to nonwords, NO responses to words, or lacks of response) were not included in the latency data analyses. All the response times above or below the 2 standard deviation cutoffs were triggered out for the analyses. Figure 1 summarizes the reaction times and error rates associated to the experimental set of each of the groups of children in a graphical report. Instead of using the arithmetical mean, we chose the median for the analyses, since there is empirical evidence showing that this is the best option for contaminated distributions (see Ratcliff, 1993; Perea & Algarabel, 1999; see also Acha & Perea, in press, for a study with beginning readers). ANOVAs were conducted for participant (F1) and item (F2) median response times, based on a 6 (Grade: 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, and 6^{th}) x 2 (Neighborhood Density: Dense, Sparse) design**.** *MinF* values are also provided (Clark, 1973).

Response Times

ANOVAs on the response latencies of the words showed a main effect of Grade, revealing that children from higher educational levels responded faster to the stimuli than children from lower levels, $F1(5, 256) = 53.48$, $p < .01$, $1\text{-}\beta = 1$; $F2(5, 263) = 135.37$, $p < .01$, $1\text{-}\beta = 1$; $minF(5, 433) = 38.34$, $p < .01$. Also, the main effect of Neighborhood Density was

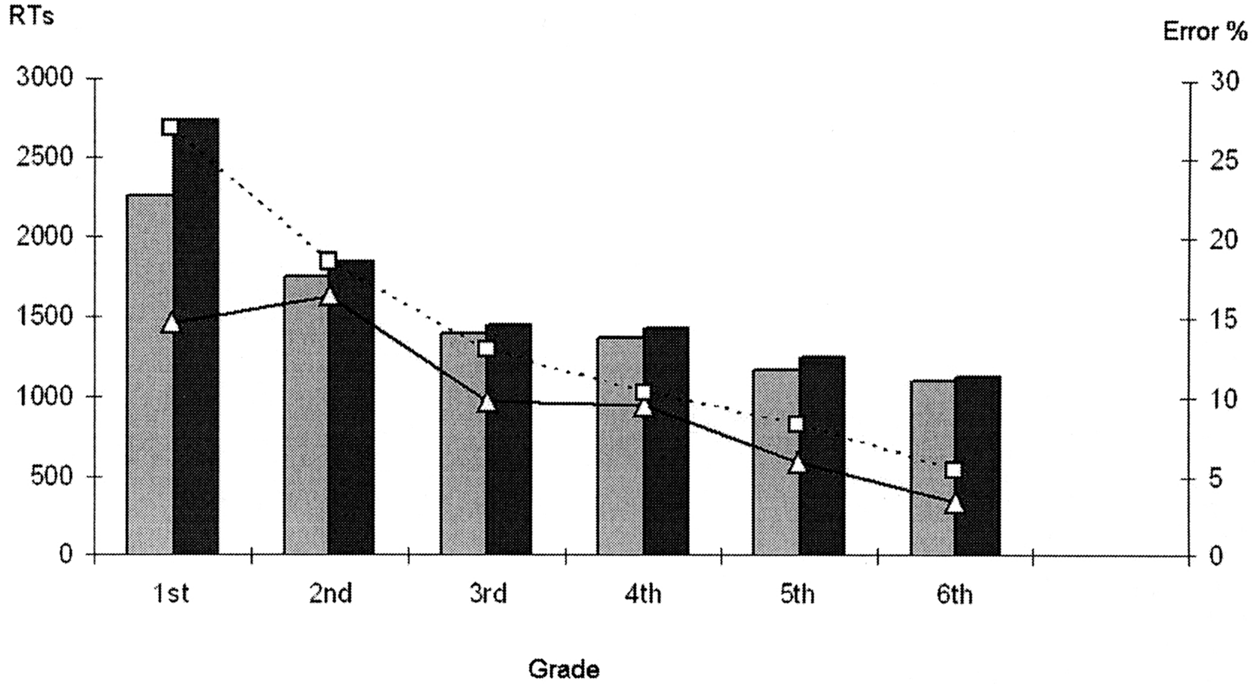

Figure 1. Lexical decision times in medians (in ms) and percentage of errors for words. Grey bars refer to the reaction times in the dense neighborhood condition. Black bars refer to the reaction times in the sparse neighborhood condition. The line with triangles refers to the percentages of errors in the dense neighborhood condition. The dotted-line with squares refers to the percentages of error in the sparse neighborhood condition.

significant, $F1(1, 256) = 131.57$, $p < .01$, $1\text{-}\beta = 1$; $F2(1, 263) = 10.96$, $p < .01$, $1\text{-}\beta = .91$; $minF(1, 306) = 10.11$, $p < .01$. This effect showed that words in the dense neighborhood condition were responded to faster than words in the sparse neighborhood condition (130 ms faster)[1] . The interaction between the two factors was only significant in the analysis by participants, and not in the analysis by items, nor in the *minF*, $F1(5, 256) = 28.65$, $p < .01$, $1\text{-}\beta = 1$; $F2(5, 263) = 1.84$, $p = .11$, $1\text{-}\beta = .62$; $minF(5, 297) = 1.73$, $p = .13$. Planned comparisons were carried out for each level of Grade: First grade students, $t1(27) = 9.00$, $p < .01$; $t2(42) = 2.25$, $p < .03$; Second grade students, $t1(32) = 2.85$, $p < .01$; $t2(42) = 1.64$, $p = .11$; Third grade students, $t1(44) = 1.35$, $p = .18$; $t2(42) = .87$, $p = .39$; Fourth grade students, $t1(39) = 2.63$, $p < .02$; $t2(42) = 1.15$, $p = .26$; Fifth grade students, $t1(59) = 4.11$, $p < .01$; $t2(42) = 1.36$, $p = .18$; Sixth grade students, $t1(55) = 2.20$, $p < .04$; $t2(42) = .13$, $p = .90$.

Error rates

Regarding the percentages of errors associated to the words, the Grade factor resulted in a significant effect, showing that students from higher levels committed less errors than students from lower levels, $F1(5, 256) = 33.87$, $p < .01$, $1\text{-}\beta = 1$; $F2(5, 263) = 7.16$, $p < .01$, $1\text{-}\beta = .99$; $minF(5, 341) = 4.48$, $p < .01$. Importantly, words in the dense neighborhood condition were responded to more accurately than words in the sparse neighborhood condition (a 3.8% difference), $F1(1, 256) = 75.92$, $p < .01$, $1\text{-}\beta = 1$; $F2(1, 263) = 4.68$, $p < .0.3$, $1\text{-}\beta = .58$; $minF(1, 295) = 4.41$, $p < .04$.

A strong Neighborhood Density effect was observed in the present experiment. The interaction between this effect and the educational level of the participants was only significant in the analysis by participants, and therefore, one could not argue that the effect is totally different for younger than for elder scholars. If one looks at the pattern for the 90, 70, 50, 30, and 10% quantiles of the distributions (see Figure 2), it seems clear that all the groups show a shift of the entire reaction time distribution for the dense neighborhood and sparse neighborhood conditions, in a very similar fashion: the shifts for the 2nd-6th grade students are almost identical, showing a virtually equal effect. The children from 1st grade are the only ones showing a disproportionate N density effect; whereas the rest show similar patterns and magnitudes. However, when we performed a logarithmic transformation of these data, and therefore removed the proportional increase between groups, the interaction that resulted significant (in the analysis by participants) was no longer significant ($p > .09$)[2].

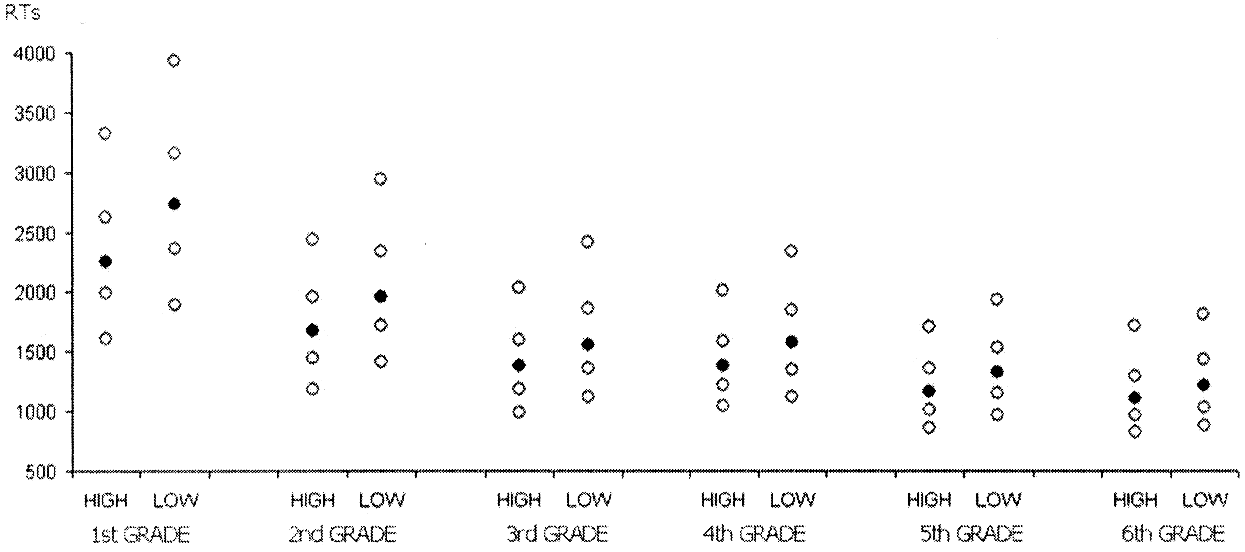

Figure 2. Group response time distributions for the experimental pairs. The circles represent the 10%, 30%, 50% (in bold), 70%, and 90% quantiles. These values were computed by computing the quantiles for individual participants and then averaging the computed values for each quantile over the participants**.**

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[1] Even though we conducted the analyses using the median values instead of the arithmetical mean, the effects reported in this section did not differ widely when the same analyses were conducted with the arithmetical mean. The main effect of Neighborhood Density was significant, $F1(1, 256) = 179.03$, $p < .01$; $F2(1, 263) = 14.84$, $p < .01$; $minF(1,3\ 06) = 13.70$, $p < .01$. Also the effect of Grade was significant when analyzing the data with arithmetical mean, $F1(5, 256) = 48.82$, $p < .01$; $F2(5, 263) = 149.61$, $p < .01$; $minF(5, 408) = 36.80$, $p < .01$.

[2] We thank an anonymous reviewer for suggesting this analysis.

Discussion

The present findings are clear-cut. First, we have been able to replicate the substitution neighborhood density effect with beginning readers. Second, we have shown that this effect is not progressively degraded, but that, except for children in the 1st grade, the other readers do show virtually the same pattern of effects. Third, the present work reveals that children not only show N effects in their response accuracy, but that these effects can be efficiently captured by reaction times. And fourth, our data reveal that orthographic effects in children can be satisfactorily studied by mimicking the tasks and paradigms that are commonly used with adult readers.

Adult readers generally respond faster and more accurately to words with many substitution neighbors (e.g., *SAND*) than to words with few or no substitution neighbors (e.g., *LYNX*). These neighborhood density effects have been largely investigated and replicated (see Andrews, 1989, 1992, 1997; Carreiras et al, 1997; Grainger & Jacobs, 1996; Perea, 1998). These effects have yielded numerous theoretical consequences, and many models of visual word recognition have had to implement changes in their frameworks in order to correctly capture N effects (e.g., Interactive Activation model by McClelland & Rumelhart, 1981; Parallel Distributed Processing model by Rumelhart & McClelland, 1986; Multiple Read Out model by Grainger & Jacobs, 1996; Dual Route Cascade model by Coltheart, Rastle, Perry, Ziegler, & Langdon, 2001). Similarly, recent models of orthographic encoding have been satisfactorily designed, including specific mentions of these N effects (e.g., SOLAR model by Davis, 1999; SERIOL model by Whitney, 2001; Overlap model by Gómez, Ratcliff, & Perea, 2007). However, the evidence with other populations, such as children, is scarce, even though the implications for models in reading acquisition are vast.

Previous evidence has shown that neophyte readers do show neighborhood density effects (Laxon et al., 1988; Laxon et al., 2002; Laxon et al., 1994). These studies mainly investigated children from 1st to 3rd grade, and revealed that children responded more accurately to words from dense neighborhoods (words with many substitution neighbors) than to words from sparse neighborhoods (words with few substitution neighbors) or hermits (words with no substitution neighbors). In fact, these results entitled the seminal work by Laxon et al. (1988): 'Children find friendly words friendly too: words with many orthographic neighbors are easier to read and spell'. All the effects they showed were based on accuracy analyses, revealing that words from dense neighborhoods and words from sparse neighborhoods differed in more than 10% in terms of correct responses. This difference is enormous when compared to adult data, which normally shows differences not higher than 4%. This difference motivated the current study, since it looked like progressive reading skill acquisition could modulate neighborhood effects.

The present results claim against a progressive gradation of the neighborhood density effects, because, except for 1st grade readers, the other children show approximately similar patterns, not only in reaction times, but also in error rates. It seems clear that only children from 1st grade show around a 10% difference effect in accuracy (similarly to the results from Laxon and colleagues), whereas the rest of the groups show a relatively low but significant effect, which resembles the effect in adult samples. The same comparison with reaction times yield to an identical conclusion: only 1st grade students show a huge reaction time effect, whereas the rest of children show more similar patterns. Therefore, it could be that the same underlying mechanisms responsible for the N density effects in adults are also responsible for the effects in children, and that it is not reading fluency or lexicon size, nor expertise itself, that is modulating these effects. One plausible explanation for integrating Laxon's results and our data could be that the children they tested were not proficient enough, and that, as do our children from 1st grade, they present great variability associated to the high number of errors committed (note that in Laxon et al., 1988, the participants failed in more than 20% of the trials, irrespectively of the neighborhood density condition, as was the case in the younger readers from our experiment). In addition, we conducted an Age of Acquisition norming study with the materials in the present experiment. Twenty-eight undergraduate students from the University of La Laguna and the University of Valencia rated each word in a 1-to-7 scale (each punctuation referring to the age range in which they though a given word was learnt). Words in Dense Neighborhoods were rated with a mean of 2.9 points, whereas words in Sparse Neighborhoods were rated with a mean of 3.7 points ($p < .01$). Interestingly, the age values associated to each of these punctuations were 6 and 7 years respectively. Therefore, a possible explanation for the disproportionate N effect shown in the 1st graders could be reflecting the fact that some of the words in the Sparse Neighborhoods were not acquired by that group at the time of the data collection (note that this is in line with the accuracy rates of this group).

What do the present neighborhood density effects tell us about lexical access in children? On the one hand, many researchers have consistently found orthographic effects with beginning readers (Castles, Davis, & Forster, 2003; Perea & Estévez, 2008; Sebastián-Gallés & Parreño, 1995). These results have led to the conclusion that children do develop preferences for the use of the lexical route, more than grapheme-to-phoneme conversion rules. This is totally in line with connectionist interactive models of reading acquisition and development (e.g., McClelland, 1989), and partially challenges stage models, which assume that there is a progression from logographic to alphabetic to orthographic representations in separated stages (Laxon et al., 1994). On the other hand, some other researchers propose that these preferences for using the lexical route are language-dependent, claiming that young readers from transparent languages might preferably use grapheme-to-phoneme conversion mechanisms (Ziegler & Goswami, 2006). For this last claim to be valid, we should have found no (or little) neighborhood density effects in Spanish, since it is a consistent/transparent language with clear correspondence between graphemes and phonemes (note that all the previous evidence with children's N effects was obtained in an opaque language such as English). It is clear, however, that this was not the case in the present study: novel readers from a transparent language do show strong N effects.

Further, there are interesting recent data that, together with ours, rule out Ziegler and Goswami's argument (2006). Lavidor et al., (2006) studied the case of F.M., a man with dyslexia, severe phonological problems and great difficulty in correctly developing grapheme-to-phoneme conversion rules. They studied the N density effects for this man, and revealed that the N effect was much larger for this man and other dyslexic students, than for a control group (see also Snowling, 2000). Lavidor and colleagues concluded that "people with dyslexia are relatively advantaged in processing words that share letter strings with orthographic neighbors, because of a preference for global processing that capitalizes on the coarse coding of orthography-phonology mappings" (p.325; see Harm, McCandliss, & Seidenberg, 2003, for a similar view). If N effects are generally obtained when a direct lexical route is used, no grapheme-to-phoneme conversions seem to be involved in these effects and reader groups from both transparent and opaque language show these effects, then there is no reason *a priori* to discard the lexical route as the mainly adopted route even by very young beginning readers. However, since no measures of grapheme-to-phoneme reading were employed, these ideas are just speculation at this stage. Future research in this direction should be done in order to clarify the role of grapheme-to-phoneme conversion routines in comparison with direct lexical access.

In summary, the present experiment provides evidence supporting the early existence of substitution neighborhood density effects in children. Moreover, we have shown that the pattern of the effects in children is quite similar to the pattern of the effects in adult readers. Both adults and children «find friendly words friendly». Finally, we have provided evidence in favor of a predominant use of the lexical route in beginning readers.

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APPENDIX

The 44 words used in the present study (in parenthesis their neighborhood density): *ahí*(4), *ajo*(9), *bajo*(8), *caliente*(2), *centro*(1), *charco*(4), *ciervo*(6), *deuda*(0), *diez*(1), *estado*(1), *fiel*(5), *fresca*(3), *islote*(0), *jefe*(1), *largo*(3), *lío*(8), *llanura*(0), *luego*(3), *lugar*(5), *menta*(8), *miedo*(0), *olfato*(0), *pajar*(6), *paz*(6), *persona*(0), *planeta*(0), *proceso*(1), *puerta*(6), *reja*(7), *riesgo*(0), *roce*(3), *rural*(1), *siesta*(1), *sombra*(1), *suela*(4), *texto*(1), *treinta*(0), *triste*(1), *valiente*(2), *ventaja*(1), *vía*(11), *virus*(0), *viuda*(1), *voto*(11).