UC Merced
Proceedings of the Annual Meeting of the Cognitive Science Society

Title
Can Interactive Activation Models Accommodate Neighborhood Distribution Effects in Visual Word Recognition?

Permalink
https://escholarship.org/uc/item/5pt8s1v0

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 29(29)

ISSN
1069-7977

Authors
Illera, Victor
Sainz, Javier S.

Publication Date
2007

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Can Interactive Activation Models Accommodate Neighborhood Distribution Effects in Visual Word Recognition?

Víctor Illera (VILLERA@Psi.Ucm.Es) & Javier S. Sainz (JSAINZ@Psi.Ucm.Es)
Psycholinguistic Research Unit
Departamento de Procesos Cognitivos
Universidad Complutense de Madrid

Summary

The effects of neighborhood distributions on word recognition were investigated by manipulating the position of the highest frequency neighbor. In the Twin condition, a word had two higher frequency neighbors with a letter change in the same position. In the Single condition a word also had two higher frequency neighbors, but the letter change was made in a different position for each neighbor. The letter position involved could be internal or external, depending on whether the change took place in an intermediate or start/end position. Participants made lexical decisions about postmasked letter strings, while response times and evoked-related potentials were recorded. Results show a significant effect of the Single vs Twin manipulation with Twin targets RTs slower than Single RTs. Furthermore, ERP data reveal that in the parietal area of both hemispheres, words with Twin targets result in less brain activity than words with Single targets, specifically in later decisional stages (P400). An analysis by position reveals how this Twin / Single contrast stems from the effects of interaction between the type of distribution (Twin / Single) and the position of the highest frequency neighbor (Internal / External). The results obtained are not easily reconciled with a theoretical framework that proposes a "Gang Effect" as part of a model including intralexical inhibition mechanisms (McClelland & Rumelhart, 1981; Grainger & Jacobs, 1996).

Keywords: lexical similarity; letter position coding; neighborhood distribution effects; interactive activation model; evoked-related potentials; visual word recognition.

Measuring Lexical Similarity

The decisions which lead to the identification of a word entry are the result of a forced selection process, which assigns as default the entry which best matches the available cues. This probabilistic approach means that the lexical selection of an entry depends on cues which distinguish it from any other lexical entries competing for selection, subject to lexical activation and attention according to task demands. The selection of a lexical pattern is the result of word recognition processes that evaluate pattern similarity of word candidates. To operationalize this variable a measure known as the "N-metric" or neighborhood density (Coltheart, Davelaar, Jonasson & Besner, 1977) was introduced, where the N value of a word is calculated as the number of orthographic neighbors a word has. An orthographic neighbor is a lexical entry which differs from the target in just one letter in a particular position.

Since it was first introduced, numerous studies have shown the importance of the N measure in the word recognition process, largely studied using the standard lexical decision task (Andrews, 1997) where participants make a decision as to whether the letter string presented is a word or not. Nonetheless, studies of the effect of neighborhood density on word recognition have produced some contradictory results (Andrews, 1997). First, for low frequency words N has been found to facilitate word recognition: the greater the value of N, the lower the response latency. The effect has been replicated in English, French and Spanish (Andrews, 1997; Carreiras, Perea & Grainger, 1997; Forster & Shen, 1996). In contrast, using progressive unmasking techniques, Snodgrass and Mintzer (1993) show how it is possible to provoke both facilitatory and inhibitory effects of N in word recognition, depending on the deductive possibilities offered by the task stimuli. On the other hand, manipulating the relationship between N for words and N for pseudowords, Johnson and Pugh (1994) obtain effects in both directions. The empirical anomalies of the N-metric provided an incentive for new studies.

When neighborhood density was controlled for, Grainger, O'Reagan, Jacobs and Segui (1992) observed the role played by the relative frequency of lexical neighbors (NF) of a target word: in French the recognition of words with at least one higher frequency neighbor requires RTs greater than those without higher frequency neighbors. The inhibitory effect of the NF has been replicated in different languages (Carreiras, Perea & Grainger, 1997; Mathey & Zagar, 2000). It has been claimed that the inhibitory effect of NF is restricted to low frequency words, but there are studies that detail facilitatory effects of the higher frequency neighbor (Sears, Hino, & Lupker, 1995).

N and NF are measures that refer to the relationship between target and candidates, whilst the relationship between candidates -including the target- is neglected. Pugh and colleagues (Johnson & Pugh, 1994; Pugh, Rexer, Peter & Katz, 1994) introduced the NP measure (the number of letter positions with at least one neighbor) after discovering that two words with the same N might differ in the position of the neighbors within the letter string. The NP measure was a better predictor of response times than N in word recognition; Pugh and his colleagues found inhibitory effects of the higher frequency position in word recognition when the participants could not base their responses on the global activation of the lexicon, and had to resolve the cohort: the greater the NP with neighbors of higher

frequency than the target, the greater the response latency in lexical decision tasks. When NP is controlled and N is manipulated, an increase in the latter actually facilitated the response latency for words. Johnson and Pugh (1994) conclude that a high N reveals the lexical status of the word. In comparison, the effect of NP would be fundamentally inhibitory.

Although all these measures have proved to be reliable predictors of word recognition, empirical evidence suggests that there is more to pattern similarity and word recognition than a simple computation of number of neighbors of a word target (N), relative frequency of competing candidates (NF) and number of positions with at least one neighbor (NP). These measures cannot account for the full diversity of empirical findings involving word pattern recognition, and here lies the main concern of this article.

An illustration of these problems concerns word pattern similarity. Studies using the priming technique have shown how an entry such as JUGDE primes JUDGE, a case that illustrates the transposition effect (Perea & Lupker, 2004). Transposed letter patterns such as LEAK, or TEAM are excluded from the N measure of the base targets LAKE and MEAT, on the grounds that they do not conform to the definition. However, letter migration between these lexical entries can occur under specific conditions (Prinzmetal, & Lyon, 1996). A pattern such as LAEK seems to be closer to LAKE than LEAK is to LAKE despite the fact that both letter patterns are cases of letter transposition. BRANE can be a prime for BRAIN despite the fact it certainly does not pertain to its neighborhood; this phenomenon illustrates the pseudohomophone effect. Moreover, in word recognition and naming tasks, neighborhood density effects seem to arise from phonological rather than orthographic neighbors (Mulatti, Reynolds & Besner, 2006; Yates, 2005). No matter how indisputable behavioral evidence can be, some studies have shown no difference in brain activity for variations in neighborhood (Binder, McKiernan, Parsons, Westbury, Possing, Kaufman, Buchanan, 2003). The problematic status of neighborhood density confronts us whatever our approach to measuring pattern similarity.

Neighborhood Distribution Effects

To overcome some of these empirical anomalies, as well as some theoretical issues, Mathey and Zagar (2000) introduced the notion of neighborhood distribution (ND). ND refers to the way higher frequency neighbors are distributed across positions of a target word.

Mathey and Zagar (2000) manipulated the stimuli so that the targets for lexical decision were words with two higher frequency neighbors distributed within the letter string in different ways, making a distinction between two kinds that they called Single and Twin. Two low frequency word patterns, similar in other respects, may differ in the way high frequency neighbors are distributed across their positions: in Spanish, for instance, the word ACRE (i.e. acre) has two neighbors of higher frequency, AIRE (i.e. air) and OCRE (i.e. ocher); yet, the position involved for each neighbor is different. Similarly, the word ASCO (i.e. nausea) has two neighbors of higher frequency, ASEO (i.e. bathroom) and ASNO (i.e. ass), but both involve the same position. According to Mathey and Zagar's classification, the first case expresses a single (S) condition, whereas the second represents a twin (T) condition.

When N, NF and NP are rigorously controlled, Mathey and Zagar (2000) obtain a facilitatory neighborhood distribution effect (ND) for words in French. The analysis of participant response times showed how words with Single type neighbors received quicker responses than targets with Twin type neighbors (Mathey & Zagar, 2000). Whilst the neighbors of the Twin type words share all but one of the letters of a 4-letter word, the neighbors of the Single type words share only two in the case of 4-letter words; lower similarity means greater mutual inhibition. This series of experiments and the simulation Mathey and Zagar ran are used to test the multiple read-out model, an extension of McClelland and Rumelhart's (1981) interactive activation model proposed by Grainger and Jacobs (1996). Mathey and Zagar's results seem to corroborate the predictions of the interactive activation models.

Interactive activation models which assume lexical entries are activated after the local computation of lexical cues resulting from segmental analysis, and word nodes active in the lexicon as a result of this analysis, can easily accommodate the usual N, NF and NP effects. The activation of a unitary pattern depends on the local activation that reverberates between any segmental units and the lexical entries responsible for facilitatory effects of high N. As for the size of these segmental units, a subsidiary assumption of the interactive activation models is that they are simply letters.

The inhibitory strength of a lexical representation is a function of its level of activation, such that words with higher frequency neighbors receive greater inhibition than others that do not have this neighbor type. It is this kind of inhibitory activity between lexical representations which accounts for the inhibitory effects of neighborhood frequency, number of positions with a neighbor and neighborhood density. One crucial assumption of the interactive activation models underlies all of these effects: all activated lexical entries inhibit one another. Do active lexical entries constrain comparison between neighbor word candidates and the actual target in some way? Do these inhibitory processes have homogeneous effects across all competing lexical candidates?

The interactive activation models' prediction is that the Twin type neighbors would be more strongly activated, and would generate greater competition among themselves than the Single type neighbors, as the former act together to increase their activation based on letter-level activation. This effect was dubbed the "Gang Effect" (McClelland & Rumelhart, 1981; 1982): the activated words that share all letters but one are members of the "gang". They observed that when a pseudoword like *mave* was presented to the

model, the words *move* and *save* were activated. Of the two, *save*, a word of lower frequency than *move*, reached high levels of activation more quickly. The explanation for this phenomenon was that *save* received additional activation from the five neighbors that had the three letters "—ave", while there were no other neighboring words with the letters "*m - ve*" with which *move* could receive further activation. It follows that Twin neighbors are more strongly activated as they share more letters, and thus are more difficult to reject from the cohort of candidates. As a result, word recognition with Twin neighbors is inhibited more powerfully. Inhibitory effects for pseudowords, and the results of the simulation in French confirm expected results (Mathey, Robert, & Zagar, 2004; Mathey & Zagar, 2000). Their results endorsed the multiple read-out model (Grainger and Jacobs, 1996), an extension of McClelland and Rumelhart's (1981) interactive activation model.

Comparing Neighborhood Distribution Effects

In contrast with the mixed effects (both facilitatory and inhibitory) found by Grainger and Jacobs (1996) manipulating neighborhood distribution, Pugh's pioneering studies (Johnson & Pugh, 1994; Pugh, Rexer, Peter, & Katz, 1994) uncovered only inhibitory effects of ND related to letter position. Even though Pugh and his colleagues did not control the number of higher frequency neighbors, their results partially contradict those observed by Grainger and Jacobs (1996) and Mathey et al. (2000, 2004). The problem is informational: How can a lexical neighbor contribute to the recognition of an actual target?

Any lexical neighbor can, in principle, increase or reduce uncertainty about which lexical entry best matches incoming cues. If a single position is involved in Twin targets, compared with two positions for Single targets, Twin targets should be processed more quickly, as found by Mathey and Zagar (2000). A reduction in uncertainty, though, depends on the structural cues of the active neighbors in each position, and the way these neighbors reflect structural properties of the lexicon. In particular, it is the way these neighbors actually represent letter transition probabilities in the lexicon, after segmental analysis of the lexical candidates, which reduces uncertainty. The pseudoword MAVE is a better cue for SAVE than MOVE because there are many neighbors that share three out of four letters with the target in a single contiguous letter string –AVE. Here, M_VE requires the resolution of two broken letter strings instead of just one - in other words two letter transition probabilities. Both the number of neighbors containing the string –AVE and the number of broken strings to be restored favor the activation of SAVE rather than MOVE. There is one further reason to suspect that SAVE will be activated rather than MOVE. The phonological realization of SAVE is favored by the rhyme –AVE. Were this explanation correct under certain conditions, a decision on Twin targets should be easier than on Single targets, just the opposite of what Mathey and Zagar (2000) and Grainger and Jacobs' model would predict. Subjects have to restore the letter string of Twin targets twice instead of once for Single targets. This alternative explanation could account for results contradicting the findings of Mathey and Zagar (2000), but it certainly does not account for their results. In the absence of a thorough analysis of their stimuli, indirect evidence can be provided by using well-controlled stimuli in Spanish. A new variable was introduced into the design to control for position effects: Twin and Single targets were used where the position could be external or internal – letters at the start or end of a word versus intermediate letters. Given the Twin target ASCO (i.e. nausea), the higher frequency neighbors ASEO (i.e. bathroom) and ASNO (i.e. ass) involve an internal position; given the Twin target CENSO (i.e. census) the higher frequency neighbors DENSO (i.e. dense) and TENSO (i.e. tense) involve an external position. A corollary of this prediction is that letter position must be explicitly coded and not implicitly as assumed by interactive activation models. As a consequence, we predict that ND will not have a homogeneous effect regardless of the letter positions involved. According to Pugh and colleagues (Johnson & Pugh, 1994; Pugh, Rexer, Peter & Katz, 1994), position plays a major role in the expression of neighborhood distribution effects. We therefore predict opposite results to those obtained by Mathey and Zagar (2000) in French: Single targets should be more difficult to process than Twin targets, since (again according to Pugh and colleagues) they involve the distribution of neighbors across two different positions.

It is important to remember that Spanish (and some other languages with a transparent orthography such as Italian, Finnish and Serbo-Croatian) can be easily read by simply assembling phonological syllables. This configurational property lends support to the idea that Single targets should break up the word more easily than Twin targets in Spanish. If this is true, response latencies to Twin targets should be lower than to Single targets - again the effect is in the opposite direction to that observed by Grainger and Jacobs (1996) and Mathey and Zagar (2000) in French.

Last but not least, the predicted neighborhood distribution effect should be observed in temporal stages and brain areas according to the lexical decision to be made: more brain activity should be observed in Single than Twin targets. It is expected that the process itself is taking place at the point when word nodes are active and are actively compared, and activity will take place in the temporo-parietal circuit. The object of this study is to test the above predictions.

Methodology

Using SuperLab 4.0 software (Cedrus Corporation, 2006), 22 right-handed native Spanish readers, (18 women; 4 men of average age 20.4 years) were serially presented with a postmasked letter string and asked to make a lexical decision. ND was controlled for both pseudowords and words. A total of 160 Low-Frequency Single and Twin lexical patterns selected from LEXESP (Sebastián, Cuetos,

Martí & Carreiras, 2000), were randomly presented, for which N, NF and NP had been controlled.

A 2 (Lexical Status: Word vs. Pseudoword) ×2 (Neighborhood Distribution: Twin vs. Single) ×2 (Letter string length, 4-letter string vs. 5-letter string) ×2 (Higher frequency neighbor position: Internal vs. External) factorial design was used. In order to mimic Mathey and Zagar's (2000) design, two further conditions were introduced: Hermit (words and pseudowords with no higher frequency neighbor) and One (just one higher frequency neighbor). These last conditions, introduced only as controls, are not included in the analysis since they do not represent ND. The stimulus selection and procedure were identical to that followed by Mathey and Zagar (2000). Table 1 shows the descriptive statistics of ND variables controlled for words. Due to stimuli constraints, no other variables are controlled.

Table 1: Descriptive statistics of ND variables

	Neighborhood Distribution (ND)			
	Hermit	**One**	**Twin**	**Single**
F (Mean)	**1.03**	**1.45**	**2.68**	**2.45**
F (SD)	**0.79**	**0.86**	**1.39**	**1.22**
ND (Mean)	**0.00**	**4.40**	**5.40**	**6.15**
ND (SD)	**0.00**	**2.39**	**2.01**	**2.18**

Readers were asked to make a lexical decision while their brain activity was recorded using a 32-electrode cap and a BrainVision Recording System. Response times (RTs); error rates (ER) and Evoked-related Potentials (ERP) were taken as dependent measures. RTs were registered from the stimulus onset until subjects made a response.

Cross-trial average ERPs elicited by the stimuli were computed for each participant, and then averaged across subjects for every combination of Lexical Status (LS), Neighborhood Distribution (ND), Letter-string length (LL) and Higher frequency neighbor position (HFN). Following Mathey and Zagar's design, N, NF and NP were also controlled. The average amplitude in the 300 ms preprobe interval (when no stimulus is being presented before a new trial) was taken as the baseline, using the average brain activity across all electrodes. The time epoch extended from 300 ms prior to the probe onset, until the end of the response interval, 600 ms after. ERPs elicited by the probes were computed for each of 6 latency peaks (70, 100, 150, 200, 250, 300, 400) by averaging amplitudes over the latency interval peak (-25, +25 ms), once DC and ocular artifacts were removed. Since error rate was very low, all trials were used. Impedances were kept below 2k ohms.

Repeated-measures ANOVAs for behavioral and ERP measures were performed separately. ERP measures were obtained for each time interval and for every major brain area in the relevant variables by averaging amplitudes of all electrodes in the area, for each hemisphere (RO, LO, LP, RP, LT, RT, LF, RF). Only RTs and ERPs of correct responses less than 2,5 standard deviations from the average were used in statistical analyses. One subject was excluded because of her error rate (> 30%). Overall error rate was kept below 10% for every accepted subject. Non-responses and errors were substituted in each cell for the calculated cross-average for their corresponding conditions.

Results and Discussion

ERs. The analyses conducted on error rates do not reach significance concerning either Neighborhood Distribution ($F(1,20)= 0.59$, $MSe=0.102$, $p= 0.45$), or the Neighborhood Distribution (ND) × Higher Frequency Neighbor Position (HFN) interaction, ($F(1,20)= 0.017$, $MSe= 0.172$, $p= 0.897$). However, the overall trend is in line with predictions (Twin: 5.36; Single: 6.43; External Twin: 4.52; External Single: 5.48; Internal Twin: 6.19; Internal Single: 7.38).

Table 2: Mean RTs in ms for the ND x HFN interaction

	ND x Higher Frequency Neighbor Position (HFN)			
	External Position		**Internal Position**	
	Twin	**Single**	**Twin**	**Single**
RT	**659**	**662**	**657**	**706**

RTs. An ND effect found to be significant ($F(1,20)= 9.026$, $MSe=384.58$, $p<0.01$; 662 ms. for Twin vs. 686 ms. for Single). The Neighborhood Distribution (ND) × Higher Frequency Neighbor Position (HFN) interaction reaches significance ($F((1,20)= 5.373$, $MSe= 509.8$, $p< 0.05$). Bonferroni pair comparison confirms a significant difference between Internal and External positions ($F(p< 0.01)$). The average RTs are shown in Table 2.

Table 3: Mean P400 amplitudes for ND

	Neighborhood Distribution (ND)			
	Left Hemisphere		**Right Hemisphere**	
	Twin	**Single**	**Twin**	**Single**
μv	**1.60**	**1.93**	**1.70**	**2.09**

Table 4: Mean P400 amplitudes for ND x HFN Position

	Neighborhood Distribution (ND) x Higher Frequency Neighbor Position (HFN)			
	Right Hemisphere			
	External Position		**Internal Position**	
	Twin	**Single**	**Twin**	**Single**
μv	**1.88**	**2.11**	**1.53**	**2.07**
	Left Hemisphere			
	External Position		**Internal Position**	
	Twin	**Single**	**Twin**	**Single**
μv	**1.74**	**1.86**	**1.46**	**2.00**

ERPs. ANOVAs conducted in the 400 ms. peak interval on mean voltage amplitudes show a significant main effect of Neighborhood Distribution for both RH and LH ($F(1,42)=16.509$, $MSe= 0.341$, $p< 0.001$, $Power= 0.978$);

Bonferroni pair tests show significant differences between both levels of the ND conditions ($F(1,42)= 6.982$), with significantly more brain activity for Single targets than for the Twin Targets in the parietal sites of the LH ($p< 0.05$) and RH ($p< 0.01$), a result that replicates those observed with behavioral measures. These results are shown in Table 3. Both interactions, the double Lexical Status (LS) × Higher Frequency Neighbor Position (HFN) interaction and the triple interaction LS × ND × HFN reach significance ($F(1,42)= 8.286$, $MSe= 1.651$, $p< 0.01$; $F(1,42)= 8.266$, $MSe= 8.218$, $p< 0.01$, respectively). Bonferroni pair tests show significant differences between both levels of the HFN Position conditions in the parietal sites of the LH ($p< 0.01$) and RH ($p< 0.01$). Table 4 shows the relevant data.

The results show how the neighborhood distribution of the targets makes a significant difference to brain activity: Single targets require more processing time than Twin targets, and this processing takes place, fundamentally, in the parietal area of the RH (P400). For the three measures taken, the direction of the ND effect is the same: greater response latencies, greater error rates, and greater brain activity for Single targets than for Twin targets.

As for the interactions that involve Higher Frequency Neighbor Position, despite the fact that both ERP and RT measures coincide in a significant difference between Single targets and Twin targets, the discrepancy between latencies and ERPs seems incongruent: External positions cause a small but significant difference, while there is a large difference between Internal positions for ND conditions. The direction of the effect for Internal positions is again increased processing time for Single targets compared to Twin targets. However, as Table 4 indicates, whilst the time measurements for Internal / Single targets show *later* responses compared to the three remaining conditions all with virtually identical response times, the ERP show how the Internal / Twin condition leads to a *lower* activation level in P400 while the remaining conditions all present similar brain activity. These P400 effects are congruent with top-down activation of fronto-parietal circuits involved in attention and decision taking. At the time subjects have to make a lexical decision, Twin targets are resolved when an internal position is involved, while Single targets still require additional attentional resources. Holcomb, Grainger and O'Rourke (2002) report N400 effects larger for high N words than for low N words. The effect is compatible with both Single and Twin targets being assessed in terms of N, although they differ not in terms of N but in terms of ND. As Holcomb et al. suggest, a positive 400 effect can be observed when a lexical decision task is being made.

General Discussion

The results obtained in this experiment sit uneasily within an interactive activation model framework. Presumably a simulation of these results with a new set of appropriate parameters would match our findings. Our results do dispute the functional description of intralexical inhibition mechanisms in terms of Gang Effects, however.

The results obtained using ND effects in French by Mathey et al. (2000, 2004) are explained in a partially satisfactory manner by IA models - facilitatory effects for Single type targets and inhibitory effects for Twin type targets - based on intralexical inhibition and interactive activation mechanisms between nodes of letters and words. Nonetheless, our results show that the neighborhood distribution effect is in fact inhibitory. The interactive activation models' prediction is that the Twin type neighbors would be more strongly activated, and would generate greater competition among themselves than the Single type neighbors due to the so-called "Gang Effect". The models' prediction for the Single condition is that these neighbor types should inhibit one another more consistently, since they share fewer letters than Twin type neighbors. Since our procedures mimic those followed in French by Mathey et al (2000, 2004), the discrepancy cannot be attributed to differences in the desing, but rather is an indicator of crosslinguistic differences (Andrews, 1997).

The bimodal interactive activation model explains the direction of neighborhood density effects in visual word recognition according to grapheme-phoneme consistency (Grainger, Muneaux, Farioli, & Ziegler, 2005). The congruence between orthographic and phonological densities determines the direction of the effect. Yates (2005) observes that this congruence might be relative, but even so in Spanish the inconsistency between orthography and phonology is negligible. Thus, the bimodal IA model cannot account for distribution density effects in Spanish unless we use different lexical similarity measures from those proposed by Coltheart (1977) and distinguish between orthography and phonology. Whilst there are experimental procedures to tease apart phonology and orthography, such manipulation would significantly depart from Mathey and Zagar's (2000) original approach.

The differences between positions may well be due to the fact that the Single neighbors, when the higher frequency of the two is in an internal position, provide a "powerful" break in the syllabic structure - both among the neighbors themselves, and between neighbors and target. This incongruence (which in the Twin condition is always in fact lower) may cause the rise in response times mentioned earlier. This is precisely the opposite of what the intralexical inhibition mechanisms of the interactive models would lead us to predict. Congruence facilitates the response, because it facilitates the synthesis of cues during recognition, whereas incongruence inhibits the response by complicating this synthesis of cues. The greater ease of recognition in the Twin condition could be due to the fact that this neighborhood distribution implies a lesser break in the phono-orthographic structure of the target stimulus pattern (Mulatti, Reynolds & Besner, 2006), an interpretation that is compatible with the involvement of parietal sites.

Johnson and Pugh (1994) claim that the accumulated presence of neighbors in letter positions is a word indicator.

If this is the case, it may also be that in Spanish the system has developed mutual inhibition mechanisms that favor inhibition between candidates. Mathey et al. (2000) attribute the inhibitory effects obtained by Johnson and Pugh (1994) to a failure to control the number of neighbors by letter position, while Johnson and Pugh attribute them to the greater processing burden imposed by having to resolve similarity conflicts in several letter positions. It could be argued, though, based on similar results obtained in Spanish, that in English there is more probability of a word when there are more neighbors in the same letter positions. We could also postulate that as the distribution increases, the number of words from the linguistic corpus that meet this condition seem to become fewer, as suggested by Johnson and Pugh (1994) when they found facilitatory effects of N when ND is controlled in English. The inhibitory effects obtained cannot be blamed purely on intralexical inhibition mechanisms as the IA models suggest, but rather on the fact that the probability of the lexical status of a word based on its neighborhood distribution results in a combination of similarity cues that favors the inhibition of targets with a greater accumulated number of neighbors in the same letter positions.

References

Andrews, S. (1997).The effect of orthographic similarity on lexical retrieval: Resolving neighbourhood conflicts. *Psychonomic Bulletin and Review, 4*, 439 – 461.

Binder, J.R., McKiernan, M.E., Parsons, M.E., Westbury, C.F., Possing, E.T., Kaufman, J.N., Buchanan, L. (2003) Neural correlates of lexical access during visual word recognition. *Journal of Cognitive Neuroscience, 15*, 3, 372 – 393.

Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of orthographic neighbourhood in visual word recognition: Cross-task comparisons. *Journal of Experimental Psychology: Learning, Memory and Cognition, 23*, 857 – 871.

Cedrus Corporation (2006). *Stimulus Presentation Software SuperLab 4.0*. Pedro, CA: Cedrus Corporation

Coltheart, M., Davelaar, E., Jonasson, J.T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance: Vol VI. Proceedings of the sixth international symposium on attention and performance* (pp. 535 - 555). London: Academic Press

Forster, K.I., & Shen, D. (1996). No enemies in the neighbourhood: Absence of inhibitory neighbourhood effects in lexical decision and semantic categorization. *Journal of Experimental Psychology: Learning, Memory and Cognition, 22*, 696 - 713

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review, 103*, 518 – 565

Grainger, J., Muneaux, M., Farioli, F., & Ziegler, J.C. (2005). Effects of phonological and orthographic neighbourhood density interact in visual word recognition. *Quarterly Journal of Experimental Psychology, 58*, 981-998.

Grainger, J., O´Reagan, J.K., Jacobs, A.M., & Segui, J. (1992). Neighbourhood frequency effects and letter visibility in visual word recognition. *Perception & Psychophysics, 51*, 49 - 56

Holcomb, P.J., Grainger, J., and O'Rourke, T. (2002). An electrophysiological study of the effects of orthographic neighborhood size on printed word perception. *Journal of Cognitive Neuroscience ,14*, 938-950.

Johnson, N.F., & Pugh, K.R. (1994). A cohort model of visual word recognition. *Cognitive Psychology, 26*, 240 – 346

Mathey, S., & Zagar, D. (2000). The neighbourhood distribution effect in visual word recognition: Words with twin and single neighbours. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 1129 - 1157

Mathey, S., Robert, C., & Zagar, D. (2004). Neighbourhood distribution interacts with orthographic priming in the lexical decision task. *Language and Cognitive Processes, 19* (4), 533 - 559

McClelland, J.L.., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: 1. An account of basic findings. *Psychological Review, 88*, 375 – 407.

McClelland, J.L.., & Rumelhart, D. E. (1982). An interactive activation model of context effects in letter perception: 2 The Contextual Enhancement Effect and Some Tests and Extensions of the Model. *Psychological Review, 89*, 1, 60 – 94

Mulatti, C., Reynolds, G.R., & Besner, D. (2006) Neighbourhood effects in reading aloud: new findings and new challenges for computational models. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 4, 799-810

Perea, M. y Lupker, S.J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language, 51*, 231–246

Prinzmetal, W., and Lyon, Ch.E. (1996). The word-detection effect: Sophisticated guessing or perceptual enhancement?. *Memory and Cognition, 24*(3), 331-341.

Pugh, K.R., Rexer, K., Peter, M., & Katz, L. (1994). Neighbourhood effects in visual word recognition: Effects of letter delay and nonword context difficulty. *Journal of Experimental Psychology: Learning, Memory and Cognition, 20*, 639 - 648

Sears, C.R., Hino, Y., & Lupker, J. (1995). Neighbourhood size and neighbourhood frequency effect in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 876 - 900

Sebastián, N., Cuetos, F., Martí, M. A., & Carreiras, M. (2000). *LEXESP. Léxico informatizado del español* [Lexesp: A Spanish Computerized Lexical DataBase] Barcelona: UB.

Snodgrass, J.G., & Mintzer, M. (1993). Neighbourhood effects in visual word recognition: Facilitatory or inhibitory? *Memory and Cognition, 21*, 247 – 266

Yates, M. (2005). Phonological neighbors speed visual word processing: Evidence from multiple tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*, 1385-1397.