No more problems in Coltheart’s neighborhood: resolving neighborhood conflicts in the lexical decision task

Johannes C. Ziegler¹,²,*, Conrad Perry³

¹School of Behavioural Sciences, Macquarie University, Sydney, NSW 2109, Australia
²CREPCO-CNRS, Aix-en-Provence, France

Received 13 May 1998; accepted 30 June 1998

Abstract

In the area of visual word recognition, there is considerable disagreement as to whether neighborhood effects for words in the lexical decision task are facilitatory or inhibitory: While they seem to be mostly facilitatory in English, they tend to be absent or inhibitory in French or Spanish. The present study investigated the possibility that the facilitatory neighborhood effect obtained in English is due to the fact that most neighbors in English are body neighbors (i.e. they share the same orthographic rime). Our results showed that when words were matched for orthographic neighborhood (N), the effects of body neighbors (BN) were facilitatory (i.e. shorter reaction times for words with many body neighbors than for words with few body neighbors). In contrast, when words are matched for BN, the effects of N are unreliable with a tendency towards inhibition. In conclusion, it appears that research conducted in English has always found neighborhood effects to be facilitatory because of the dominant role of body neighbors in English. In contrast, neighborhood effects in French and Spanish may have been more ambiguous because these languages either do not confound N and BN, or they do not require a greater sensitivity to the body/rime unit. © 1998 Elsevier Science B.V. All rights reserved

Keywords: Neighborhood effects; Body effects; Visual word recognition

1. Introduction

Neighborhood effects are among the most widely investigated effects in visual
word recognition. This is because they provide crucial information about the organization of and access to the mental lexicon. The most common neighborhood metrics (N) was defined by Coltheart et al. (1977) as the number of words that can be obtained by changing a single letter from the target word (e.g. the word cheat has the four orthographic neighbors cheap, chest, cheat, and wheat). In their seminal study, Coltheart et al. (1977) found that nonwords with many orthographic neighbors produced slower lexical decision latencies than nonwords with only few orthographic neighbors. This neighborhood size effect was not obtained for words, however.

Since this finding, more than 15 studies have been devoted to the study of neighborhood effects (for a comprehensive review see Andrews, 1997). The extended research interest in neighborhood effects was nourished by conflicting results with respect to the inhibitory versus facilitatory nature of neighborhood effects in the lexical decision task. While some authors found facilitatory neighborhood size effects on lexical decision latencies to words (Andrews, 1989, 1992; Sears et al., 1995; Forster and Shen, 1996), others found null effects (Carreiras et al., 1997; Coltheart et al., 1977) or inhibitory neighborhood frequency effects1 (Grainger, 1990; Grainger et al., 1989, 1992; Huntsman and Lima, 1996; Carreiras et al., 1997; Perea and Pollatsek, 1998). Whether neighborhood effects are facilitatory or inhibitory has important theoretical implications: finding inhibitory neighborhood effects supports the idea of a competitive lexical selection process in which orthographically similar word representations mutually inhibit one another (lexical inhibition principle; see Grainger and Jacobs, 1996). Conversely, finding facilitatory neighborhood effects suggests that mechanisms other than lexical competition play a role in accessing the mental lexicon.

When reviewing the existing evidence in favor of facilitatory versus inhibitory neighborhood effects, Andrews (1997) noted that the patterns of facilitation and inhibition may not only change as a function of whether neighborhood size or neighborhood frequency was manipulated but also as a function of the language in which the study was carried out. She pointed out that most of the studies that reported inhibitory effects in the lexical decision task were done in French or Spanish, while most of the studies that reported facilitatory effects were done in English.

How could cross-language differences account for these conflicting effects? First of all, in English, many orthographic neighbors are also body neighbors, that is, they share the same orthographic rime (e.g. cleat, wheat, meat and heat are all body neighbors of cheat). Second, it has been argued that the body/rime unit plays a fundamental role in skilled reading and reading acquisition in English (Bowey, 1990; Treiman et al., 1995). This may be the case because the body/rime unit disambiguates the highly variable vowel pronunciation more efficiently than any other sublexical unit does (Treiman et al., 1995). Thus, if most orthographic neighbors are body neighbors and if the body/rime unit plays a special role in English, it

1Note that some researchers manipulated the number of orthographic neighbors (i.e. the neighborhood size effect) while others manipulated the number of higher frequency neighbors (i.e. the neighborhood frequency effect). However, this cannot explain the contradictory findings because (1) words with higher frequency neighbors are also likely to have large neighborhoods, and (2) studies which manipulated both variables orthogonally still obtained conflicting results (e.g. Sears et al., 1995).
may well be possible that the facilitatory N effect in English is actually due to the influence of words that share the body with the target (body neighbors) rather than due to the influence of traditional orthographic neighbors.

There is empirical support for the idea that neighborhood effects are, at least partially, determined by body neighbors. In previous masked priming studies, Forster and colleagues consistently found that high-N words did not exhibit form priming effects (Forster et al., 1987; Forster and Davis, 1991). However, when the number of body neighbors was manipulated, Forster and Taft (1994) obtained masked form priming effects even for high-N words. That is, lexical decision performance for high-N words was facilitated when prime and target shared a low-frequency body. They concluded that the body seems to play an important role in form priming.

If facilitatory neighborhood effects in lexical decision are determined by body neighbors, then it is less surprising that neighborhood effects are different in languages in which the body/rime unit does not play a dominant role. In Spanish, for example, most of the 4- and 5-letter words are bi-syllabic. There is thus no reason to assume that the reading system would acquire a greater sensitivity to body/rime units than to syllabic units. Indeed, Perea and Carreiras (1998) have recently shown that in Spanish the number of syllabic neighbors has an inhibitory effect on lexical decision latencies over and above the traditional neighborhood effect. Similarly, Peereman and Content (1997) argued that the body/rime unit plays a less important role in French than in English because it does not disambiguate the pronunciation of the vowel more than any other sublexical unit.

Taking these crosslinguistic considerations together, it is possible that the strong facilitatory neighborhood effect obtained in English is due to the fact that most neighbors in English are body neighbors and that the body helps disambiguating a word’s phonology (Treiman et al., 1995). If this is true, then it should be harder to obtain strong facilitatory N-effects when items are matched for body neighborhood (BN). At the same time, if BN is responsible for the facilitatory nature of N-effects, then the failure to find facilitatory N-effects in languages that do not require a greater sensitivity to the body/rime unit (e.g., French or Spanish) is less puzzling.

In the present study, we investigated this issue in a lexical decision task in English. We manipulated N (i.e. the number of orthographic neighbors according to Coltheart’s traditional definition) and BN (i.e. the number of neighbors that share the same body) in a quasi-orthogonal fashion. We hypothesized that when items are matched on N, there should still be a strong facilitatory BN-effect on lexical decision latencies for words. In contrast, when items are matched on BN, we expected no facilitatory N-effects for words.

2. Method

2.1. Participants

Thirty-one undergraduate psychology students at Macquarie University partici-
pated in the experiment. All were native English speakers. They received course credit for their participation.

2.2. Stimuli and design

A perfectly orthogonal manipulation of N and BN cannot be obtained in English because there are only a limited number of words with many orthographic neighbors and few body neighbors. Similarly, the number of words with many body neighbors but few orthographic neighbors is also fairly limited. Thus, as an approximation to the orthogonal design, we manipulated BN while keeping N constant and N while keeping BN constant. This manipulation was done for both words and nonwords. Items were selected from the computerized database described in Ziegler et al. (1997).

The critical stimulus set consisted of 160 items, 80 words and 80 nonwords. Half of the items were five-letters long and half were four-letters long. All words were of low frequency according the word frequency count by Kucera and Francis (1967). In the BN manipulation, 20 words had few body neighbors (BN < 3) and 20 words had many body neighbors (BN > 14). For these 20 pairs, N was kept constant (4.3, respectively). In addition, both groups were matched for word frequency and word length. In the N manipulation, 20 words had few orthographic neighbors (N < 3) and 20 words had many orthographic neighbors (N > 5). For these 20 pairs, BN was held constant (8.4 and 8.7, respectively).

The nonword manipulation mirrored the word manipulation. That is, 20 nonwords had few body neighbors and 20 had many body neighbors while keeping N constant (BN manipulation); 20 nonwords had few orthographic neighbors and 20 had many orthographic neighbors while keeping BN constant (N manipulation). The stimulus characteristics for both words and nonwords are presented in Table 1. All items are listed in Appendix A.

2.3. Procedure

Participants were seated 50 cm in front of a computer screen and were given verbal instructions. They were presented with 10 sample trials consisting of five familiar words and five nonwords. The experiment started with three filler trials followed by the 160 experimental trials. The experimental trials were presented in random order for each participant.

Each trial began with a 700 ms presentation of a fixation mark (‘:’) in the center of the screen. The fixation mark was replaced by the stimulus that remained on the screen until the response was given. Participants were instructed to indicate as rapidly as possible, but not at the expense of accuracy, whether the stimulus was an English word. They gave their response by pressing either of two keys labeled ‘yes’ and ‘no’. Except for the sample trials, no immediate feedback was given. All stimuli were presented in lowercase letters using a standard Macintosh font (Courier, size 28). The experiment was controlled by an Apple Macintosh Quadra 610. Reaction times (RTs) were measured between the onset of the stimulus and the participant’s response.
3. Results

Mean correct RTs and error rates for the four groups of words and nonwords (small BN, large BN, small N, large N) are presented in Table 2. The trimming procedure excluded scores that were more than three standard deviations above or below a participant’s grand mean. This procedure affected 21 word and 39 nonword scores (1.2% of the data). One word from each group was excluded because of error rates greater than 35% (these items are marked with an asterisk in Appendix A). Because BN and N could not be manipulated in a strictly orthogonal fashion, the effects of BN and N are analyzed in separate analyses of variance (ANOVAs) with subjects (F1) and items (F2) as the random variables.

As can be seen in Table 2, the data exhibited a strong facilitatory BN effect for words: lexical decision latencies were 32 ms faster for words with many body

Table 1
Stimulus characteristics for words and nonwords with few versus many body neighbors (BN) and with few versus many letter neighbors (N)

<table>
<thead>
<tr>
<th></th>
<th>BN manipulation</th>
<th>BN manipulation</th>
<th>N manipulation</th>
<th>N manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small BN</td>
<td>Large BN</td>
<td>Small N</td>
<td>Large N</td>
</tr>
<tr>
<td>BN</td>
<td>2.1</td>
<td>16.6</td>
<td>8.4</td>
<td>8.7</td>
</tr>
<tr>
<td>N</td>
<td>4.3</td>
<td>4.3</td>
<td>14</td>
<td>8.9</td>
</tr>
<tr>
<td>Frequency</td>
<td>5.9</td>
<td>5.7</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td>PBF</td>
<td>7043</td>
<td>7387</td>
<td>5631</td>
<td>6959</td>
</tr>
<tr>
<td>CR</td>
<td>0.86</td>
<td>0.86</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>No. of irregular words</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

PBF, summed positional bigram frequency; CR, consistency ratio = friends/(friends + enemies).

Table 2
Mean lexical decision latencies and error rates for words and nonwords with few versus many body neighbors (BN) and with few versus many letter neighbors (N)

<table>
<thead>
<tr>
<th></th>
<th>BN manipulation</th>
<th>BN manipulation</th>
<th>N manipulation</th>
<th>N manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small BN</td>
<td>Large BN</td>
<td>Small N</td>
<td>Large N</td>
</tr>
<tr>
<td>Error rate (%)</td>
<td>7.5</td>
<td>4.2</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td>SE</td>
<td>1.1</td>
<td>0.8</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Mean latency (ms)</td>
<td>657</td>
<td>625</td>
<td>636</td>
<td>650</td>
</tr>
<tr>
<td>SE</td>
<td>11.9</td>
<td>10.7</td>
<td>11.6</td>
<td>10.4</td>
</tr>
<tr>
<td>Net effect (ms)</td>
<td>+32 ms</td>
<td>-14 ms</td>
<td>-14 ms</td>
<td>-45 ms</td>
</tr>
</tbody>
</table>
neighbors than for words with only few body neighbors ($F(1,30) = 20.82, P < 0.0001; F(1,36) = 4.96, P < 0.05$). The error data essentially mirrored the RT data except for the fact that the BN effect was not significant by items ($F(1,13) = 6.13, P < 0.05; F(2,136) = 2.68, P < 0.11$).

As concerns the traditional N effect for words, there was a small inhibitory N effect of 14 ms that failed to reach significance in the item analysis ($F(1,30) = 4.15, P < 0.05; F(2,36) = 1.17, P > 0.10$). In the error data, there was no hint of an N effect (all $F$-values $<1$).

As concerns decisions to nonwords, we obtained the following pattern of results: There was no BN effect whatever on either nonword latencies or error rates (all $F$-values $<1$). In contrast, the data exhibited a strong inhibitory N effect on nonword RTs ($F(1,30) = 42.59, P < 0.0001; F(2,36) = 9.48, P < 0.01$) that failed to reach significance on errors ($F(1,30) = 2.52, P > 0.10; F(2,36) = 1.76, P > 0.10$).

4. Discussion

The present study investigated the hypothesis that contradictory findings concerning the facilitatory versus inhibitory nature of neighborhood effects in the lexical decision task are due to a confound of BN and N. More precisely, we hypothesized that neighborhood effects for words in a lexical decision task in English should be clearly facilitatory when BN is manipulated. These facilitatory neighborhood effects should diminish or disappear when N is manipulated, however.

The major findings of our study confirmed these predictions:² When words were matched for N, the effects of BN were facilitatory (i.e. shorter RTs for words with many body neighbors than for words with few body neighbors). In contrast, when words were matched for BN, the effects of N were unreliable with a tendency to inhibition (i.e. slightly longer RTs for words with many neighbors than for words with few neighbors). With respect to nonwords, we found an inhibitory N effect (i.e. longer RTs to nonwords with many neighbors than to nonwords with few neighbors). Surprisingly, BN had no inhibitory effects on nonword latencies (see below).

Together, the present word data suggest that the facilitatory N effect typically obtained in English is determined by a subset of orthographic neighbors, namely body neighbors. This is in line with Forster and Taft’s conclusion (Forster and Taft, 1994) that neighborhood density effects cannot uniquely be described in terms of number of letter neighbors (Coltheart’s N). Recently, Peereman and Content (1997) came to the similar conclusion that ‘not all neighbors are equally influential in orthographic space’ (p. 382). In particular, they showed that orthographic neighbors facilitated naming only when they were also phonological neighbors, in particular,

²Note that our conclusions are exclusively based on the RT data because (a) all previous lexical decision studies focused on RTs rather than errors, and (b) the effects of both BN on word errors and N on nonword errors were not significant in the item analysis.
body neighbors. The fact that \( N \) is not the only and perhaps not the best predictor of lexical decision or naming performance is neither surprising nor disappointing. The \( N \) metric provided a first powerful approximation as an estimator of lexical similarity. However, it relied on the strong assumption that words are coded in terms of position specific representations (slot based position coding). As a consequence, only words of the same length were considered to be orthographic neighbors (e.g. FEET and FLEET were not neighbors). Clearly, this assumption must have necessarily been an oversimplification of lexical similarity.

It remains to be explained why BN has a facilitatory effect on word latencies while \( N \) has a slightly inhibitory effect, if anything at all. With respect to BN, there is a large amount of evidence that suggests that the body/rime is a special unit in English because it provides a reliable interface between orthography and phonology (e.g. Bowey, 1990; Treiman et al., 1995; Andrews, 1997). The body/rime may acquire a special status in the course of reading development because it helps disambiguate word phonology in English. Thus, a word with many body neighbors, which therefore contains a common body/rime unit, may speed up lexical access by reducing ambiguity and by increasing the word’s overall activation (familiarity). When BN is controlled for, there is a small but unreliable inhibitory \( N \) effect that may possibly reflect competition between orthographically similar word units during lexical selection (see Grainger and Jacobs, 1996). As a matter of fact, Andrews (1996) showed that such inhibitory \( N \) effects could be obtained in English under specific conditions, such as when a target word had a neighbor that was identical except for the transposition of two adjacent letters (e.g. SLAT/SALT). Interestingly, a regression analysis of her data showed that these inhibitory effects of transposed letter neighbors were independent from facilitatory effects of \( N \). This pattern is fairly similar to ours, in which slightly inhibitory or absent effects of letter neighbors seem to be independent from facilitatory effects of body neighbors.

It also remains to be explained why \( N \) has clearly inhibitory effects on nonword latencies while BN has apparently no effect on nonwords. With respect to \( N \), the clear inhibitory effects are not surprising. All published neighborhood studies consistently found inhibitory neighborhood effects for nonwords independent of whether the study was done in English, French or Spanish (e.g. Coltheart et al., 1977; Carreiras et al., 1997). The underlying principle for this consistent effect seems straightforward: \( N \) increases the word-likeness of a nonword, and the more word-like a nonword, the harder it is to reject. According to this account, we should have also found inhibitory BN effects for nonwords because it is likely that BN increases the word-likeness of nonwords much in the same way as \( N \). In fact, we do not see any reason to expect anything else but an inhibitory BN effect for nonwords. Thus, we will postpone any conclusions concerning this null effect until further experiments confirm the absence of a BN effect on nonword latencies. Note, however, that the main focus of the present study was on word RTs. Word decisions are theoretically far more interesting than nonword decisions, because, according to most accounts, nonwords are rejected by default – they are timed out – when not enough word evidence is available (e.g. Coltheart et al., 1977; Grainger and Jacobs, 1996). Thus, it seems more important to understand how word representations are
accessed and selected rather than what information affects the temporal threshold procedure that rejects nonwords.

What are the implications of our results for current models of visual word recognition? Interactive activation models (e.g. McClelland and Rumelhart, 1981; Grainger and Jacobs, 1996) and current dual route-models (Coltheart et al., 1993) will not be able to simulate the facilitatory BN effect because they are not sensitive to the body/rime unit. In order to accommodate for the facilitatory BN effect, they may be forced to give up the slot based position coding and allow body neighbors like FEET and SLEET to become orthographic neighbors. However, because mutual inhibition between neighbors is expected in these models according to the lexical inhibition principle, these models would still need to explain why body neighbors facilitate rather than inhibit. Alternatively, to account for facilitatory BN effects, interactive activation models could implement a level of body representations (for a detailed suggestion along this line see Taft, 1991). Parallel distributed processing models (e.g. Seidenberg and McClelland, 1989; Plaut et al., 1996) may quite naturally account for the facilitatory BN effect. It is likely that these models could become sensitive to the body grain size during learning without having explicit body representations. For example, Plaut et al. (1996) analyzed the structure of the componential attractors that resulted from learning in their model and found ‘a slight interdependence among the vowel and coda, consistent with the fact that the word bodies capture important information in pronunciation’ (p. 87). However, only simulations can tell us whether their model actually predicts a facilitatory BN effect in the lexical decision task.

In sum, the present study may provide clarifying evidence as to why neighborhood effects for words differed in English, French, and Spanish (i.e. mostly facilitation in English; mostly inhibition or null effects in French and Spanish). As our experiment shows, BN effects are clearly facilitatory in English. Thus, it is possible that previous neighborhood studies have consistently found facilitatory neighborhood effects in English, even if they manipulated N rather than BN, because in English most orthographic neighbors are body neighbors. In contrast, when BN is controlled for, it seems that N itself has a weak inhibitory or no effect on lexical decision latencies for words. Thus, in languages like French and Spanish that either do not confound BN and N or in which the body does not constitute a more reliable statistical unit (see Peereman and Content, 1997), N effects should be inhibitory if anything at all. This is precisely what has been observed in French and Spanish (Grainger et al., 1989, 1992; Grainger and Jacobs, 1996; Carreiras et al., 1997). In conclusion, a natural confound of N and BN in English along with the differential importance of the body/rime unit in English, French, and Spanish may be able to explain previously conflicting results concerning the facilitatory versus inhibitory nature of neighborhood effects in the lexical decision task.

3Simulations with MROM of Grainger and Jacobs (1996) and DRC of Coltheart et al. (1993) confirmed this claim.
4Grainger and Jacobs (1996) showed that facilitatory neighborhood size effects can emerge in their model when yes-responses in the lexical decision task are made on the basis of the global (overall) activity in the orthographic lexicon (i.e. summed activity across all the orthographic word units).
Appendix A

Words:

N constant/few BN: harp, curd, mule, warp, melt, rude, dusb, bolt, fond, leaf, perch, badge, terse*, torch, leash, marsh, scalp, bulge, merge, boost
N constant/many BN: swap, crow, clan, chop, flaw, brew, vain, spit, pray, wing, clove, sneak, trash, grain*, bleed, cheat, glare, blink, bleak, straw
BN constant/few N: rich, smog, grub, frog, knob, shed, clue, doom, veer*, howl, flour, ghost, spoil, flair, float, blunt, chess, thorn, frost, gleam
BN constant/many N: fold, dole, heal, gull, lust, rust, tile, loot, sage, poke, mound, sleet*, cough, grape, batch, hound, steer, witch, peach, crane

Nonwords:

N constant/few BN: muge, ferd, fowd, lurd, gult, roaf, hund, soid, tabe, misk, pulch, chaim, trabe, ladge, broze, lauge, beash, moute, beeth, moun
N constant/many BN: noak, yibe, hoak, glir, crem, fumb, siff, scoy, nirt, yeet, sench, stroy, pance, stime, slawn, ploak, frode, flimp, slorm, fripe
BN constant/many N: noak, yibe, hoak, glir, crem, fumb, siff, scoy, nirt, yeet, sench, stroy, pance, stime, slawn, ploak, frode, flimp, slorm, fripe

References