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Neighborhood Size Effect in Naming: Lexical Activation or Sublexical Correspondences?

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Naming latencies are generally shorter for letter strings that are orthographically similar to many words than for those that have few lexical neighbors. Two experiments were conducted to explore the locus of the neighborhood size effect in a naming task. Experiment 1 showed that the neighborhood size effect was restricted to low-frequency words and was of comparable magnitude for words and for pseudowords. Experiment 2 examined performance as a function of the composition of the experimental lists. Target words were mixed with word or pseudoword fillers. The neighborhood size effect decreased in the pseudoword context relative to the word context. The data are compatible with the notion that the neighborhood size effect follows from the activation of specific word knowledge during print-to-sound computation.

Word recognition is generally considered to be a result of the adequate matching of the sensory input with one lexical representation. Most word recognition models assume that lexical access is accompanied by the activation of several lexical representations that are structurally related to the stimulus word (Forster, 1987; McClelland & Rumelhart, 1981; Morton, 1970; Paap, Newsome, McDonald, & Schvaneveldt, 1982). This pool of form-related candidates is often called the lexical neighborhood. In the present study we investigated the influence of the lexical neighborhood in a word naming task. Our main objective was to determine whether the neighborhood size effect is indicative of the activation of lexical candidates similar to the stimulus string or whether it follows from sublexical processes specific to naming.

The operational definition of neighborhood, which has been used in many studies (e.g., Andrews, 1989; Grainger, 1990), has been popularized by Coltheart, Davelaar, Jonasson, and Besner (1977). These authors defined the neighbor of a letter string as any word that can be generated by replacing a single letter from the base string. For instance, the words *some* and *name* are neighbors of the word *same,* and the words *wave* and *lace* are neighbors of the pseudoword *wace.*

Several studies have shown that naming latencies tend to be shorter for words or pseudowords that have large neighborhoods than for words or pseudowords that have small neighborhoods. With words, a facilitatory effect has been reported in experiments by Andrews (1989, 1992). The effect was restricted to the low-frequency items in the first experiment (Andrews, 1989), but a second experiment (Andrews, 1992) also revealed a slight facilitatory effect for high-frequency words. For pseudowords, McCann and Besner (1987) found a positive correlation between neighborhood size and naming latencies, which was recently confirmed by Laxon, Masterson, Pool, and Keating (1992).

One interpretation of these findings, which was proposed by Andrews (1989), is that a large neighborhood facilitates word identification. An important element in Andrews' line of argumentation comes from her finding that neighborhood size also speeds up responses for low-frequency words in the lexical decision task. On grounds of parsimony, Andrews favored a unique explanation for both naming and lexical decision findings. Her hypothesis is based on the notion of feedback activation from word nodes to letter nodes, within the framework of the interactive activation theory of word identification (McClelland & Rumelhart, 1981). Andrews argued that because the stimulus word and its neighbors include similar letters, the feedback is higher when the neighborhood is large. Boosting the activation level of the letters would presumably facilitate word recognition. This feedback should be beneficial mainly for the low-frequency words. For high-frequency words, the recognition threshold would be reached too quickly for the effect of feedback to be visible.

However, in recent years the assumption that the lexical decision task taps directly and transparently into lexical identification processes has been questioned by various researchers. For instance, according to the analysis proposed by Balota and Chumbley (1984), lexical decision involves a nonlexical process based on the evaluation of letter strings along a familiarity–meaningfulness (F–M) dimension. Fast responses are made if the computed value falls below a low criterion or exceeds a high criterion. Further processing is needed if the F–M value falls between the two criteria. If

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words with many neighbors get higher F–M values, then fast criterion-based positive responses will be more likely to occur for them than for small neighborhood words. So, the neighborhood size effect observed with low-frequency words would result from the contribution of familiarity-based decisions.

The familiarity confound explanation specifically appeals to the nature of the lexical decision task and cannot apply to naming. Nevertheless, interpretations of the neighborhood size effect that refer to task-specific factors can also be invoked for the naming situation. Two such accounts can be put forward. One is that orthographic lexical neighbors contribute to phonological translation, and the other is that neighborhood size is confounded with the strength of sublexical correspondences.

Since Glushko's (1979) seminal article, a number of researchers (e.g., Kay & Bishop, 1987; Taraban & McClelland, 1987) have attempted to demonstrate that lexical instances influence print-to-speech conversion. Most of these have used a different notion of orthographic similarity, which applies only to monosyllables. We shall henceforth refer to this notion as *word-body neighborhood* and reserve the term *neighborhood* for the Coltheart et al. (1977) metrics. The word-body neighbors of a letter string are the words that share all letters except the initial consonant or consonant cluster. Word-body neighbors have been categorized further as friends when they share the pronunciation of the rhyme with the target (e.g., *name-same; doom-bloom*) or enemies in the opposite case (*neat-great*). The main findings of the research since Glushko's article have been that consistent letter strings (those having friends but no enemies) are named faster than inconsistent words (which have both friends and enemies) and that the consistency effect is limited to low-frequency words (Seidenberg, Waters, Barnes, & Tanenhaus, 1984).

Because consistency phenomena depend on both orthographic and phonological similarity, it seems natural to locate them at the level of print-to-speech translation. One interpretation, cast in terms of dual-route models, supposes that both sublexical and lexical phonological codes are integrated into a single phonological representation (Coltheart, Curtis, Atkins, & Haller, 1993; Norris & Brown, 1985). In this context, activation of diverging phonological information due to enemies would delay the elaboration of a unitary response code.

In the same vein, the neighborhood size effect might be attributed to the contribution of lexical neighbors to phonological computation. Because of the high degree of systematicity in the mapping between letters and phonemes, the pronunciation of most neighbors will be highly similar to the target's phonological representation. Consequently, the phonological translation might be accelerated by the convergent information provided by the neighbors. The account is thus analogous to the lexical activation explanation of the consistency effect initially proposed by Glushko (1979).

One major difference, though, is that the lexical interpretation of the consistency effect relies on the notion of competition between alternative phonological encodings. However, facilitation would need to be invoked to explain the positive influence of neighbors on pronunciation times, and, at present, whether such facilitatory effects exist is not clear. Although Brown (1987) reported a 20 ms pronunciation time advantage for words with friends only over words with neither friends nor enemies, Jared, McRae, & Seidenberg, (1990) found a nonsignificant facilitation effect of friends.

Consistency effects have not always been interpreted as evidence that lexical candidates contribute to phonological computation. Other explanations, both in the framework of multiple-route models (Patterson & Morton, 1985) and in the Parallel Distributed Processing (PDP) framework (Seidenberg & McClelland, 1989), are based on the frequency or the strength of sublexical correspondences. Similarly, another interpretation of the neighborhood size effect involves the consideration that it constitutes an indirect indicator of the frequency of sublexical correspondences. Despite some variation in the way alphabetic writing systems encode phonology, words that are spelled alike generally sound alike. Words orthographically similar to many other words therefore include orthographic units that occur frequently to represent the same phonological units. So, on average, the frequency of the correspondences between orthographic and phonological units should be higher for words similar to many other words than for words with few neighbors.[1] These natural variations are likely to have consequences for reading aloud processes. Hence, slower sublexical phonological translation would be expected when the stimulus contains infrequent spelling-to-sound correspondences.

According to this assumption, the neighborhood size effect is no longer considered to be a consequence of lexical similarity per se but is attributed to variables that correlate with neighborhood size. This type of interpretation holds for a subset of dual-route theories in which the strength of sublexical correspondences varies as a function of their frequency in the language (e.g., Paap, McDonald, Schvaneveldt, & Noel, 1987; Patterson & Morton, 1985; Taft, 1991). In fact, it is the only way to account for neighborhood size effects at the phonological level in horse-race models (Patterson & Morton, 1985, Paap et al. 1987), because phonological conversion is assumed to be realized through an autonomous set of sublexical graphophonological associations stored independently of lexical knowledge, and the response is driven by the faster of the two processes.

The same interpretation of the neighborhood size effect is valid in the context of Seidenberg and McClelland's (1989) model of print-to-speech translation. In this parallel distributed processing theory, the orthographic and the phonological representations of strings do not correspond to single units but to patterns of activation over sets of units, and a single set of

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[1] Matching the words with few or many neighbors on bigram frequencies could reduce but not abolish the difference, because bigram frequency is an index of orthographic redundancy, not of spelling-to-sound mapping frequency. Also, when words are equated on mean bigram frequency, this is generally because the items with few neighbors include one or two very frequent bigrams. In short, although words can be matched on mean bigram frequencies they nevertheless continue to differ on the frequency of the less common bigram. For example, although the items used by Andrews (1992) were matched in mean bigram frequencies, the frequency of the less common bigram was higher ($p < .05$) for words with a large neighborhood than for words with a small neighborhood (769 and 493, respectively, according to the positional bigram frequencies of Solso & Juel, 1980).

connections implements the mapping from orthography to phonology through an intermediate layer of units. Thus, contrary to dual-route theories, the distinction between a lexical and a sublexical component becomes meaningless. The strength of the connections between the orthographic and phonological units varies as a function of the frequency and consistency of the mapping in the training corpus. Thus, neighborhood size effects on conversion are handled as a confound of the frequency of sublexical associations. Indeed, a successful simulation of Andrews's (1989) results was reported by Seidenberg and McClelland.

Experiment 1

Our aim in Experiment 1 was to compare directly the neighborhood size effect for words and pseudowords because both types of letter strings had not been considered together in previous research. The stimuli consisted of high- and low-frequency French words and pseudowords varying in neighborhood size.

If the main contribution of neighborhood size is to accelerate lexical identification, larger effects should be observed for words than for pseudowords, because only real words may benefit from faster activation of their lexical entry. Moreover, according to Andrews's (1989) analysis, the beneficial effect of neighbors should be less visible for high-frequency words because they have higher resting levels and thus reach threshold faster.

In contrast, if neighborhood size affects phonological computation, the pattern of effects should be different. Within the framework of dual route models, the findings that high-frequency words are pronounced faster than low-frequency words (e.g., Forster & Chambers, 1973) and that the latter are pronounced faster than pseudowords (e.g., Frederiksen & Kroll, 1976) suggest that the phonological code is more often obtained through its orthographic address in the case of frequent words than it is in the case of rare words and pseudowords. Hence, larger effects of neighborhood should occur for pseudowords than for words, and among the latter, for low-frequency words than for high-frequency words. Similar predictions also hold in a PDP account of phonological computation, because performance varies as a function of the frequency of sublexical patterns. Letter strings pertaining to large neighborhoods benefit from the cumulative effect of the frequency of their constituent letter groups, but this effect can be overriden by the frequency of the word itself.

As the stimulus categories were not matched on the initial phoneme, a delayed naming task was also included in order to assess differences resulting from the ease of articulation and the triggering of the voice key. Participants were instructed to read the letter strings silently and to wait for a response cue before pronouncing.

Method

Participants. Eighteen students at the Free University of Brussels participated in the experiment for partial fulfillment of a course requirement. All were native speakers of French.

Stimuli. Four categories of monosyllabic words were created by the factorial combination of two variables: frequency (low vs. high) and neighborhood (small vs. large). There were 23 words in each category. Neighborhood size, defined as the number of words obtained by single letter substitution, was calculated using the lexical database developed by Content, Mousty, and Radeau (1990) for the French language.

The experiment also included pseudowords, which were generated with the constraints to include only legal bigrams and to end with a legal trigram. Because of difficulties in finding pseudowords of approximately the same mean bigram frequency as the words, only 58 pseudowords were used. All were monosyllabic and were easily pronounceable. Half the pseudowords had few neighbors, half had many neighbors. Descriptive statistics about stimulus sets appear in Table 1.[2] The list of words and pseudowords is included in the Appendix.

Procedure. The stimuli appeared singly, in lower-case, on a video screen. Presentation and timing were controlled by an Apple IIe computer. Words and pseudowords appeared in separate lists. Order of presentation of the two lists was counterbalanced across participants. Each list was preceded by 16 practice trials (words or pseudowords). Participants were asked to pronounce each letter string as quickly and accurately as possible. The response activated a voice key connected to the computer. Each trial began with a warning signal (a + sign) presented for 300 ms. It was immediately followed by the letter string. The target remained on the screen until the response was made or for a maximum of 2 s. The intertrial interval was 1 s.

Following the immediate pronunciation task, participants performed a delayed naming task with the same stimuli. The delayed naming task was identical to the immediate naming task except that the participants waited until the appearance of a response cue (a horizontal bar) before pronouncing the letter string as quickly as possible. When the stimulus appeared, the participant had unlimited time to read the letter string silently. He or she then removed the stimulus by pressing a button on the computer keyboard. The response cue was displayed 1 s after the disappearance of the stimulus. The time elapsing between the appearance of the response cue and the triggering of the voice key was recorded by the computer.

Finally, in order to validate frequency norms, participants were instructed to rate each word for its familiarity on a 6-point scale (from 1 = *unknown* to 6 = *very frequent*).

Results

Response latencies above 1 s or below 200 ms were excluded from the analysis. Response times corresponding to words not known by the participants were also discarded. This led to the rejection of 1.0% of the words and 1.1% of the pseudowords in the immediate naming task, and of 5.0% of the words and 4.4% of the pseudowords in the delayed naming task. The greater number of rejected trials in the delayed naming task follows from the participants' tendency to start pronunciation before the onset of the response cue. Response latencies corresponding to errors were also discarded (2.3% in immediate naming; 0.4% in delayed naming). Separate analyses were conducted on the immediate and delayed naming tasks.

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[2] In Table 1, as well as in following analyses, sums of log-transformed frequencies were used rather than token counts in order to minimize the effect of the skewness of the word frequency distribution (see Frauenfelder, Baayen, & Hellwig, 1993, for an example of similar treatment and for further justification). Although it has been argued that log transformed frequency constitutes a better predictor of human reaction times (Murray & Forster, 1992), we admit that the question about whether summed log-transformed frequencies provide a more appropriate estimate of neighborhood than raw token count remains unanswered.

Table 1
Descriptive Statistics for the Stimulus Stimulus Sets Used (Mean Values)

Variable	High frequency Small N	High frequency Large N	Low frequency Small N	Low frequency Large N	Pseudowords Small N	Pseudowords Large N
Word frequency	2.20	2.13	0.40	0.42		
Frequency range	26–1482	31–1241	0.2–11	0.2–9		
N size	1.43	10.40	1.47	11.08	1.86	10.62
Summed neighbors frequency	1.47	11.49	1.95	9.91	1.66	10.67
Summed friends frequency	5.25	10.75	6.00	5.18	2.39	7.15
Summed enemies frequency	0.10	0.04	0.50	0.65	0.31	0.16
Summed N-friends frequency	0.50	6.11	0.80	3.56	0.53	5.36
Summed N-enemies frequency	0.06	0.04	0.00	0.18	0.00	0.00
Length in letters	3.83	3.83	3.83	3.83	4.24	4.24
Bigram frequency	6.00	6.08	6.96	6.06	6.26	6.20

Note. The letter *N* stands for neighborhood. Frequencies are expressed in $\log_{10}$ scale. Word frequencies (per million) are from Imbs (1971). Bigram frequencies are from Content and Radeau (1988). Friend and enemy frequencies (per million) are computed on all monosyllabic words (n = 2,458) in Content, Mousty, and Radeau (1990). N-friends and N-enemies correspond to the friends and the enemies within the stimulus's neighborhood.

Word familiarity ratings. Results for 2 participants were discarded because their ratings were performed on a 5-point scale instead of a 6-point scale. Mean familiarity ratings were the following: 5.4 and 5.4 for high-frequency words with small and large neighborhoods, respectively, and 3.9 and 3.6 for low-frequency words with small and large neighborhoods, respectively. No significant differences were found between small- and large-neighborhood word sets, but there was a significant difference between high- and low-frequency sets, $t(90) = 15.0, p < .01$. Thus, word classification according to familiarity ratings agrees with word classification based on objective frequency.

Immediate naming task. Analyses of variance (ANOVAs) including the variables target type (high-frequency word, low-frequency word, and pseudoword) and neighborhood size (small and large) were conducted on naming latencies (F_s represents by-subjects analysis; F_i represents by-items analysis). Because the word and the pseudoword sample sizes were unequal, item analysis was carried out using the proportionate subclass numbers method. As Table 2 shows, large-neighborhood letter strings yielded shorter naming latencies than did small-neighborhood letter strings, $F_s(1, 17) = 72.60$, $MSE = 5{,}764$, $p < .005$; $F_i(1, 144) = 8.62$, $MSE = 8{,}607$, $p < .005$. There was a main effect of target type, $F_s(2, 34) = 19.81$, $MSE = 40{,}536$, $p < .005$; $F_i(2, 144) = 56.91$, $MSE = 56{,}823$, $p < .005$, and the interaction between target type and neighborhood size was significant in the subject analysis, $F_s(2, 34) = 5.18$, $MSE = 913$, $p < .025$, but failed to reach significance in the item analysis ($p > .10$). Planned comparisons indicated a significant effect of neighborhood size for low-frequency words, $F_s(1, 17) = 18.11$, $MSE = 3{,}192$, $p < .001$; $F_i(1, 144) = 3.52$, $MSE = 3{,}513$, $p = .06$, and pseudowords, $F_s(1, 17) = 24.46$, $MSE = 4{,}312$, $p < .001$; $F_i(1, 144) = 10.64$, $MSE = 10{,}625$, $p < .005$. In contrast, neighborhood size did not affect naming latencies for high-frequency words.

Further analyses were carried out to compare low-frequency words and pseudowords. As Table 2 indicates, letter strings with many neighbors were pronounced faster than were letter strings with few neighbors, $F_s(1, 17) = 49.90$, $MSE = 7{,}462$, $p < .005$; $F_i(1, 144) = 12.74$, $MSE = 12{,}727$, $p < .001$, and low-frequency words were pronounced faster than were pseudowords, $F_s(1, 17) = 11.41$, $MSE = 32{,}982$, $p < .005$; $F_i(1, 144) = 46.33$, $MSE = 46{,}262$, $p < .005$. Neighborhood size did not interact with target type (both $F_s < 1$).

Delayed naming task. Similar analyses were carried out on the delayed naming data. As shown in Table 2, a main effect of target type was observed, $F_s(2, 34) = 7.88$, $MSE = 10{,}127$, $p < .005$; $F_i(2, 144) = 22.63$, $MSE = 14{,}852$, $p < .005$. Naming

Table 2
Mean Naming Latencies (in Milliseconds) and Percentage of Errors (in Parentheses) as a Function of Task, Target Type, and Neighborhood (N) Size in Experiment 1

Target type	Immediate Small N	Immediate Large N	Immediate Difference	Delayed Small N	Delayed Large N	Delayed Difference
High frequency	463 (0.7)	460 (1.7)	3 (−1.0)	328 (0.0)	328 (0.0)	0 (0.0)
Low frequency	494 (2.4)	475 (1.9)	19 (0.5)	334 (0.4)	334 (0.0)	0 (0.4)
Pseudowords	538 (3.4)	517 (3.4)	21 (0.0)	359 (1.1)	361 (0.7)	−2 (0.4)

times for pseudowords were longer than for low-frequency words, $F_s(1, 17) = 6.49$, $MSE = 11{,}679$, $p < .025$; $F_i(1, 144) = 26.22$, $MSE = 17{,}210$, $p < .005$, as well as for high-frequency words, $F_s(1, 17) = 10.45$, $MSE = 18{,}018$, $p < .005$; $F_i(1, 144) = 40.42$, $MSE = 25{,}050$, $p < .005$.

Because a significant lexicality effect was observed in the delayed naming data, an additional analysis was conducted to compare the lexicality effect in immediate and delayed naming. There was a small length difference between words and pseudowords, thus constituting a potential confound with lexicality, so this analysis used only four- and five-letter low-frequency words ($n = 17$) and the same number of pseudowords of each length chosen at random. A small reduction of the lexicality effect was observed in delayed relative to immediate naming (28 ms vs 43 ms, respectively), but the Task × Lexicality interaction was not significant, $F_s < 1$; $F_i(1, 64) = 1.98$, $p > .10$.

Discussion

The results show that pseudowords and low-frequency words are pronounced faster when they are orthographically similar to a large number of words than when they are similar to only a few words. Conversely, the size of the orthographic neighborhood did not affect naming latencies for high-frequency words. The neighborhood size effect on pseudowords is compatible with the data reported by McCann and Besner (1987) and by Laxon et al. (1992). The influence of neighborhood size on the latencies for low-frequency words but not for high-frequency words agrees with the findings reported by Andrews (1989).

The effect of neighborhood size did not differ for low-frequency words and pseudowords. This finding does not support the notion that neighborhood size accelerates lexical identification per se, because it suggests that the largest part of the effect is due to nonlexical processes. At first sight, the identity of neighborhood size effects for pseudowords and for low-frequency words also seems incompatible with the other hypotheses we proposed. As we argued earlier in this article, accounts that locate the influence of neighborhood size at the level of phonological conversion predict larger effects for pseudowords than for words. This prediction however presupposes that low-frequency words are pronounced faster than pseudowords. Because there was no significant reduction of the lexicality effect in the delayed naming task relative to immediate naming, it is unclear whether the advantage of low-frequency words over pseudowords reflects faster phonological computation or differences in articulatory characteristics.

An alternative account of the delayed naming data could be that phonological computations are not entirely over at the time the response cue is presented. Although the time interval between the disappearance of the letter string and the response cue (1 s) seems sufficiently long to allow for full response preparation, the target was removed by the participant's key press and was thus presented for a variable duration. Because this procedure permits very short presentation duration, the stimulus information could have been only partially extracted before the disappearance of the letter string. The 1 s delay could have been too short (particularly for pseudowords) for participants to identify fully the target and to prepare the response.[3] In Experiment 2, we tried to avoid this problem by using a fixed presentation duration (1200 ms).

The three interpretations of the neighborhood size effect in immediate naming discussed earlier in this article share the idea that neighborhood size facilitates, rather than impedes, responses. An alternative explanation of the difference in naming latencies between large- and small-neighborhood-size stimuli is that they differed in spelling–sound consistency. In a careful investigation, Jared et al. (1990) showed that consistency is a matter of degree. They argued that the size of the effect is determined mainly by the ratio of the cumulative frequency of friends and enemies. Consistency was not controlled in the present study and a few of the words had enemies (13% of the low-frequency words and 10% of the pseudowords were inconsistent in terms of body pronunciation). Because small-neighborhood letter strings are expected to have fewer friends than are large-neighborhood letter strings, they might suffer more from the presence of enemies. In this view, the neighborhood size effect would result from the disadvantage incurred by small-neighborhood letter strings.

Examination of the mean cumulative frequency of friends and enemies (Table 1) reveals that the friends to enemies ratio was indeed higher for large-neighborhood pseudowords than for small-neighborhood pseudowords. However, a trend in the opposite direction was indicated for the low-frequency words. Moreover, a post hoc analysis restricted to all consistent items was conducted on reaction times (RTs). The analysis included 16 large-neighborhood and 20 small-neighborhood low-frequency words (mean word length was 3.8 letters in both cases) and 27 pseudowords (mean length was 4.2 letters in both cases) in each neighborhood size category. The results showed clear effects of neighborhood size on RTs for naming of words (490 ms and 470 ms, for small and large neighborhoods, respectively; $F(1, 34) = 5.27$, $MSE = 3{,}618$, $p < .05$) and of pseudowords (542 ms and 514 ms, for small and large neighborhoods, respectively; $F(1, 52) = 7.40$, $MSE = 10{,}278$, $p < .01$). The present data thus support accounts of the neighborhood size effect in terms of facilitation. The aim of Experiment 2 was to examine whether this facilitation could be attributed to the activation of lexical neighbors or to faster phonological computation resulting from the presence of more frequent graphophonological correspondences.

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[3] Stimulus duration was not recorded; therefore, no comparison can be made with other experiments. The mean delayed naming latencies for words in Experiment 1 are in the same range as those described in the literature (331 ms in Experiment 1; 335 ms in McRae, Jared, & Seidenberg, 1990, Experiment 1; 302 ms in Connine, Mullennix, Shernoff, & Yelen, 1990). However, the mean difference between immediate and delayed naming is smaller in the present experiment (143 ms) than in the others (e.g., 203 ms in Savage, Bradley, & Forster, 1990, Experiments 1 and 2; 211 ms in Connine et al.; 228 ms in McRae et al.) Such a difference might suggest that our participants were not fully prepared when the response cue was displayed. However, these results should be considered with caution because naming task is generally a between-subjects variable.

Experiment 2

Several recent findings indicate that the list composition influences the relative contribution of word-specific knowledge and overall regularities in naming. In an experiment examining the influence of list composition on the regularity effect, Content and Peereman (1992) showed that, for high-frequency French words, the disadvantage of exception words over regular ones was larger when the lists also included pseudowords. In addition, regularization errors were more frequent in the presence of pseudowords. Monsell, Patterson, Graham, Hughes, and Milroy (1992) had participants read pure or mixed lists of pseudowords and exception words, and also observed more regularization errors and slower naming of exception words in mixed lists. It has also been reported that in Persian (Baluch & Besner, 1991) and in Italian (Tabossi & Laghi, 1992), the semantic priming effect vanishes when the words are mixed with pseudowords. Taken together, these results imply that there is room for adaptive modulation of word naming processes as a function of the demands of reading materials. They further suggest the existence of two different and at least partially separable systems.

Two different functional architectures can be envisaged: the standard dual-process framework and the PDP framework proposed by Seidenberg and McClelland (1989). Within the standard dual-process framework, the main partition concerns the distinction between sublexical analytical regularities (the assembly mechanism) and word-specific knowledge (the addressing mechanism). According to this view, the findings suggest that phonological assembly is more often involved in pronouncing words when pseudowords are also expected. Thus, the presence of pseudowords in the stimulus set diminishes the relative weighting of lexical information that must be pooled together with sublexical information.

In addition to the direct mapping from orthography to phonology, the alternative theoretical framework advanced by Seidenberg and McClelland (1989) posits the existence of a distinct and separate processing pathway, in which activation flows in an interactive fashion from the orthographic layer up to the phonological level through intermediate activation of semantic codes. It would thus seem plausible to account for the increase of regularity effects and the decrease of the semantic priming effect in pseudoword background by proposing that the strategic modulation consists of reducing the contribution of the semantic (orthographic-semantic-phonological) pathway.

The standard dual process and the PDP accounts lead to partially different predictions about the influence of list composition on the neighborhood size effect. In the PDP framework, neighborhood size partly determines the strength of connections in the orthography–to–phonology pathway. If the presence of pseudowords decreases the role of the semantic route, neighborhood size effects should increase just like regularity effects. In the standard dual-process framework, two opposite predictions can be formulated. If the neighborhood size effect is attributed to faster assembly when the letter string includes frequent sublexical correspondences, then the inclusion of pseudowords should enhance the neighborhood size effect because pseudoword background increases reliance on the assembly process. Conversely, if neighborhood size effects originate from activation of lexical instances, the effect should be reduced when pseudowords are present.

In Experiment 2, the target words from Experiment 1 were mixed with either pseudoword fillers (a mixed list of words and pseudowords) or word fillers (a pure list of words) and were presented to different groups of participants. To maximize the contrast between the two list backgrounds, the fillers in the pure word lists consisted of high-frequency items. In addition, target word frequency was blocked to avoid the risk of contamination of high-frequency word processing by the presence of some very rare, and possibly unknown, words. The target pseudowords of Experiment 1 were presented in a pure list to all participants. So, performance on a common list of pseudowords could be used as a baseline to evaluate the effect of background manipulation. Also included was a delayed naming task with the same design as that of the immediate naming task.

Method

Participants. The participants were 72 students at the Free University of Brussels. All were native speakers of French and all participated in the experiment either for partial fulfillment of a course requirement or for a small monetary reward. Forty participants completed the immediate naming task, and 32 participants completed the delayed naming task. None of the participants had been involved in Experiment 1.

Stimuli and procedure. The words and the pseudowords used in Experiment 1 served as targets. High-frequency words, low-frequency words, and pseudowords appeared in separate lists. In each naming task, half of the participants saw the target words mixed with pseudowords. These participants constituted the pseudoword background groups. Sets of high- and low-frequency target words were each combined with 80 filler pseudowords. For the remaining participants (word background groups), the filler pseudowords were replaced by high-frequency filler words. All participants also received a third list, which was made of target pseudowords and did not include fillers.

For each background group, the order of presentation of the lists of low- and high-frequency target words was counterbalanced across participants. In addition, half of the participants began with the list including the target pseudowords, whereas the other half began with the lists including the target words. Before each list, participants were informed about the lexical status (words, pseudowords, or both) of the set.

The immediate naming task started with practice trials that consisted of 10 words, 10 pseudowords, or 6 pseudowords and 4 words, depending on the nature of the first experimental list. Presentation and timing conditions were the same as in Experiment 1. After the experimental session, knowledge of the low-frequency words was assessed by asking the participants to underline each word they did not know on a sheet of paper.

In the delayed naming task, each trial started with a 300-ms warning signal. The letter string was then displayed for 1,200 ms and was followed by a screen that was blank for 1,300, 1,500, 1,700, or 1,900 ms. The response cue (a ??? sign) was then presented, and the time until the onset of the participant's response was measured. To increase attention to the response cue, an auditory warning signal was presented 1 s after the removal of the letter string. For each participant, the four delay intervals were equally likely to occur and did so in random order. The delay interval was changed between participants so that, across participants, each letter string was presented equally often with each delay. The task started with 25 practice trials in which lexical status depended on the content of the first experimental list. The intertrial interval was 2 s.

Results

Immediate naming. As in Experiment 1, response latencies falling out of the range between the two cutoff values (200–1000 ms) were excluded from the analysis (0.3% of the trials). Naming latencies corresponding to errors (3.1% of the trials) or to words not known by the participants (4.4% of the trials) were also discarded. The mean latencies and percentage of errors in responses to target words and to target pseudowords appear in Table 3. Because of numerous empty entries, the errors were not analyzed. Note that 36.2% of the errors in responses to the target pseudowords were caused by three items (one with a small neighborhood, the others with a large neighborhood).

ANOVAs including the variables target type (high-frequency word, low-frequency word, and pseudoword), neighborhood size (small and large) and list background (high-frequency word fillers and pseudoword fillers) were conducted on naming latencies. There was a main effect of neighborhood size, $F_s(1, 38) = 76.37$, $MSE = 14{,}821$, $p < .001$; $F_i(1, 144) = 12.54$, $MSE = 21{,}583$, $p < .001$, with large-neighborhood letter strings yielding shorter naming latencies than those for small-neighborhood letter strings. The effect of target type was also reliable, $F_s(2, 76) = 43.56$, $MSE = 44{,}053$, $p < .001$; $F_i(2, 144) = 33.08$, $MSE = 56{,}929$, $p < .001$. High-frequency words were pronounced faster than low-frequency words, $F_s(1, 38) = 29.67$, $MSE = 30{,}003$, $p < .001$; $F_i(1, 144) = 17.89$, $MSE = 30{,}785$, $p < .001$, and low-frequency words were pronounced faster than pseudowords, $F_s(1, 38) = 14.75$, $MSE = 14{,}919$, $p < .001$; $F_i(1, 144) = 13.44$, $MSE = 23{,}138$, $p < .001$. The effect of list background reached significance in the item analysis only, $F_s(1, 38) = .65$, $MSE = 14{,}539$, $p > .10$; $F_i(1, 144) = 50.33$, $MSE = 15{,}997$, $p < .001$.

As in Experiment 1, the interaction between target type and neighborhood size was significant, $F_s(2, 76) = 33.06$, $MSE = 4{,}518$, $p < .001$; $F_i(2, 144) = 3.46$, $MSE = 5{,}952$, $p < .05$. Local comparisons showed that the neighborhood-size effect was significant for low-frequency words, $F_s(1, 76) = 82.90$, $MSE = 11{,}329$, $p < .001$; $F_i(1, 144) = 7.31$, $MSE = 12{,}585$, $p < .01$, and for pseudowords, $F_s(1, 76) = 91.28$, $MSE = 12{,}475$, $p < .001$; $F_i(1, 144) = 13.69$, $MSE = 23{,}555$, $p < .001$, but not for high-frequency words ($p > .10$).

There was a significant interaction between target type and list background, $F_s(2, 76) = 3.72$, $MSE = 3{,}763$, $p < .05$; $F_i(2, 144) = 14.63$, $MSE = 4{,}650$, $p < .001$. Finally, the interaction between neighborhood size and list background and the interaction between all three variables were significant by subjects, $F_s(1, 38) = 5.37$, $MSE = 1{,}042$, $p < .05$; $F_s(2, 76) = 4.02$, $MSE = 550$, $p < .05$, respectively, but not by items ($p > .10$ in both cases).

An additional analysis was run on word targets as a function of neighborhood size, frequency, and list background. There was a main effect of frequency, $F_s(1, 38) = 33.06$, $MSE = 30{,}003$, $p < .005$; $F_i(1, 88) = 31.53$, $MSE = 30{,}785$, $p < .005$. The interaction between list background and frequency was reliable, $F_s(1, 38) = 4.85$, $MSE = 4{,}400$, $p < .05$; $F_i(1, 88) = 31.18$, $MSE = 6{,}339$, $p < .005$, with the word frequency effect being larger in the word background than in the pseudoword background. Most important, neighborhood size interacted with list background, $F_s(1, 38) = 10.61$, $MSE = 1{,}632$, $p < .01$; $F_i(1, 88) = 6.16$, $MSE = 1{,}252$, $p < .05$. As shown in Table 3, the neighborhood size effect was reduced in the pseudoword background. Although this reduction was larger for low-frequency words (20 ms) than for high-frequency words (6 ms), the three-way interaction between list background, frequency, and neighborhood size approached significance by subjects, $F_s(1, 38) = 3.92$, $MSE = 508$, $p = .055$, but not by items ($F > 1$).

Finally, a potential criticism regarding the design of the present experiment is that the performance on target pseudowords could itself be affected by previous experimental lists. A further analysis was performed to examine whether performance on the target pseudoword list (the baseline condition) was affected by the composition of the preceding target word lists (pure lists of words or mixed lists of words and pseudowords). This analysis only included the participants who began the experiment with the target word lists. Target pseudowords were named 3 ms faster when preceded by the pure lists of words (399 ms on average) than by the mixed lists of words and pseudowords (402 ms on average). This difference was nonsignificant ($p > .10$ in both analyses). Thus, there is no indication

Table 3

Mean Naming Latencies (in ms) and Percentage of Errors (in Parentheses) as a Function of List Background, Target Type, and Neighborhood (N) Size in the Immediate and Delayed Naming Conditions in Experiment 2

Naming condition and target type	Pseudoword fillers			Word fillers		
	Small N	Large N	Difference	Small N	Large N	Difference
Immediate						
High Frequency	370 (0.2)	375 (0.0)	−5 (0.2)	373 (0.4)	372 (1.3)	1 (−0.9)
Low Frequency	396 (3.0)	382 (2.2)	14 (0.8)	427 (3.9)	393 (1.1)	34 (2.8)
Pseudowords[a]	419 (4.8)	394 (6.2)	25 (−1.4)	444 (5.2)	420 (5.7)	24 (−0.5)
Delayed						
High Frequency	200 (0.0)	213 (0.0)	−13 (0.0)	211 (0.3)	222 (0.0)	−11 (0.3)
Low Frequency	212 (4.1)	216 (1.6)	−4 (2.5)	219 (1.6)	213 (0.5)	6 (1.1)
Pseudowords[a]	211 (1.7)	215 (3.0)	−4 (−1.3)	215 (0.0)	222 (2.3)	−7 (−2.3)

[a] The same pseudoword list was presented without fillers to both groups.

that previous blocks influence the way participants deal with homogeneous lists of pseudowords.

Delayed naming. Naming latencies corresponding to erroneous responses (1.3% of the trials), to anticipated responses (i.e., starting before the response cue; 1.0% of the trials), and to RTs shorter than 80 ms or longer than 1,000 ms (2.4% of the trials) were excluded from the analysis. ANOVAs including the variables target type (high-frequency words, low-frequency words, and pseudowords), neighborhood size (small and large), list background (high-frequency word fillers and pseudowords fillers) and delay (1,300, 1,500, 1,700, and 1,900 ms) were conducted on the naming latencies. Delay was highly significant, $F_s(3, 90) = 82.89$, $MSE = 65{,}748$, $p < .001$; $F_i(3, 432) = 72.69$, $MSE = 95{,}986$, $p < .001$, with naming latencies being shorter at longer intervals (239, 214, 203, and 198 ms at the four delays, respectively). Neither list background nor target type interacted with other variables or was significant. As shown in Table 3, similar RTs were obtained for high-frequency words, low-frequency words, and pseudowords. Neighborhood size was significant in the by-subject analysis, $F_s(1, 30) = 11.0$, $MSE = 5{,}219$, $p < .005$, but not in the analysis by item ($p > .10$). The interaction between neighborhood size and target type also reached significance in the by-subject analysis, $F_s(2, 60) = 3.5$, $MSE = 2{,}283$, $p < .05$, but not in the by-item analysis ($p > .10$). As shown in Table 3, for high-frequency words there was a small advantage of small-neighborhood items over large-neighborhood items.

Discussion

To summarize, immediate naming latencies in responses to pseudowords and to low-frequency words were shorter when the letter strings had many neighbors. The neighborhood size effect was larger when the stimuli appeared in pure lists of words than when they were mixed with pseudoword fillers. Similarly, the word frequency effect was more noticeable in a word background than in a pseudoword background, a result in agreement with recent observations by Baluch and Besner (1991) using phonologically transparent Persian words and by Content and Peereman (1992) using French words.

On the basis of raw data (see Table 3), it appears that low-frequency words were named more slowly in the word than in the pseudoword context, whereas no list context effect was evident for high-frequency words. However, the list context manipulation was a between-subjects factor. The pseudoword naming data, which corresponded to the same list presented without fillers, suggest that the word background group was slightly slower overall. Thus, if pseudoword naming latencies are used as a baseline, list background did not affect naming latencies for low-frequency words (18 ms and 22 ms of advantage for low-frequency words over pseudowords in the pseudoword and word background, respectively), whereas high-frequency words were named more quickly in word background (60 ms difference) than in pseudoword background (34 ms).[4]

In the delayed naming task, neither the lexicality nor the frequency effect approached significance, and neither interacted with list background. This pattern suggests that the lexicality effect observed in the delayed naming data of Experiment 1 resulted from insufficient response preparation.

Surprisingly, among high-frequency words, small-neighborhood items gave rise to shorter latencies than did large-neighborhood items. It seems likely that the 12-ms difference for high-frequency words was caused by artefactual variations in articulatory characteristics. Hence, this difference may have hidden a small effect of neighborhood size on the high-frequency words in the immediate naming situation.

In our view, the most interesting observation is that the neighborhood size effect decreased in the pseudoword background. This finding appears incompatible with the notion that neighborhood size effects in naming are due to the frequency or the strength of analytical correspondences. Indeed, in that case, the effect should have increased. It seems that the simplest account of the present data is to assume that the effect follows from lexical activation of the neighbors. Such a facilitation could result from lexical contribution to either orthographic encoding or to phonological computation.

A prediction that follows from the hypothesis that the neighborhood size effect mainly results from lexical contribution to phonological conversion is that phonologically similar neighbors should be more beneficial than phonologically dissimilar neighbors. To test this prediction, two different indexes of phonological distance were developed. The first one relied on the body criterion. For each stimulus, the frequency of the body-rhyme correspondence was computed, either within the set of all monosyllabic words, or within the neighborhood of the stimulus (see Table 1). For the second index, close neighbors were those including a maximum of one phoneme not shared by the target (target SAGE, /sa3/; CAGE, ka3/; SAPE, /sap/; SALE, /sal/); the others were classified as distant (SAGA, /saga/). Multiple stepwise regression analyses were performed on the data for low-frequency words and for pseudowords, using the following five predictor variables: (a) the summed log frequencies of friends, (b) the summed log frequencies of friends within the neighborhood, (c) the summed log frequencies of close neighbors, (d) the summed log frequencies of distant neighbors, and (e) the summed log frequencies of all neighbors. The dependent variable was the RT averaged on the two background conditions. The results showed that the summed log frequency of close neighbors was the only significant predictor variable, $F(1, 44) = 14.4$, $p < .001$; $r = -.49$; $r^2 = .23$, for low-frequency words, and $F(1, 56) = 12.0$, $p < .001$; $r = -.42$; $r^2 = .17$, for pseudowords.[5] This observation

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[4] Using the pseudoword list as reference, when the two slowest participants in the word background and the two fastest participants in the pseudoword background were discarded, the mean latencies for the pseudoword list became exactly equal (420 ms). A 19 ms difference in favor of the word background group was obtained for the high-frequency words, and a null difference was obtained for the low-frequency words. The Neighborhood × List Background interaction remained significant by participants and by items.

[5] Jared et al. (1990) reported that naming latencies in responses to consistent and inconsistent words were better accounted for by using word–body neighbor token, rather than type counts. For that reason, summed neighbor frequencies were used in the analyses. Note however that the same pattern of results was obtained when the five predictor variables were based on type counts. For both low-frequency words and pseudowords, the number of close neighbors was the only significant predictor variable ($p < .001$ in both cases).

gives further support to the hypothesis that neighborhood size effects in naming follow specifically from phonological computation processes.

General Discussion

The purpose of the present study was to investigate the nature and locus of the influence of lexical neighborhood size in naming. In both experiments, significant effects of neighborhood size were observed for low-frequency words and for pseudowords. Delayed naming data were also collected. No neighborhood size effect was found, thus demonstrating that the phenomenon cannot be ascribed to differences in articulatory characteristics. A significant lexicality effect was observed in delayed naming in Experiment 1. However, the difference between low-frequency words and pseudowords disappeared in Experiment 2 when preparation delays were increased and the stimuli remained on screen for a fixed duration. Finally, in Experiment 2, the neighborhood size effect was assessed under two different list background conditions. It was found that the neighborhood size effect, as well as the frequency effect, significantly interacted with list composition. Both effects were reduced when pseudoword fillers were included in the experimental lists.

The Neighborhood Size Effect

It has been suggested by Grainger (1990) that, in lexical decision, the neighborhood size effect might be due to unmatched bigram frequencies between items with large and small neighborhoods. According to Grainger, the neighborhood size effect "may simply reflect the facilitatory effects of higher bigram frequency on word processing" (p. 229). This account was countered by Andrews's (1992) study in which neighborhood size effects were still observed in naming and lexical decision when items were carefully matched for mean bigram frequencies. Our data replicate Andrews's findings in naming. They lend further support to the conclusion that the neighborhood size effect is a robust phenomenon and does not constitute a confound of orthographic redundancy. It could however be argued that mean bigram frequency is an inappropriate index and that better measures of redundancy might still explain the effect. The finding that it varies as a function of list background renders this explanation even more hazardous, because there is no a priori reason to expect orthographic redundancy to be more influential in a word than in a pseudoword background.

One hypothesis, derived from Andrews's (1989, 1992) discussion of the lexical decision data, attributed the effect of neighborhood size to facilitation of lexical identification. We reasoned that in this case the effect should be more prominent for words than for pseudowords because only real words may benefit from faster lexical activation. On the basis of our present finding that the neighborhood size effect depends on list background, the comparison becomes slightly more difficult. Thus, the appropriate comparison needs to equate list backgrounds as far as possible. This is done in the pseudoword background condition of Experiment 2, in which the neighborhood size effect was numerically smaller for low-frequency words than for pseudowords, contrary to Andrews's (1989) hypothesis. This observation is even more striking given that the presence of a lexicality effect indicates that the naming of low-frequency words partly relies on lexical identification. We thus feel entitled to reject the claim that the main effect of neighborhood size in naming consists of boosting the activation of lexical nodes corresponding to the presented word.

It is worth noting that in a recent study based on perceptual identification of degraded stimuli, Snodgrass and Mintzer (1993) reported inhibitory effects of neighborhood size when using Andrews's (1989) low-frequency stimuli. According to Snodgrass and Mintzer, when unique identification is required, neighborhood size is inhibitory. In the lexical decision task, a facilitatory effect comes out because some responses can be based on overall word likeness. They concluded that the perceptual identification task may provide a more accurate measure of unique lexical identification than either lexical decision or naming, and that Andrews's (1989, 1992) lexical decision and naming results may be attributed to task-specific factors. Thus Snodgrass and Mintzer's interpretation of the neighborhood size effects fits nearly perfectly with our account. For the naming task however, they argued that the facilitatory effect is due to the contribution of nonlexical phonological processes, although this claim was not backed up by any direct evidence. Although confirming that phonological processes are likely to explain the naming results, the data from our present study indicate that lexical contribution to phonological conversion provides a better account.

Another hypothesis that we considered earlier in this article attributed the existence of the neighborhood size effect to differential strength of analytical graphophonological correspondences. Because it was assumed that these correspondences might play a more important role when pseudowords are included, the hypothesis was rejected given that the neighborhood size effect decreased in conditions involving a pseudoword background.

Thus, the best account of the neighborhood size effect on naming latency appears to involve the notion that the pool of lexical candidates activated by the input directly contributes to the activation of sublexical orthographic or phonological codes. One possibility that we have considered is that the lexical candidates' phonological codes contribute to the elaboration of a phonological representation. A slightly different interpretation, cast in the interactive activation framework, is our proposal that the parallel activation of multiple lexical candidates reverberates to letter nodes and that the faster accrual of orthographic activation would thus facilitate all subsequent processes.

It is hard to see how these two possibilities can be disentangled. The main difference lies in the assumption of word to letter top-down connectivity, which is fundamental for the orthographic encoding hypothesis only. We believe that the current state of the evidence favors the phonological hypothesis. The notion of top-down word–letter connectivity was introduced in the interactive activation model to account for the advantage of words and pseudowords in the Reicher paradigm (McClelland & Rumelhart, 1981). However, other models have disputed the necessity of the word–letter links (e.g., Paap et al., 1982). Furthermore, the notion that word–

letter feedback has to account for the neighborhood size effects in lexical decision can be challenged on the basis of a set of simulations directly comparing the interactive activation and the noninteractive activation architectures (Jacobs & Grainger, 1992). Only the noninteractive version predicted an inhibitory effect of neighborhood size for low-frequency words on unique identification times, which is quite similar to the results reported more recently by Snodgrass & Mintzer (1993) in a perceptual identification task. This suggests that the presence of top-down connections may in some cases hinder the adequate simulation of empirical results.

Finally, in the present study, some support for the phonological hypothesis comes from a post hoc regression analysis through which we found that the summed log frequency of phonologically close neighbors was a better predictor of naming latencies than the summed log frequency of all neighbors. The arguments reviewed above suggest that the notion of word–letter reverberation is not necessary. The present data also suggest that the word–letter reverberation explanation is not sufficient to account for neighborhood size effects in naming.

Strategic Modulation and Models of Print-to-Sound Computations

In Experiment 2, a significant interaction was observed between list background and word frequency. The word frequency effect was smaller for the group tested with pseudoword fillers. A similar interaction of list composition and frequency was found in a previous study, in which regular and exception words were presented as either a pure list of words or mixed with a set of pseudoword fillers (Content & Peereman, 1992). Monsell et al. (1992) also observed that the presence of pseudowords lengthened latencies to high-frequency exception words more than to low-frequency exception words. Other results compatible with this pattern were reported by Frederiksen & Kroll (1976) and by Hudson & Bergman (1985). Finally, using phonologically transparent Persian words, Baluch and Besner (1991) obtained a word frequency effect in pure lists but not in mixed lists.

In addition to the evidence of list composition influences on frequency and neighborhood size effects obtained in the present study, the inclusion of pseudowords has also been shown to increase the regularity effect on naming latencies (Content & Peereman, 1992) and the rate of regularization errors (Content & Peereman, 1992; Monsell et al., 1992), to increase the word length effect (Content & Peereman, 1992), and to decrease the semantic priming effect (Baluch & Besner, 1991; Tabossi & Laghi, 1992). We shall now discuss how this set of findings can be accomodated by either dual-process theories or PDP approaches.

In the dual-process framework, the increase of regularity and length effects and the decrease of semantic priming and frequency effects have been interpreted (e.g., Baluch & Besner, 1991; Content & Peereman, 1992) as being indicative of more reliance on assembly processes when pseudowords are included than when they are not included. Given that the neighborhood size effect decreases in pseudoword context, we are attributing the effect to the incorporation of lexical knowledge into phonological computation. Our conclusion is at variance with theories positing two independent routes to phonology (e.g., Patterson & Morton, 1985; Paap et al., 1987) and adds to a growing body of evidence challenging such models (e.g., Peereman, 1991; Rosson, 1983). On the contrary, models assuming that phonological information from activated lexical instances is pooled with phonological information based on analytical correspondences (e.g., Coltheart et al., 1993; Shallice & McCarthy, 1985) should be able to account for the interaction of list composition and neighborhood provided that some flexibility is allowed in the contribution of lexical instances to the print-to-sound translation process. One simple way to implement such flexibility (already suggested by Brown, 1987) would be to modulate the connections from orthographic word form units to phonological word form units. We have argued (Content & Peereman, 1992) that such flexibility may be necessary to avoid the risk of lexicalization errors. The same principle would account for the concomitant fluctuations of regularity, frequency, priming, and length effects.

As discussed earlier, consistency effects have often been interpreted as demonstrations of a lexical contribution to conversion processes. However, as Patterson and Morton (1985) and others pointed out, even within the framework of an independent nonlexical mechanism of phonological assembly, consistency effects can be explained if the phonological alternatives of the body are represented with different probabilities. More convincing demonstrations of lexical involvement are evident from Content and Peereman's (1992) and Peereman's (1991) data showing the influence of a particular neighbor on the pronunciation of a letter string. For example, in French, the pronunciation of the letter G always depends on the following vowel (/g/ before A, O, and U; /3/ before E, I, and Y). Despite these perfectly regular rules, participants mispronounced the letter G included in pseudowords. In addition, it was observed that errors were more frequent when the pseudowords (e.g., girnir) were orthographically similar to a word (garnir) favoring an incorrect pronunciation of the letter G.

In contrast to previous models, Seidenberg and McClelland (1989) have proposed a parallel distributed processing model in which the distinction between addressing and assembling is no longer functional. The implemented network of Seidenberg and McClelland has been challenged on several grounds. Besner, Twilley, McCann, & Seergobin (1990; see also Coltheart et al., 1993) have noticed that the simulation network performed much less successfully than did human participants on pseudowords. Although the critique was acknowledged by Seidenberg and McClelland (1990), it appeared impossible to decide whether this defect was due to the specific characteristics of the sample used to train the network, to theoretically irrelevant implementational details (such as details of representational choices, learning algorithm, etc.), or to principled features of the particular model or of the general approach. As a matter of fact, further simulation work (Plaut & McClelland, 1993) suggests that much better generalization performance can be obtained with nearly the same word sample, and a very similar modelling architecture, in which no a priori discrimination is imposed between word-specific and general knowledge.

We believe that the present findings, together with other data revealing strategic influences of list composition on naming performances, address a more general feature of the theory from which the implemented model was derived. Although the implemented network simulates both the frequency and the neighborhood size effects, it is unclear how it could handle the variation of both effects as a function of list composition. In addition to the direct mapping from orthography to phonology, Seidenberg and McClelland's (1989) general theory includes a semantic route from orthography to phonology. Because this route requires the use of two nonoverlapping sets of connections, it could be more sensitive to frequency than the orthography-to-phonology (OP) pathway. Thus, enhancing the use of the OP route (when pseudowords are included) could reduce the frequency effect. However, neighborhood size effects were simulated within the OP mapping system. Furthermore, because there is no reason to expect that similar words would activate congruent semantic features, it seems highly unlikely that the semantic pathway plays any role in the account of neighborhood effects. Consequently, Seidenberg and McClelland's (1989) theory should predict a larger neighborhood size effect when pseudowords are included. Contrary to that prediction, we observed a decrease of the neighborhood size effect in our present study.

Seidenberg and McClelland (1989) have insisted on the homogeneous division of labor among hidden units in the OP route. We have suggested as an alternative that the hidden units might attain a certain degree of specialization (Content & Peereman, 1992). If the hidden units capture relations between orthography and phonology in a manner that preserves to some extent the distinction between whole-word or large orthographic patterns and analytical or subwords patterns, then it may be possible to account for the kind of adaptive modulations observed in the present experiments. Of course, an additional modulatory mechanism (e.g., gating units, as suggested by Monsell et al., 1992) would need to be posited to account for the strategic weighing of different subpools of connections.

Given our previous findings (Content & Peereman, 1992) that the regularity and length effects increase with pseudoword fillers, it seems natural to assume that analytical correspondences are somehow enhanced in that context. If the influence of analytical associations increases relative to global associations, the resulting phonological code for exception words should deviate more from its target, and, following Seidenberg and McClelland's (1989) interpretation of the phonological error score, this increase in error should correspond to a cost in response times.

To provide an appropriate account of the variation of the neighborhood effect, one further constraint is that the units implementing the analytical knowledge should be less sensitive to neighborhood size than the orthographic and phonological units coding for the global associations. In such a distributed system, the consistency effect would be explained much as in the dual-route framework: It results from the disruptive contribution of inconsistent global, whole-word correspondences. Thus, if our interpretation is correct, the presence of pseudoword fillers would be expected to produce both a reduction of the neighborhood size facilitatory effect and a reduction of the negative influence of inconsistent word-body neighbors. The notion of specialization that we have introduced in the present study should not be taken to imply the existence of prewired structure. It is conceivable, though at present rather speculative, that specialization results from the dynamics of training and properties of the environment. For instance, if the learning algorithm rewards stability of the intermediate unit's behavior, and allows new units to be recruited during training, it is likely that older units will capture the most frequent and thus more analytical regularities, whereas younger units will be dedicated to more complex and idiosyncratic correspondences. In small scale simulations we are currently conducting, we have observed specialization patterns even though plain back-propagation was used (see also Bullinaria & Chater, 1993). Whether such natural specialization is sufficient to account for the empirical dissociations observed here and in related studies is a matter for further research.

Conclusions

In this study, we have investigated different interpretations of the role of the lexical neighborhood in naming. The findings suggest that the facilitatory effect of neighborhood size on naming latency is best interpreted as the result of the contribution of lexical candidates to the generation of phonological codes. As such, our conclusions are at odds with two classes of models of lexical access: the PDP account proposed by Seidenberg and McClelland (1989), and models based on the assumption of two independent routes to phonology (Patterson & Morton, 1985). Both kinds of theories share the notion that neighborhood effect on naming are mediated by the frequency and consistency of analytical print-to-sound associations. On the basis of the present findings, we contend conclusions that some degree of functional separation is needed between whole-word and analytical orthographic–phonological connections. We have suggested two different accounts, of which one is based on dual-route principles such that information from the two pathways is pooled in a manner allowing for differential weighting of the two contributions. The other account is a modification of the PDP model such that some degree of specialization would emerge in the hidden units mediating between orthography and phonology.

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Appendix

Stimulus List

High frequency words		Low frequency words		Pseudowords	
Large N	Small N	Large N	Small N	Large N	Small N
bon	air	coi	ode	nire	nèle
vie	eau	vis	tri	sare	eude
mot	nom	soc	nef	moie	gude
roi	art	bol	gag	mendre	lattre
sol	sud	bac	gel	dage	dède
pain	fuir	rade	joug	saie	mouc
rire	deux	raie	ogre	pien	pran
porte	corps	moule	cycle	meste	membe
salle	arbre	cotte	flair	ronte	plute
fou	nul	rot	glu	bire	blir
page	dieu	rate	daim	corte	ponre
rare	coup	cale	crue	aite	gret
soin	date	pore	laps	mide	clue
main	quoi	gale	urne	gire	elde
cave	juin	mime	glas	pibe	fède
pape	drap	tare	gril	rile	unce
sage	arme	bris	malt	falle	frout
lire	cuir	mare	seau	lure	vone
bain	nord	mite	jade	doule	birde
race	long	paie	bouc	fide	fude
aide	ivre	cane	thon	pase	prue
port	banc	taie	lest	lage	cril
lien	pied	rame	guet	lain	leue
				dare	atre
				rine	vule
				aige	arce
				rise	anle
				cate	fome
				fite	ince

Note. The letter *N* stands for neighborhood.

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