Journal of Psycholinguistic Research, Vol. 31, No. 3, May 2002 (© 2002)

Orthographic Neighbors and Visual Word Recognition

Laree A. Huntsman[1,3] and Susan D. Lima[2]

Two lexical decision experiments, using words that were selected and closely matched on several criteria associated with lexical access, provide evidence of facilitatory effects of orthographic neighborhood size and no significant evidence of inhibitory effects of orthographic neighborhood frequency on lexical access. The words used in Experiment 1 had few neighbors that were higher in frequency. In Experiment 2, the words employed had several neighbors that were higher in frequency. Both experiments showed that words possessing few neighbors evoked slower responses than those possessing many neighbors. Also, in both experiments, neighborhood size effects occurred even though words from large neighborhoods had more potentially interfering higher-frequency neighbors than words from small neighborhoods.

KEY WORDS: orthographic neighborhoods; visual word recognition; lexical access; orthographic neighborhood size; orthographic neighborhood frequency; lexical decision task.

INTRODUCTION

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Given that the average adult reader has approximately 50,000 words comprised of only 26 letters stored in lexical memory (Monsell, Doyle, &

Preparation of this report was supported in part by a California State University Research Funds Award, a California State University Lottery Funds Professional Development Award, and a San Jose State University Psychology Department Research Grant to Laree A. Huntsman. We are indebted to Jonathan Grainger for constructive comments on an earlier version of this report. We would like to thank Katherine Lemkuil, Jennifer Skinner, and Joseph Tajnai for their assistance with stimuli development, Todd Moore and Kenneth Smith for their assistance with data collection, and especially Guy Woffindin for his invaluable programming assistance.

[1] Department of Psychology, San Jose State University, San Jose, California 95192-0120, USA.

[2] Department of Psychology, University of Wisconsin-Milwaukee, P.O. Box 413, Milwaukee, Wisconsin 53201.

[3] To whom all correspondence should be mailed. email: huntsman@email.sjsu.edu

Haggard, 1989), it is logical that theories of lexical access examine the issues associated with orthographic overlap. One such measure used in investigations of visual word recognition is the classic Coltheart, Davelaar, Jonasson, and Besner's (1977) *N* metric of neighborhood size. *N* refers to the words (i.e., neighbors) that can be derived by changing one letter while maintaining letter position. For example, FACE, FAST, PACT, and TACT are neighbors of FACT. Numerous studies (Andrews, 1989, 1992, 1997; Grainger, 1990; Grainger & Jacobs, 1996; Grainger, O'Regan, Jacobs, & Segui, 1989; Grainger & Segui, 1990; Huntsman & Lima, 1996; Perea & Pollatsek, 1998) have investigated the effects of a word's orthographic neighborhood on lexical access, and two conflicting findings have emerged: the neighborhood size effect and the neighborhood frequency effect. Explanations of the neighborhood size effect assume that neighbors become activated when a neighboring word is presented that would facilitate word recognition (Andrews 1989, 1992, 1997). Therefore, words with many neighbors would be processed faster than words with few neighbors. Explanations of the neighborhood frequency effect also assume that neighbors become activated when a word is presented, but in this model, the activation from neighbors that are higher in frequency produce effects of inhibition (Grainger, 1990; Grainger & Segui, 1990; Snodgrass & Mintzer, 1993).

Neighborhood Size Effects

Coltheart, Davelaar, Jonasson, and Besner (1977) reported that neighborhood size did not affect lexical decisions to words. In contrast, other researchers have found facilitatory effects attributable to neighborhood size. For instance, Luce (1986) discovered that the identification accuracy of masked words increased as neighborhood size increased. Gunther and Greese (1985) and Scheerer (1987) reported that naming latencies to German words are faster if the words came from large as opposed to small neighborhoods. Similarly, Laxon, Coltheart, and Keating (1988) found that children were more accurate when they were naming words that had many neighbors than when they were naming words that had few neighbors.

Andrews (1989) manipulated neighborhood size and word frequency and found lexical decisions and naming latencies to low-frequency words to be influenced by neighborhood size. Responses to low-frequency words with many neighbors were faster than responses to low-frequency words with few neighbors. Responses to high-frequency words with many neighbors were not significantly faster than responses to high-frequency words with few neighbors. In 1992, Andrews responded to critics (Grainger, 1990; Grainger, O'Regan, Jacobs, & Segui, 1989; Grainger & Segui, 1990) by controlling for bigram frequency (e.g., the word DANCE is comprised of the bigrams DA, AN, NC, and CE) and replicated the 1989 findings of a neighborhood size effect for low-frequency words and a lack of effect for high-frequency words. Of interest, the stimuli used by Andrews (1989, 1992) were not matched on the frequency of words within the neighborhood. More specifically, words from small neighborhoods had, on average, 1.08 higher-frequency neighbors; whereas words from large neighborhoods had, on average, 5.44 higher-frequency neighbors. Although the large neighborhood words had more higher-frequency, potentially interfering neighbors, responses to words from large neighborhoods were faster.

Lima and Huntsman (1989) examined neighborhood size while controlling for neighborhood frequency by conducting an experiment that closely matched words on frequency, average neighborhood frequency, and frequency of the target neighbors relative to the frequencies of its neighbors. Using low-frequency words ($M = 3.11$ per million words of text) that had mostly higher-frequency neighbors, they found, as Andrews (1989, 1992) did, that lexical decision response latencies were faster for words with many neighbors than for words with few neighbors. This neighborhood size effect occurred even though the low-frequency words originated from neighborhoods where most of the neighbors were higher in frequency.

Using Andrews' stimuli (1989), Snodgrass and Mintzer (1993) employed a progressive word defragmentation technique that replaced expunged blocks of pixels that made up a word. Participants typed in their word responses as soon as they could identify the word. Facilitatory effects of neighborhood size were found, and the participants guessed less and waited longer for a clearer version before identifying words with few neighbors. However, using fixed limits of fragmentation or the speeded identification task, neighborhood size inhibited identification accuracy of low-frequency words. Snodgrass and Mintzer theorized that the gradual word clarification that was used may have encouraged the elimination of neighboring competitors as sources of interference, thus, allowing for neighborhood size effects. But when fixed levels of fragmentation were used, the high-frequency neighbors interfered with the identification process of low-frequency neighbors, thus producing inhibitory effects of neighborhood size. Snodgrass and Mintzer reasoned that if a word's neighborhood had several higher-frequency neighbors, then neighborhood size would have an inhibitory effect on lexical access. Conversely, if a word's neighborhood had few higher-frequency neighbors, then neighborhood size would have a facilitatory effect on lexical access.

Sears, Hino, and Lupker (1995) examined neighborhood size and controlled for neighborhood frequency and found that lexical decision and naming latencies were faster for low-frequency words from large neighborhoods. Furthermore, in contradiction to neighborhood frequency theories

(Grainger, 1990; Grainger *et al.,* 1989, 1992; Grainger & Segui, 1990; Snodgrass & Mintzer 1993), Sears *et al.* reported that responses were faster for words that had 1 or more higher-frequency neighbors than for words with no higher-frequency neighbors. The facilitation occurred for words from both small and large neighborhoods. However, the neighborhood size and frequency effects obtained by Sears *et al.* failed to reach significance when the data were averaged over items in four out of six of their experiments.

Forster and Shen (1996) reported the presence of facilitatory neighborhood size effects using the lexical decision task. However, when the semantic categorization task was used, these neighborhood size effects were not observed. Additionally, Forster and Shen did not observe neighborhood frequency effects in the lexical decision task but found some evidence for neighborhood frequency effects in the semantic categorization task. More specifically, inhibitory neighborhood frequency effects were found for words with one neighbor, but not for words with three or four neighbors. Their conclusion was that neighborhood size effects were mediated by task-dependent efforts as opposed to lexical access and that the inconsistent neighborhood frequency effects suggest that competition does not play a vital role in lexical access.

Neighborhood Frequency Effects

Using French words and participants, Grainger *et al.* (1989) found that lexical decision response times and gaze durations were slower for words with at least one higher-frequency neighbor then they were for words with no higher-frequency neighbors. Employing a progressive demasking technique, Grainger and Segui (1990) demonstrated that masked identification latencies for low-frequency words were slower when they had several higher-frequency words in their neighborhoods. These results were interpreted to mean that high-frequency neighbors interfere with the recognition of a neighbor that is lower in frequency. Although Grainger controlled neighborhood frequency, neighborhood size was not controlled for. An example is the Grainger *et al.* (1989) paper, where the words in the three conditions had an average of 2.2 (lower-frequency neighbors only), 2.6 (one higher-frequency neighbor), and 7.9 (several higher-frequency neighbors) neighbors. That the number of higher-frequency neighbors was manipulated, but the number of neighbors was not controlled for may call the results into question.

Huntsman and Lima (1996) controlled for neighborhood size, word frequency, word length, and number of syllables and replicated Grainger *et al.* (1989) when they detected a neighborhood frequency effect for moderate-frequency words ($M = 22$ per million words of text). They found that lexical decision responses were faster and less error-prone for words that had no, or very few, higher-frequency neighbors, compared with words that had many higher-frequency neighbors. Furthermore, responses to words with no higher-frequency neighbors were faster than responses to words with one, two, or more than two, higher-frequency neighbors.

Perea and Pollatsek (1998) controlled for neighborhood size, word frequency, and string-length and detected a neighborhood frequency effect for words that had at least one higher-frequency neighbor, compared with words that had no higher-frequency neighbor. The target words were embedded in sentences that had been matched on context, and participants' eye-movements were monitored. Results indicated that participants made more regressions and took more time reading subsequent text when the target words with higher-frequency neighbors were employed. By studying eye-movements in normal reading, the Perea and Pollatsek study provides evidence that the effects of orthographic neighborhoods are not restricted to artificial laboratory procedures.

The Present Studies

Clearly, the jury is still out on the competing roles of neighborhood size and neighborhood frequency. Jacobs and Grainger's (1992) computer-simulated response latencies within the interactive activation model (McClelland & Rumelhart, 1981) indicated that neighborhood size produced inhibitory effects for high-frequency words and a lack of facilitation for low-frequency words. However, data from Andrews (1989) and data from computer simulations within the parallel distributing processing (PDP) paradigm (Seidenberg & McClelland, 1989) demonstrated a reduction of neighborhood size effects with an increase in frequency, yet no inhibition was noted. Snodgrass and Mintzer (1993) contend that facilitatory effects of neighborhood size occur only for words with few higher-frequency neighbors, and inhibitory effects of neighborhood size occur for words with many higher-frequency neighbors. Conversely, Lima and Huntsman (1989) report facilitatory effects of neighborhood size for words that had mostly higher-frequency neighbors. Obviously, additional experimentation needs to be done to help clarify the issue of why neighborhood size and neighborhood frequency effects are not always observed and how the two effects interact. In Experiment 1, word frequency, average neighborhood frequency, word length, and the number of syllables were held constant while the number of neighbors and number of higher-frequency neighbors was varied. Experiment 2 employed the same controls used in Experiment 1 except that the words had more neighbors that were higher in frequency. In terms of frequency of the words relative to the frequency of their neighbors, words in Experiment 1 tended to be at the *top* of their neighborhoods, whereas in Experiment 2, the words tended to be in the *middle* of their neighborhoods. Thus, these experiments were designed to determine whether neighborhood size effects would persist when neighborhood frequency was altered.

EXPERIMENT 1

Experiment 1 was conducted to determine whether neighborhood size effects would occur for words that had very few, if any, higher-frequency orthographic neighbors. Therefore, one set of words, termed *large-N* words, had many words in their neighborhoods. The other set, termed *small-N* words, had few neighbors. Because neighborhood frequency theorists (Grainger, 1990; Grainger, *et al.*, 1989, 1992; Grainger & Segui, 1990; Snodgrass & Mintzer 1993) would predict effects of inhibition if words having higher-frequency neighbors were used, Experiment 1 employed words whose neighbors were mostly lower in frequency.

Method

Participants

Twenty-four university undergraduates from San Jose State University participated for course credit. All were right-handed and all were native speakers of English.

Materials

Thirty critical monomorphemic content word pairs were selected from the Kucera and Francis (1967) norms. The members of each pair were approximately matched on frequency ($M = 51.50$ per million words of text), mean frequency of words (including the base word) in the orthographic neighborhood ($M = 28.73$), number of letters ($M = 4.00$), and number of syllables ($M = 1.05$). In addition, the members of each pair differed on the number of neighbors and the number of higher-frequency neighbors. One member of a pair had many neighbors ($M = 9.83$, with a range of 8 to 13), whereas the other had few neighbors ($M = 3.97$, with a range of 2 to 6). The words from large neighborhoods had on average 1.40 higher-frequency neighbor while the words from small neighborhoods had on average .27 higher-frequency neighbors.

Membership in the neighborhood was exclusive and included only those words appearing in Kucera and Francis. For example, one pair was

SHIP and TEAM. Both have a word frequency of 83 per million, both are in neighborhoods in which the mean frequency of a member of the neighborhood is about 28.75 per million (26.50 for SHIP's neighborhood and 31.00 for TEAM's neighborhood), and both have no higher-frequency neighbors. Additionally, SHIP and TEAM are both four letters long and monosyllabic. However, SHIP has seven orthographic neighbors appearing in Kucera and Francis (i.e., CHIP, WHIP, SKIP, SLIP, SHOP, SHIN, and SHIT), whereas TEAM has only three (i.e., BEAM, SEAM, and TEAR). Characteristics of the stimulus words are summarized in Table I (see Appendix A for a complete list of stimulus words).

The 60 non-words used in the experiment were pronounceable and orthographically legal (e.g., BIPE, DEWT, LERT, NABE, TALP, VATH). The non-words exactly matched the word-pairs on length and approximately matched the word-pairs on initial letter. The non-words did not overlap in neighborhood with each other or with the words. Additionally, the non-words were not homophonic with any English word.

Design

Experimental lists consisted of the 60 experimental words plus 60 non-words. Each word and nonword was presented individually, and a different randomized presentation order was used for each participant.

Apparatus

The words and non-words were displayed one at a time in lowercase letters on a computer monitor. Letters were white and the background was black. An IBM-compatible microcomputer equipped with a World Commerce, Inc. Psycholinguistic Testing Station [computer program] controlled the experiment and recorded response latencies and error rates. A

Table I. Mean Characteristics of Stimulus Words

	Experiment 1 word type		Experiment 2 word type	
Characteristic	Large	Small	Large	Small
Number of neighbors (*N*)	9.83	3.97	10.87	3.60
Word frequency	53.00	50.00	42.50	42.50
Neighborhood frequency	28.05	29.40	40.85	40.83
Number of higher-frequency neighbors	1.40	.27	3.53	.96
Number of letters	4.00	4.00	4.00	4.00
Number of syllables	1.00	1.10	1.00	1.00

comfortable viewing distance was chosen by each participant. Stimulus strings subtended a visual angle of approximately 2 degrees. The response box contained three buttons, one for initiating trials and two for indicating lexical decision responses.

Procedure

The participants placed both hands on the response box, which had three buttons that were arranged in an inverted triangle fashion. The pacing of trials was controlled by the participant. At the start of each trial, a fixation asterisk (*) appeared at the center of the screen. To initiate a trial, the participant used both thumbs to press a button centered on the lower-half of the response box, causing the disappearance of the asterisk. The letter string appeared in the center of the screen 350 ms later and remained until the participant made his or her response. Responses were indicated by pressing one of two buttons on the upper-half of the response box with the appropriate index finger, the left-hand button for non-word responses and the right-hand button for word responses. Feedback was provided by the sound of a beep whenever an error was committed. The participants were instructed to respond as rapidly and accurately as possible.

Each participant completed 30 practice trials before proceeding to the 120 experimental trials. The practice items consisted of words and non-words not appearing elsewhere in the experiment. Upon completion, the participants were debriefed about the general nature of the experiment. The entire session required less than 30 minutes for each participant.

Data Scoring

Data from any trial that resulted in an error were eliminated from the response time analyses. The occasional extremely long response times (i.e., those more than 2.5 standard deviations greater than the subject's mean for that type of trial) were replaced by the cutoff value of 2.5 standard deviation units plus the subject's mean for that trial type. Data sets for participants and for stimulus items were computed from the response latency and error rate data. In the subject analysis (t_1), two data sets were formed by computing mean response latencies and error rates over stimulus items for each participant. In the item analysis (t_2), two data sets were formed by computing mean response latencies and error rates over participants for each stimulus item.

Results and Discussion

The results indicated that words such as SHIP (large-neighborhood words) yielded faster responses than words such as TEAM (small-neighborhood words). The mean response latencies were 749 ms for *large-N* words and 777 ms for *small-N* words. The 28-ms difference was significant by subjects ($t_1(23) = 4.65$, $p < .001$) and by items ($t_2(29) = 2.25$, $p < .05$). The mean error rate was 3.47% for *large-N* words and 3.75% for *small-N* words. While in the predicted direction, the 0.28% difference was not significant by subjects ($t_1 < 1$) or items ($t_2 < 1$).

The results of Experiment 1 demonstrate that neighborhood size is a determinant of lexical decision performance. Words with many neighbors yielded faster lexical decision responses than words with few neighbors when frequency, average neighborhood frequency, and frequency relative to the frequencies of other neighbors are controlled for. This suggests that a range of orthographically similar lexical representations is activated prior to selection of the correct lexical representation. Significant neighborhood size effects were not apparent in the error rate data, however. Nevertheless, in resect to the response latencies, these findings join others in suggesting that word recognition is sensitive to neighborhood size (Andrews, 1989, 1992, 1997; Goldinger, Luce, & Pisoni, 1989; Gunther & Greese, 1985; Laxon, Coltheart, & Keating, 1988; Lima & Huntsman, 1989; Luce, 1986; Luce, Pisoni, & Goldinger, 1990; Scheerer, 1987; Sears *et al.,* 1995).

EXPERIMENT 2

The purpose of Experiment 2 was to determine whether neighborhood size effects generalize to another experiment employing a more stringent test. As described in the Introduction, Grainger and colleagues (1990; Grainger *et al.,* 1989, 1992; Grainger & Segui, 1990), posit that word recognition is not affected by neighborhood size, but instead is affected by the frequency of the neighbors. Because Experiment 1 employed words that tended to be at the *top* of their neighborhoods in terms of frequency relative to the frequency of other neighbors, it is possible that neighborhood size effects occurred because the frequency of the neighbors were lower. For this reason, Experiment 2 was designed to test the possibility that neighborhood size effects might disappear if words that are not among the highest in frequency in their neighborhoods were used. Consequently, Experiment 2 employs words that tended to be in the *middle* of their neighborhoods in terms of frequency relative to the frequencies of other neighbors. If high-frequency neighbors inhibit low-frequency neighbors, then neighborhood size effects would be obscured by the interference created by the high-frequency neighbors.

Method

Participants

Twenty-four university undergraduates from San Jose State University participated for course credit. All were right-handed native speakers of English. None had participated in Experiment 1.

Materials

Thirty critical word pairs were selected from Kucera and Francis (1967). As in Experiment 1, the members of each pair were approximately matched on frequency ($M = 42.50$), mean frequency of words in the orthographic neighborhood ($M = 40.84$), word length ($M = 4.00$ letters), and number of syllables ($M = 1.00$). Again, the members of each pair differed on the number of neighbors and number of higher-frequency neighbors. One member of a pair had many neighbors ($M = 10.87$, ranging from 8 to 15), and the other had few neighbors ($M = 3.60$, ranging from 2 to 5). The words from large neighborhoods, in Experiment 2, had more higher-frequency neighbors ($M = 3.53$) than the large neighborhood words used in Experiment 1 ($M = 1.40$). In Experiment 2, the words with many neighbors had on average 3.53 neighbors, whereas the words with few neighbors had on average .96 neighbors. The important characteristics of the stimulus words are summarized in Table I (see Appendix B for a complete list of the stimulus words). Like Experiment 1, 60 non-words were used in Experiment 2.

Design, Apparatus, Procedure, and Data Scoring

The design, apparatus, procedure, and method of scoring the data were the same as those used in Experiment 1.

Results and Discussion

As in Experiment 1, it was found that large-neighborhood words yielded faster responses than small-neighborhood words. The mean response latencies were 735 ms for *large-N* words and 778 ms for *small-N* words. The 43-ms difference was significant by subjects ($t_1(23) = 5.86$, $p <$ .001) and by items ($t_2(29) = 2.65$, $p < .02$).

An analysis of the error rate data revealed the same pattern as observed in the reaction time data. The mean error rate was 5.00% for *large-N* words and 9.03% for *small-N* words. The 4.03% difference was significant by subjects $t_1(23) = 3.57$, $p < .001$) and by items ($t_2(29) = 2.10$, $p < .05$).

The results of Experiment 2 are in the opposite direction to that predicted by Grainger's hypothesized inhibition from higher-frequency neighbors. Neighborhood size effects occurred in Experiment 2 even though the words were not among the highest in frequency in their neighborhoods.

Combined Analyses

One way to unravel the competing roles of neighborhood size and neighborhood frequency effects is to combine the results of both experiments into a 2 (neighborhood size: large and small) × 2 (neighborhood frequency: top and middle) analysis of variance. Specifically, a post-hoc analysis was conducted to determine whether the neighborhood size effects observed in the experiments would differ for the top-position words used in Experiment 1 and the middle-position words used in Experiment 2.

The combined mean response latencies for both experiments as a function of neighborhood size and neighborhood frequency are presented in Fig. 1. The combined mean response latency as a function of neighborhood size was 742 ms for *large-N* words and 778 ms for *small-N* words. The 37-ms difference was significant by subjects, $F_1(1,69) = 67.43$, $p < .01$ and by items, $F_2(1,87) = 4.19$, $p < .05$. The combined mean response latency as a function of neighborhood frequency was 763 ms for *top* words and 757 ms for *middle* words. The 6-ms difference was not significant by subjects, $F_1 < 1$ nor by items, $F_2(1,87) = 1.31$, $p > .05$.

The interaction between neighborhood size and neighborhood frequency was not significant in the response time data by subjects, $F_1 < 1$ nor by items, $F_2(1,87) = 2.73$, $p > .05$. This indicates that the 15-ms difference in neighborhood size effects observed between the experiments are not sig-

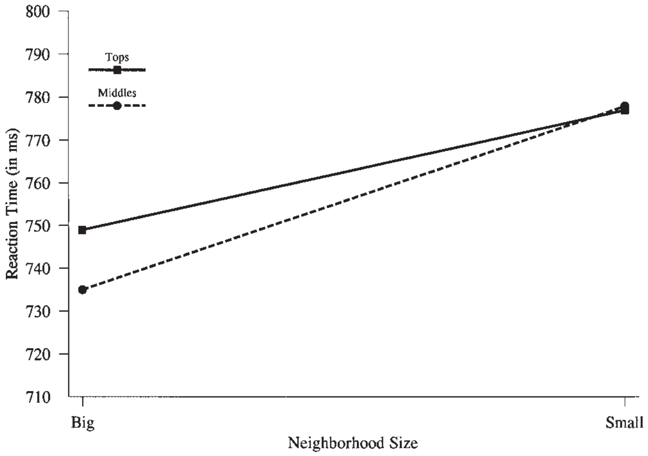

Fig. 1. The combined mean response latencies for Experiments 1 and 2 as a function of neighborhood size and neighborhood frequency.

nificantly different for words that are at the top or the middle of their neighborhoods in terms of frequency relative to the frequencies of their neighbors. Although not significant, the pattern of results is in the opposite direction to that found by Grainger and colleagues (1990; Grainger *et al.*, 1989, 1992; Grainger & Segui, 1990) and Huntsman and Lima (1996), who reported inhibition from higher-frequency neighbors in their studies. The results of the current effort indicate that *large-N* words from the *middle* of their neighborhoods (735 ms) were 14 ms faster even though they had more potentially interfering higher-frequency neighbors than *large-N* words from the *top* of their neighborhoods (749 ms). The *small-N* words differed by only 1 ms, depending on whether they came from the *top* (777 ms) or *middle* (778 ms) of their neighborhoods. Perhaps words residing beneath many higher-frequency neighbors (i.e., *bottoms*) are inhibited by the lexical representations of these neighbors, whereas words residing above lower-frequency neighbors (i.e., *tops* and *middles*) are not.

The combined mean error rate as a function of size was 4.24% for *large-N* words and 6.39% for *small-N* words. The 2.15% difference was significant by subjects, $F_1(1,69) = 8.78$, $p < .01$ and by items $F_2(1,87) = 4.91$, $p < .05$. The combined mean error rate for neighborhood frequency was 3.61% for *top* words and 7.02% for *middle* words. The 3.41% difference was significant by subjects, $F_1(1,69) = 12.71$, $p < .01$ but not by items, $F_2(1,87) = 2.23$, $p > .05$. The interaction between neighborhood size and neighborhood frequency was significant in the error rate data by subjects, $F_1(1,69) = 6.32$, $p < .05$ but not by items, $F_2(1,87) = 1.76$, $p < .05$. Although not significant by items, for error rates the pattern of results is in the same direction as other studies reporting inhibition from higher-frequency neighbors (Grainger, 1990; Grainger *et al.*, 1989, 1992; Grainger & Segui, 1990; Huntsman & Lima, 1996).

Additionally, the interaction between neighborhood size and neighborhood frequency was not significant in the response time data by subjects, or by items, and the interaction between neighborhood size and neighborhood frequency was significant in the error rate data by subjects only.

GENERAL DISCUSSION

The results of the experiments provide clear evidence of facilitatory effects of neighborhood size without significant evidence of inhibitory effects of neighborhood frequency. The results of Experiments 1 and 2 indicate that when word frequency, average neighborhood frequency, word length, and number of syllables are held constant, neighborhood size effects are apparent. If there are few neighbors, then lexical access is slowed. In both experiments, the words from large neighborhoods tended to have more higher-frequency neighbors than the words from small neighborhoods, but the words from large neighborhoods were nonetheless responded to more quickly. These findings support past findings of neighborhood size effects using the lexical decision task (Andrews, 1989, 1992, 1997; Lima & Huntsman, 1989; Sears *et al.*, 1995). However, because inhibitory as opposed to facilitatory effects of neighborhood size have been found using perceptual identification type paradigms such as progressive demasking (Grainger & Segui, 1990) and progressive defragmentation (Snodgrass & Mintzer, 1993), it has been suggested that lexical decision response times may be influenced by task-dependent processes not associated with lexical access (Besner & McCann, 1987; Forster & Shen, 1996). But is it not also possible that sophisticated guessing strategies influence the perceptual identification task? Concerned with these issues, researchers (Andrews, 1989; Forster & Shen, 1996; Sears, *et al.* 1995) have varied the difficulty of the word–non-word discrimination by manipulating the neighborhood size of the non-words (i.e., how many words that can be created by changing one letter of the non-word) or by using non-words that were hard to pronounce or that contained illegal letter clusters (e.g., TYMB, NAUR, HIEF, YABT). The results from these studies demonstrate that neighborhood size effects for lexical decision response latencies to words occur regardless of whether non-words with large neighborhoods (i.e., more word-like) or non-words with small neighborhoods (i.e., less word-like) are used. However, neighborhood size effects appear to be stronger when the word–non-word discrimination task is make easier by using less word-like non-words.

The results of the current effort also converge with those of previous investigations of word recognition coming from a variety of theoretical and empirical approaches (Andrews, 1989, 1992, 1997; Goldinger *et al.*, 1989; Gunther & Greese, 1985; Laxon, *et al.*, 1988; Lima & Inhoff, 1985; Luce, 1986; Luce *et al.*, 1990; Marslen-Wilson & Welsh, 1978). For example, facilitatory effects of neighborhood size have been reported by researchers using the naming (Andrews, 1989, 1992; Sears *et al.*, 1995), masked naming (Luce, 1986), and children’s naming (Gunther & Greese, 1985; Laxon *et al.*, 1988) tasks. Interestingly, increasing neighborhood size appears to produce inhibitory effects in speech perception. According to the cohort model of speech perception (Marslen-Wilson & Welsh, 1978), the initial few phonemes of a word activates a cohort set in the lexicon. This cohort set or “neighbors” contains a representation for all words that begin with the phonemes that are currently available. The point of recognition occurs when only one candidate in the cohort that uniquely specifies the input word remains. Marslen-Wilson and Welsh (1978) found that for some words, recognition occurs before the full word is presented. Specifically, they determined word recognition to be affected by uniqueness points; the more cohorts that were activated by the speech input, the longer it took the participants to perceive the speech input. Similarly, neighborhood size effects have also been investigated under the context of phonetic neighborhoods in auditory word recognition (Goldinger, *et al.,* 1989; Luce, 1986; Luce *et al.,* 1990).

Speech researchers have reported that an increase in phonetically similar neighbors is associated with a corresponding increase in reaction time and error rates for the auditory word naming and auditory lexical decision tasks. The evidence indicates that neighborhood size may produce opposite effects in reading and speech research. Lexical access processes involved in naming and making lexical decisions to visually presented stimuli appear to be facilitated by orthographic neighbors (Andrews 1989, 1992, 1997; Gunther & Greese, 1985; Laxon *et al.*, 1988; Luce, 1986). However, lexical access processes involved in word naming and making lexical decisions to auditory stimuli appear to be inhibited by phonetically similar neighbors (Goldinger *et al.*, 1989; Luce 1986; Luce *et al.*, 1990). Apparently, orthographic overlap among words gives lexical access a boost during reading; however, in hearing, phonological overlap among sounds results in confusion.

The present results also converge with the results of eye movement research. Lima and Inhoff (1985) visually presented words that were embedded in sentence contexts. The critical words varied in the degree of constraint provided by the first three letters of the words. For example, DWARF is a high-constraint word because DWA produces very few word candidates. Conversely, CLOWN is a low-constraint word because CLO produces many possible candidates (e.g., CLONE, CLOSE, CLOUD, and CLODS). Because word initial information has been found to be important in reading (Lima & Pollatsek, 1983), and if constraint influences lexical access in a fashion similar to speech perception, then it would be reasonable to expect monitored eye movements reflecting foveal fixations on the high-constraint words to be shorter than fixations on the low-constraint words. Results revealed that the opposite effect occurred. Even though the recognition point in DWARF occurs earlier than the recognition point in CLOWN, high-constraint items such as DWARF led to longer foveal fixations than low-constraint words such as CLOWN. The finding that words with many possible candidates receive shorter fixations converges with the findings of the present effort that words from large neighborhoods were responded to faster in the lexical decision task.

The facilitatory nature of the neighborhood size effect provides support for the view that lexical access relies on an interactive activation mechanism (Coltheart & Rastle, 1994; McClelland & Rumelhart, 1981; Rumelhart &

McClelland, 1982; Seidenberg & McClelland, 1989) as opposed to a serial search mechanism (Forster, 1976, 1989; Rubenstein, Garfield, & Millikan, 1970) that is sensitive to word frequency. An activation-verification mechanism relying on bottom-up activation that occurs from the letter to the word level (Becker, 1976, 1980; Jacobs & Grainger, 1992; Paap, Newsome, McDonald, & Schvaneveldt, 1982; Paap, McDonald, Schvaneveldt, & Noel, 1987) would predict inhibitory effects of neighborhood size as a result of the competition among neighbors receiving bottom-up activation from shared letters. Apparently, only an interactive activation mechanism relying on top-down activation that occurs from candidate words to the letter level (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) or a parallel distributed processing mechanism (Seidenberg & McClelland, 1989) relying on shared patterns of activity among lexical representations can account for neighborhood size effects.

APPENDIX A

Experiment 1 Stimulus Words

Large-*N* words	Small-*N* words
pope	trap
rank	auto
code	self
bond	coat
barn	fish
star	diet
whip	flag
lamp	scan
boss	palm
bath	fuel
buck	clue
tire	ease
tool	stem
pull	draw
wash	glad
moon	golf
feel	play
skin	soul
ship	team
safe	quit
food	baby
rush	loud
corn	tree
harm	join
gang	pulp

page	camp
flow	town
nice	plus
wing	chew
call	walk

APPENDIX B

Experiment 2 Stimulus Words

Large-*N* words	Small-*N* words
food	club
pull	draw
wash	glad
feel	kept
pick	goal
ship	team
flow	desk
pink	huge
pump	plea
lark	wisp
punk	blob
sage	yelp
slop	veer
rare	coat
mall	turf
slam	pimp
vine	helm
mink	pulp
hark	lewd
corn	golf
fool	self
rush	nude
bond	shut
sing	folk
luck	inch
flew	bomb
safe	fund
boat	plus
hole	join
moon	drop

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