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Effects of rhyming neighborhood structure on lexical access

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EFFECTS OF RHYMING NEIGHBORHOOD STRUCTURE ON LEXICAL ACCESS

A Thesis

Presented to

the Faculty of the Department of Psychology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Nicole C. Carroll

December, 1997

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ABSTRACT

EFFECTS OF RHYMING ORTHOGRAPHIC NEIGHBORHOOD STRUCTURE ON LEXICAL ACCESS

by Nicole C. Carroll

This experiment investigated phonetic and orthographic similarity effects on lexical access of printed material, using the lexical decision task. The number of higher-frequency rhyming orthographic neighbors was varied, whereas word frequency, average orthographic neighborhood size, average orthographic neighborhood frequency, number of higher-frequency orthographic neighbors, and average number of rhyming orthographic neighbors were held constant. Response times and accuracy rates for words with several higher-frequency rhyming orthographic neighbors were not significantly faster nor more accurate than responses for words with few higher-frequency rhyming orthographic neighbors; although data were in this direction. Results were inconsistent with the predicted interference effect of neighborhood frequency of serial search, activation-verification and some versions of an interactive-activation model. Results also failed to support a facilitation effect of neighborhood density as predicted by interactive-activation models and a parallel-distributed processing model, although data were in this direction.

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Effects of Rhyming Neighborhood Structure on Lexical Access

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Abstract

This experiment investigated phonetic and orthographic similarity effects on lexical access of printed material, using the lexical decision task. The number of higher-frequency rhyming orthographic neighbors was varied, whereas word frequency, average orthographic neighborhood size, average orthographic neighborhood frequency, number of higher-frequency orthographic neighbors, and average number of rhyming orthographic neighbors were held constant. Response times and accuracy rates for words with several higher-frequency rhyming orthographic neighbors were not significantly faster nor more accurate than responses for words with few higher-frequency rhyming orthographic neighbors; although data were in this direction. Results were inconsistent with the predicted interference effect of neighborhood frequency of serial search, activation-verification and some versions of an interactive-activation model. Results also failed to support a facilitation effect of neighborhood density as predicted by interactive-activation models and a parallel-distributed processing model, although data were in this direction

Effects of Rhyming Neighborhood Structure on Lexical Access

In reading research, specifically within the study of visual word recognition, the mental lexicon is the most fundamental component of study. The mental lexicon is defined as a basic unit of long-term memory in which information regarding a word's semantic (meaning), orthographic (visual), and phonological (sound) properties are coded, as well as a word's relationship to other words (Perfetti, 1985). The mental lexicon contains word knowledge of the most basic nature, such as graphemic (how it looks) and phonemic (how it sounds) feature and letter identification, as well as complex knowledge of word meaning. Theories vary in describing exactly how word knowledge is stored, accessed, organized, and integrated. However, most acknowledge the interactive process involved in the eventual ability to read. Lexical access can be defined as the process by which a given word's representation becomes activated within the mental lexicon. One major objective for any model of visual word recognition is to accurately delineate the nature of the mechanisms that govern lexical access.

An ongoing source of debate within the study of the psychology of reading has focused on specifying the relative significance of visual and phonological information during lexical access. The central question is whether activation of a word in memory occurs on the basis of phonological coding (how it sounds) or visual coding (how it looks). Some theorists take the position that information from both sources may be simultaneously activated in an interrelated, mutually-supportive process preceding lexical access (Glushko, 1979; McClelland & Rumelhart, 1981; Perfetti, 1985; Van Orden, 1987).

Others assume lexical access occurs based primarily on one source or the other. Direct-access theorists specify that a word's representation in memory is immediately identified by the visual input from printed material, without any additional information (e.g., phonological coding) required to access the internal lexicon (Baron, 1973; Bower, 1970; Forster & Chambers, 1973; Frederiksen & Kroll, 1976; Goodman, 1969; Green & Shallice, 1976; Kolars, 1970; Martin & Jensen, 1988). According to these theories, direct decoding of graphic input is the sole source of activation that precedes word identification.

Proponents of the phonological mediation hypothesis assume that some type of grapheme-to-phoneme conversion process occurs prior to lexical access (Bloomfield, 1942; Corcoran, 1966; Gibson, 1970; Gough, 1972; Hansen & Rodgers, 1968; Hillinger, 1980; Rubenstein, Lewis, & Rubenstein, 1971). Word identification is thought to occur by transforming spelling to sound and linking sound to meaning. The phonological mediation hypothesis has been criticized on the basis of the increased time of recoding required for word identification. However, models integrating a phonological component have intuitive appeal when one considers the efficacy of linking visual forms of words to phonological forms so as to exploit word memory established by speaking and hearing (Lukatela & Turvey, 1994).

Dual-access theories, introduced by Coltheart (1978), assume both orthographic and phonological sources of lexical activation. The critical question for these theories is in explaining the exact nature of collaboration between these processes and the relative time

frame in which activation of each occurs. Traditionally, phonological recoding (the process of transforming the visual representation of a word to a sound-based representation before a word can be identified) is assumed to be too slow for accessing familiar words, and its relative influence in skilled reading is assumed to be minimal (Bauer & Stanovich, 1980; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Stanovich & Bauer, 1978). Therefore, primary emphasis is placed on the visual route to lexical access (Coltheart, 1978; McCusker, Hillinger, & Bias, 1981; Seidenberg, 1985; Seidenberg, et. al., 1984; Waters, Seidenberg, & Bruck, 1984). However, other dual-access theorists propose simultaneous coding of both visual and phonological information prior to lexical access, such that activation of both kinds of word knowledge occurs directly from the stimulus in word identification (McClelland & Rumelhart, 1981; Perfetti, 1985; Van Orden, 1987). These theorists suggest that letter strings are identified by integration of parallel activation of orthographic and phonological knowledge from a number of sources in memory (Glushko, 1979).

Orthographic Neighborhood Structure

Visual factors have been a central area of study within the psychology of reading literature. Several studies within the orthographic neighborhood paradigm have focused on investigating the effects of visually similar words on recognition. Coltheart, Davelaar, Jonasson, and Besner (1977) first raised this consideration in proposing the N-metric to quantify neighborhood density. This frequently-used construct is operationally defined as the number of words that are created by changing one letter of a given letter string with

perseverance of position (e.g., NEXT has four neighbors: TEXT, NEAT, NEST and NEWT). Within this paradigm it is assumed a word's neighborhood will affect lexical access. Results of investigations of the effects of neighborhood structure have been mixed and are still unresolved. Since the initial Coltheart et al. (1977) study, in which no significant effect of neighborhood density (number of orthographically similar words) on lexical decision times was found for words, the debate has evolved to a question of whether it is neighborhood density (number of orthographically similar words) or relative neighborhood frequency (frequencies of orthographically similar words) that influences lexical access of a given word. While neighborhood density refers to the number of words which are orthographically similar to a target word; neighborhood frequency refers to the frequency of occurrence of those words which are orthographically similar to the target word. Words of higher frequency of occurrence are used more often in a given language and are therefore activated more often in memory. The frequency of a given word is operationally defined by Kucera and Francis (1967) as the number of times a given word occurs in written English per one million words.

In research by Grainger and colleagues (Grainger, 1990; Grainger, O'Regan, Jacobs, & Segui, 1989, 1992; Grainger & Segui, 1990) an inhibitory neighborhood frequency effect has been demonstrated. These investigators found lexical decision times and eye gaze durations were adversely affected by the existence of at least one higher-frequency neighbor; this indicates that neighborhood frequency, rather than neighborhood density, is the critical variable in lexical access. Huntsman and Lima (1996) reported similar results,

demonstrating an interference effect of neighborhood frequency. When a word is at or near the top of its neighborhood in terms of frequency, it is relatively unaffected by the existence of neighbor candidates, as assessed by lexical decision response times.

Conversely, when a word of the same frequency is at or near the bottom of its neighborhood in terms of frequency, it is adversely affected by the existence of neighbor candidates. More specifically, lexical decision response times are delayed and less accurate for words at or near the bottom of the neighborhood than for words at or near the top of the neighborhood; theoretically this is due to the interference created by the presence of higher-frequency neighbors. These findings may be explained by serial search and activation-verification models, which assume a frequency-ordered sequential search process within the mental lexicon, or by an activation model, which assumes mutual inhibition among competing word nodes within the mental lexicon. The three models predict that the activation of higher-frequency neighbors will interfere with the activation of the correct lexical entry; either by creating interruptions in the search process (serial search and activation-verification models), or by direct inhibitory feedback (activation models).

Very different findings have been reported by other researchers. Several studies (Andrews, 1989, 1992; Forster & Shen, 1996; Laxon, Coltheart, & Keating, 1988) have reported facilitatory effects of neighborhood density on lexical decision, word naming, and delayed word naming times and accuracy rates. Words with many neighbors were accessed faster and more accurately than words with few neighbors, regardless of

neighborhood frequency. These studies stand in sharp contrast to the interference effect of neighborhood frequency reported by Grainger and colleagues. Forster and Shen (1996) found a reliable facilitatory effect for neighborhood density using low frequency words in the lexical decision task. For each level of neighborhood density ($N=0$ to $N=5$), words with higher-frequency neighbors were directly compared to words without higher-frequency neighbors. The proposed inhibitory effect of higher-frequency neighbors was not observed. Words with one or more higher-frequency neighbors were responded to faster and more accurately than words without higher-frequency neighbors, whether the neighborhood consisted of one neighbor or three to four neighbors. Contrary to the observed interference effect of neighborhood frequency, this facilitatory effect of neighborhood density cannot be explained by search models, which predict that the existence of many orthographically similar candidates would slow lexical access due to more interruptions in the search process before the correct lexical entry can be identified. Activation models which propose excitatory links between word and letter unit levels, provide an account for this facilitatory effect of neighborhood density. While it has been clearly demonstrated that factors such as neighborhood density and neighborhood frequency affect lexical access, the question of how orthographic similarity affects lexical access remains.

Phonological Similarity Effects

Phonological similarity has also been shown to affect lexical access. Myer, Schvaneveldt, and Ruddy (1974) reported facilitation effects in a lexical decision task

when word pairs were both orthographically and phonologically similar (POUCH-COUCH), whereas they showed interference when word pairs were orthographically similar but phonologically dissimilar (TOUCH-COUCH), suggesting that participants access both orthographic and phonological codes in visual word recognition. Others have reported facilitatory rhyming orthographic neighborhood density (NR-metric) effects on lexical decision performance (Huntsman, Lockhart, & Lima, 1995). The NR of letter string is defined as the number of rhyming words that are created by changing one letter with perseverance of position. For example, the stimulus item HEAP has seven orthographic neighbors: REAP, LEAP, HELP, HEAD, HEAL, HEAR, and HEAT. Of these, REAP and LEAP rhyme with the stimulus. With orthographic neighborhood density controlled, response latencies were faster for words having many orthographic rhyming neighbors than for words with few orthographic rhyming neighbors, demonstrating that phonological similarity facilitated word recognition using both low and high frequency words as stimuli.

In research investigating effects of phonological similarity on word recognition with words presented verbally, similarity has been reported to have inhibitory effects (Luce, Pisoni, & Goldinger, 1990). Similarity neighborhoods, in auditory word recognition, are defined as words that share phonetic characteristics. For example, BAD has a phonetic transcription b`@d and BACK has a phonetic transcription b`@k. These words are phonetically similar except for the last sound d versus k. Words with large similarity neighborhoods were more poorly recognized than words with small similarity

neighborhoods. That is, the existence of many neighbors which share similar phonetic characteristics interfered with recognition of auditorily presented stimulus words. These results contradict findings reported within the orthographic neighborhood paradigm with visually presented phonetically similar items, however. In a study by Tanenhaus, Flanigan, and Seidenberg (1989) using a discrete-trials color-naming (Stroop) paradigm, orthographic and phonological similarity of prime-target pairs was varied in both auditory and visual presentation conditions. Color-naming latencies were longer when the primes and targets were orthographically and/or phonologically similar than when they were unrelated. Priming, usually attributed to automatic processing, by orthographically and/or phonologically similar words interfered with color-naming. Encoding of target words was facilitated due to orthographic and/or phonological similarity, yielding greater color-naming interference whether primes were presented visually or auditorily. These results suggest that word recognition entails activation of multiple codes and priming of orthographically similar and phonetically similar words.

The above studies suggest that orthographic and phonological codes for a word are closely integrated within the mental lexicon and that any theoretical model of lexical access must seek to explain the nature of the collaboration of the two coding processes. According to the connectionistic parallel distributed processing model (Seidenberg & McClelland, 1989), a word is represented by connected patterns of activity across a set of distributed features (orthographic, phonological, and semantic) that are shared by similar lexical representations. The correct lexical entry is accessed as the activation pattern

across several levels of features stabilizes, resulting in a pattern that uniquely identifies the stimulus word. Activation of the target node may be strengthened by partial activation of representations of similar words via phonemically coded features, as well as orthographically coded features. Similarly, an assumption of the interactive-activation model (McClelland & Rumelhart, 1981) is that partial activation of the representations of neighbors of a target boosts the activation of the target node and strengthens target activation. Both of these models predict that word recognition of target items with higher-frequency neighbors would be facilitated by the partial activation of those similar representations.

In contrast, serial search and activation-verification models predict that the presence of higher-frequency similar neighbors causes interference in lexical access. According to these models, lexical access involves a series of comparisons between the sensory representation of a target word and the mental representation of words in lexical memory (Forster & Chambers, 1973). Target word identification occurs once a match has been found between the two word representations. Frequency is assumed to determine the order in which lexical entries are searched. Therefore, higher-frequency word representations would be compared with sensory information before lower-frequency word representations, and would be identified earlier in the search process. Identification of target items with many neighbors or with neighbors of higher frequency would be delayed due to more interruptions in the search process from incorrect matches. Sequential search models predict neighborhood density and

frequency to adversely affect recognition of lower frequency stimulus items. Thus, word recognition would be inhibited for target items with many similar neighbors and words with higher-frequency neighbors.

The purpose of this study is to examine the influence of neighborhood frequency effects among words that are phonetically similar as well as orthographically similar. In particular, rhyming neighborhood frequency will be varied while rhyming neighborhood density will remain constant. Word stimuli will differ only in terms of their relative rhyming neighborhood frequency (number of higher-frequency rhyming neighbors) but will share the same number of rhyming neighbors. Word frequency, orthographic neighborhood density and frequency, and word length will be similar for all stimuli. The basic question to be investigated is whether the presence of higher frequency rhyming neighbors facilitates or interferes with lexical access of a given word. The predicted outcome is based on the theoretical standpoint of the interactive-activation model and the parallel-distributed-processing model, in which perceptual processing is assumed to be an interactive process with information (both phonetic and orthographic) from several levels of processing integrated simultaneously. It is proposed that the presence of higher-frequency rhyming neighbors will facilitate rather than inhibit lexical access. Specifically, it is predicted that words at or near the bottom of their rhyming neighborhood, benefiting from the partial activation of higher-frequency rhyming neighbors, will have faster and more accurate lexical decision times than words at or near the top of their rhyming neighborhood.

In contrast, serial search models challenge this position, predicting that the presence of higher-frequency orthographically and phonologically similar words will interfere with lexical access of target words. These models outline frequency-based, sequential processing at the word level with lexical representations in memory being compared with sensory information. Within this theoretical framework, recognition of words at the bottom of the rhyming neighborhood would be adversely affected by the activation of higher-frequency similar words, with slower lexical decision response times than words at the top of the rhyming neighborhood.

Method

Participants

Twenty-four university undergraduate students from San Jose State University participated in the study for course credit. All participants were right-handed native speakers of English.

Materials

Stimuli consisted of twenty-three critical word pairs selected from Kucera and Francis (1967). The members of each pair were matched on word frequency, number of orthographic neighbors, orthographic neighborhood frequency, number of higher-frequency orthographic neighbors, number of rhyming neighbors, and word length. However, the members of each pair differed in the number of higher-frequency rhyming neighbors. One member of each pair was one of the highest frequency rhymes in the neighborhood (top-rhyme), whereas the other member was one of the lowest frequency

rhymes in the neighborhood (bottom-rhyme). For one member of each pair, the rhyming neighborhood consisted of words lower in frequency than the stimulus item, whereas for the other member, the rhyming neighborhood consisted of words higher in frequency than the stimulus item. For example, **HEAP** and **KICK** have frequencies of approximately 15 per million, have at least seven neighbors, were fifth highest in frequency compared to their orthographic neighbors, and are four letters in length. They differ in that **HEAP** has no rhyming neighbor of higher frequency, **KICK** has four rhyming neighbors of higher frequency. More specifically, **HEAP** has seven neighbors: **REAP**, **LEAP**, **HELP**, **HEAD**, **HEAL**, **HEAR**, **HEAT**. Of these neighbors two rhyme with **HEAP** (**REAP** and **LEAP**); neither have a higher frequency of occurrence than **HEAP**. Alternately, **KICK** has ten neighbors: **DICK**, **HICK**, **LICK**, **NICK**, **PICK**, **SICK**, **TICK**, **WICK**, **KIRK**. Of these neighbors, four of the rhyming neighbors (**DICK**, **NICK**, **PICK**, and **SICK**) have a higher frequency of occurrence than **KICK**. Important characteristics of stimulus words are summarized in Table 1. All words were four letters in length. The mean frequency of occurrence of stimulus words was 18.68 per million, with a range from 6 to 26 per million. The average neighborhood consisted of nine neighbors, with a range from 4 to 14. The mean frequency of words in a neighborhood was 44.80 per million. The average number of rhyming neighbors in both conditions was approximately four, with a range from one to eight. In the top-rhyme condition, stimuli had a mean of .59 rhyming neighbors of higher frequency, whereas stimuli in the bottom-rhyme condition had an average of 2.26 higher-frequency rhyming neighbors. The rhyming neighbors of stimulus items in the top-rhyme

Table 1

Important Characteristics of Stimulus Words

Characteristic	Type of Word	
	top-rhyme	bottom-rhyme
Word length	4	4
Word frequency (mean)	18.04	19.35
Number of neighbors (<u>N</u>)	8.91	9.04
Mean frequency of neighborhood	45.90	43.71
Number of higher frequency neighbors	3.87	4.43
Number of rhyming neighbors (<u>NR</u>)	3.52	4.04
Mean frequency of rhyming neighbors	9.15	58.95
Number of higher frequency rhyming neighbors	.59	2.26

condition had a mean frequency of 9.15 per million, while rhyming neighbors of stimulus items in the bottom-rhyme condition had a mean frequency of 58.95 per million. Refer to the Appendix for a list of all stimulus words.

Design

Each stimulus list contained forty-six experimental words and an equal number of orthographically legal pronounceable nonwords. All nonwords were generated following grapheme-to-phoneme correspondence rules of standard English and all were four letters in length. Each participant viewed all items in a different randomized presentation order. The experimental pairs did not overlap in neighborhood with each other or with the nonwords.

Apparatus

Stimulus strings were displayed individually in lower-case letters on a computer monitor attached to an IBM-compatible microcomputer which recorded response latencies and error data. Letters were white against a black background. Each participant chose a comfortable viewing distance, with stimulus strings subtending a visual angle of approximately two degrees. A response box with three buttons was used for initiating trials and indication of lexical decision response.

Procedure

The lexical decision task was used. Participants identified each stimulus item individually as a word or nonword. Trials were self-paced. Each trial began with a fixation asterisk (*) appearing on the center of the screen. Participants pressed a button

on the bottom half of a response box with both thumbs to initiate each trial. This caused the asterisk to disappear and 350 milliseconds later a letter string appeared on the center of the screen and remained there until the participant made a word/nonword response. Participants used a left-hand button on the upper portion of the response box to indicate a nonword response, or the corresponding right hand button to indicate a word response. Auditory feedback in the form of a beep was immediately provided to indicate errors. Participants were asked to respond as quickly and accurately as possible. Each participant completed 30 practice trials prior to the 92 experimental trials. Practice items did not appear elsewhere in the experiment. Each session was completed in less than 30 minutes.

Results

Two separate data sets were computed from response latency and error rate data for analysis by participants and by stimulus items. Exceptionally long response times (those longer than 2.5 standard deviations greater than participant's mean for that type of trial) were replaced by a cutoff value of 2.5 units of standard deviations plus the participants mean for that trial type. For the participant analysis (t_1), two data sets were formed by computing mean response times and error rates for each participant over all stimulus items. For the item analysis (t_2), two sets of data were formed by computing mean response times and error rates for each stimulus item over all participants. Mean participant and item response latencies and error rates for stimulus words are presented in Table 2.

To investigate whether rhyming neighborhood position affects speed and accuracy of

Table 2

Mean Response Latencies (in milliseconds) and Percent Errors for words as a function of Position in the Rhyming Neighborhood

	Rhyming Neighborhood Position	
	Top-Rhymes	Bottom-Rhymes
Analysis by participant		
Reaction Time (standard deviation)	752 (76.32)	723 (69.67)
Percent Error (standard deviation)	4.71 (3.61)	1.63 (2.81)
Analysis by item		
Reaction Time (standard deviation)	757 (80.63)	725 (62.31)
Percentage Error (standard deviation)	4.71 (7.57)	1.63 (2.73)

responses to stimulus items, participant and item means were submitted to separate analysis by *t*-test, contrasting words in the bottom-rhymes condition with words from the top-rhymes condition. It was found that bottom-rhymes such as KICK (with four higher-frequency rhyming neighbors) did not yield significantly faster responses than top-rhymes such as HEAP (with no higher-frequency rhyming neighbors) as was predicted. The mean response latencies were 723 ms for bottom-rhymes and 753 ms for top-rhymes. This 30ms difference was not statistically significant, $t_1(23) = 1.38$, $p > .05$ and $t_2(22) = 1.47$, $p > .05$. In the analysis of error rate data it was found that bottom-rhymes were responded to with 3.08% more accuracy than top-rhymes. The mean percentage of error rates were 1.63% for bottom-rhymes and 4.71% for top-rhymes. This difference was significant in the analysis by participants, $t_1(23) = 3.31$, $p < .01$. However, statistical significance was not obtained in the analysis by item, $t_2(22) = 1.83$, $p > .05$.

The results of this experiment do not provide direct evidence that the presence of higher-frequency rhyming orthographic neighbors significantly facilitates lexical decision response latencies. Responses to bottom-rhymes were 3% more accurate than responses to top-rhymes in the analysis by participant; however, this difference was not statistically significant by items. All of the data were in the direction of a facilitation effect of higher-frequency rhyming neighbors.

A post-hoc correlational analysis was performed to investigate the relationship of the number of higher-frequency rhyming neighbors and lexical decisions times. The number of higher-frequency rhyming neighbors was significantly associated with reaction times,

$r(44) = -.30, p < .05$. Specifically, as the number of higher-frequency rhyming neighbors increased, lexical decision times decreased. Words with several higher-frequency rhyming neighbors were more likely to be identified quickly than words without higher-frequency rhyming neighbors.

In order to investigate the alternative explanation proposed by Grainger and colleagues which suggests that the presence of a single word level competitor of higher frequency, rather than several, causes an inhibitory effect, separate correlational analysis of reaction times and number of higher-frequency rhyming neighbors was performed for top-rhymes and bottom-rhymes. Half of the top-rhyme stimulus items had no higher-frequency neighbors while the other half had just one higher-frequency neighbor (one item had two higher-frequency rhyming neighbors). The number of higher-frequency rhyming neighbors was not significantly associated to reaction times $r(22) = -.12, p > .05$ for top-rhyme stimulus items. The increase from no rhyming neighbors of higher frequency to one higher-frequency rhyming neighbor was not significantly associated with an increase in reaction times. For bottom-rhyme items, the association between the number of higher-frequency rhyming neighbors and reaction times was stronger $r(22) = -.30, p > .05$. As the number of rhyming neighbors of higher-frequency increased, reaction times decreased, although this association did not reach statistical significance.

Discussion

The presence of higher-frequency rhyming neighbors did not facilitate lexical access of stimulus words as predicted. Lexical decision responses for bottom-rhymes were not

significantly faster than responses for top-rhymes. Words at the bottom of their rhyming orthographic neighborhood did not benefit significantly from the activation of higher-frequency phonologically and orthographically similar neighbors and did not yield significantly faster responses in the lexical decision task than words at the top of their rhyming neighborhood (without higher-frequency orthographically and phonologically similar neighbors). Lexical decision responses to bottom-rhymes were significantly more accurate in the analysis by participant, but not in the analysis by item. While orthographic neighborhood density and frequency and rhyming neighborhood density were held constant, rhyming neighborhood frequency did not play a critical role in the speed and accuracy of lexical access. However, data were in the direction of a facilitation effect, with lexical decision response times for bottom-rhymes being faster and more accurate than response times for top-rhymes (significantly so in the analysis of error rates by participant).

In contrast, none of the data here supports the idea that the presence of higher-frequency rhyming neighbors interferes with lexical access. Words with higher-frequency rhyming neighbors were not responded to more slowly or with greater error than words without higher-frequency rhyming neighbors as an interference effect, predicted by serial search models, activation-verification models and some versions of an interactive-activation model, would suggest. Serial search and activation-verification models of lexical access assume that lexical access involves a frequency-ordered sequential comparison process between stimuli and stored lexical representations, predicting that

word recognition would be adversely affected for items with several higher-frequency similar representations because the higher-frequency neighbors would be processed before the correct entry could be identified. Therefore words at the bottom of their rhyming neighborhood would have slower response times than words at the top of the rhyming neighborhood, because words at the top would be activated early in the search process, whereas words at the bottom would be activated (and thus identified) later, only after higher-frequency neighbors have been compared and rejected as a match for the stimuli. The absence of an interference effect cannot be explained within this framework.

Some versions of the interactive-activation model also predict an interference effect. This model describes a process in which the activation of a higher-frequency neighbor directly inhibits activation of the correct lexical entry in a competitive process among word units. The present findings, in which no inhibitory effect was observed, are inconsistent with this notion. If mutual inhibition among competing word nodes interferes with activation of the correct representation, as hypothesized, bottom-rhymes with several higher-frequency rhyming neighbors should have had significantly slower and less accurate responses than top-rhymes. Theoretically the inhibitory feedback from higher-frequency rhyming neighbors would delay or interfere with activation and identification of the correct lexical entry. This was not the case. In fact, bottom-rhymes were faster and less error prone (albeit not significantly so) than top-rhymes. These results are inconsistent with research on orthographic neighborhood (N-metric) frequency effects. Research by Huntsman and Lima (1996) and by Grainger and colleagues (Grainger, 1990; Grainger, et

al. 1989, 1992; Grainger et al., 1990), using orthographic neighborhood (N-metric) rather than rhyming orthographic neighborhood (NR-metric), found words at the top of their orthographic neighborhood, in terms of frequency, were responded to faster and more accurately than words at the bottom of their orthographic neighborhood; this supports the notion of mutual inhibition among word nodes creating an interference effect. While the results of this study do not unequivocally support a facilitation effect of lexical similarity, they do appear to call into question an inhibitory effect of neighborhood frequency, at least for rhyming neighborhoods.

One possible explanation for the absence of an inhibitory effect by this model is that when there are several higher-frequency neighbors they mutually inhibit one another, as well as the lower-frequency target item; keeping activation levels down for competing word nodes and allowing the target node to be activated (Grainger, 1992). In this case, the excitatory input for the target item would still be greater than the activation levels of competing neighbors. However, when there is just one higher-frequency rhyming neighbor in direct competition with the stimulus item, the proposed inhibitory effect would be observed, because the greater resting activation level of the higher-frequency neighbor would directly inhibit the activation of the competing stimulus word node. This experiment did not directly examine the influence of one versus more than one higher-frequency rhyming neighbor. However, a post-hoc correlational analysis was performed to provide some clarification on the issue.

Contrary to the previously mentioned explanation for the absence of an inhibitory

effect by activation models proposing mutual inhibition among word nodes, the increase from no rhyming neighbors of higher frequency to one higher-frequency rhyming neighbor was not associated with an increase in reaction times, as suggested. In fact, the data were in the opposite direction to that predicted by inhibition theories. In the post-hoc correlational analysis, it was found that the number of higher-frequency rhyming neighbors was significantly associated with reaction times. However, as the number of higher-frequency rhyming neighbors increased lexical decision times decreased. It appears that the presence of one or more than one higher-frequency rhyming neighbors did not hinder activation of target items. Rather, the presence of higher-frequency orthographically and phonologically similar neighbors was associated with faster recognition of target items, as measured by lexical decision response times. These results favor a facilitatory effect and contradict an inhibitory effect of rhyming neighborhood frequency.

According to previous research demonstrating a facilitatory neighborhood density effect, recognition of target items from larger neighborhoods is facilitated due to a top-down word to letter feedback process (Andrews, 1989; 1992); consistent with the basic assumptions of interactive-activation models and parallel-distributed processing models. According to this theoretical position, word nodes from large neighborhoods reach higher activation levels more quickly because of the additional excitatory and inhibitory links among word and letter level units. The presence of many orthographically and phonologically similar words strengthens the net feedback by providing additional excitatory input to the correct word and letter level units and additional inhibitory input to

the incorrect word and letter level units; thus facilitating the correct identification of the stimulus item. The results of the present experiment are consistent with this theoretical position. The presence of higher-frequency rhyming neighbors was significantly associated with faster reaction times in post-hoc correlational analysis.

It is important to clarify that in previous studies demonstrating facilitatory effects of orthographic and phonological similarity (Andrews, 1989, 1992; Huntsman, et al., 1995), it was neighborhood density, rather than neighborhood frequency, that was found to be the critical variable affecting lexical access. Because orthographic neighborhood density and rhyming orthographic neighborhood density were held constant in this study, these results do not conflict with the proposed facilitatory neighborhood density effect. The results of this investigation show that lexical access for words at the bottom of their rhyming neighborhood (with higher-frequency rhyming neighbors) was faster and more accurate than for words at the top of their rhyming neighborhood (with few higher-frequency rhyming neighbors). However, this difference did not reach statistical significance. Rhyming neighborhood frequency did not independently affect lexical decision times with orthographic neighborhood density and rhyming orthographic neighborhood density held constant. Based on these results, it appears that it is the number of rhyming neighbors, rather than neighborhood position which affects lexical access.

A parallel-distributed processing model and some versions of an interactive-activation model are the two main theories which can accommodate the current findings, specifically

the absence of an inhibitory rhyming neighborhood frequency effect. These results are consistent with the assumption of a top-down feedback process between word and letter level units, and of an interactive, simultaneous processing system as outlined by some interactive-activation models and a parallel-distributed-processing model. However the assumption by some activation models of mutual inhibition among competing word nodes was not consistent with these results.

This investigation provides one additional piece of information in attempting to understand more precisely the nature of how written language is cognitively processed. From a practical point of view, developing a better understanding of the way information is initially coded and integrated during word recognition, as well as understanding how word comprehension occurs is of fundamental importance in helping individuals acquire the ability to read written language.

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Appendix A

Human Subjects-Institutional Review Board Approval Form

San José State
UNIVERSITY

**Office of the Academic
Vice President
Associate Vice President
Graduate Studies and Research**

One Washington Square
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TO: Nicole Carroll
2151 - 44th Ave.
San Francisco, CA 94116

FROM: Serena W. Stanford *Serena W. Stanford*
AAVP, Graduate Studies & Research

DATE: March 28, 1997

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

**"Effects of Rhyming Neighborhood Structure
on Lexical Access"**

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Serena Stanford, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

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Long Beach Los Angeles Maritime Academy
Monterey Bay Pomona
Sacramento San Bernardino San Diego
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San Marcos Sonoma Stanislaus

Appendix B

Stimulus Words

top-of rhyming	bottom-of-rhyming
neighborhood	neighborhood

pond	harm
hull	pack
deck	neat
lift	noon
lock	lend
plug	palm
sink	beam
loop	card
bath	crop
foil	grip
pipe	lean
rush	whip
trim	wing
slip	seal
colt	glow
lawn	jeep
heap	kick
woke	rage
maze	clue
dash	yarn
bunk	peak
gram	hide
hunt	bold

150mm

6"

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