Effects of Lexical Factors on Lexical Access among Typical Language-Learning Children and Children with Word-Finding Difficulties*

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Key words

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lexical access

lexical neighborhood

word retrieval

word-finding

Abstract

This investigation studied the influence of lexical factors, known to impact lexical access in adults, on the word retrieval of children. Participants included 320 typical and atypical (word-finding difficulties) language-learning children, ranging in age from 7 to 12 years. Lexical factors examined included word frequency, age-of-acquisition, neighborhood density, neighborhood frequency, and stress pattern. Findings indicated that these factors did influence lexical access in children. Words which were high in frequency and neighborhood frequency, low in neighborhood density and age-of-acquisition, and which contained the typical stress pattern for the language were easier to name. Further, the number of neighbors that were more frequent than the target word also had an effect on the word's ease of retrieval. Significant interactions indicated that age-of-acquisition effects decreased with maturation for typically-learning children whereas these effects continued to impact the lexical access of children with word-finding difficulties across the ages studied, suggesting that these children's difficulties in accessing words may have prevented them from developing strong access paths to these words. These findings support a view of lexical access in which access paths to words become strengthened with successful use.

1 Introduction

As speakers, we are constantly faced with the task of accessing words we have stored in memory. Research on adult perception and production has identified a number of factors (e.g., target word frequency, neighborhood density) that might influence this process of lexical access. For example, the frequency with which a word occurs in the

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language and its similarity to other words in the lexicon are factors which may influence success at word-finding. Most of this research has focused on word-recognition (i.e., on lexical access during perception; Luce & Pisoni, 1998), but some research has examined these factors in speech production as well (Oldfield & Wingfield, 1965).

In contrast to adult research, few studies have examined the influence of these factors on lexical access in children, or how these effects may change during development (Faust, Dimitrovsky, & Davidi, 1997). Further, those child studies that have been performed have typically focused on children with lexical access problems or word-finding difficulties (Constable, Stackhouse, & Wells, 1997) and not on the lexical access issues of typical language learning children, or on how the two groups might compare. The present investigation explores how the word features examined in adult studies might influence the lexical access of typical language-learning children and those with known word-finding difficulties. Specific lexical factors considered were word frequency, age of acquisition, lexical neighborhood, and stress. Below these factors are highlighted in turn.

1.1 *Word frequency*

Word frequency has long been known to influence many different stages of lexical processing. In the area of speech perception, words that occur more frequently in the language tend to be recognized more quickly (Luce & Pisoni, 1998) and are identified more accurately both in noise and in silence (Dirks, Takayanagi, Moshfegh, Noffsinger, & Fausti, 2001). High-frequency words are also recognized more quickly when presented visually (Newbigging, 1961; Solomon & Postman, 1952).

In the realm of speech production, high-frequency words are produced more quickly (Jescheniak & Levelt, 1994; Lachman, Shaffer, & Hennrikus, 1974; Oldfield & Wingfield, 1965), are less likely to be involved in speech production errors (Dell, 1988; Vitevitch, 1997, 2002), and result in fewer tip-of-the-tongue states in both young and elderly speakers (Vitevitch & Sommers, in press). Children with word-finding difficulties have also been shown to exhibit more naming errors on low-frequency words (German, 1979, 1984). However, other researchers have found the effect of frequency on naming and perceptual identification to disappear when the age at which a word was initially acquired is held constant (Barry, Hirsh, Johnston, & Williams, 2001; Carroll & White, 1973a, 1973b; Garlock, Walley, & Metsala, 2001; Morrison & Ellis, 1995; Morrison, Ellis, & Quinlan, 1992), and many of the other tasks showing word frequency effects may likewise be confounding word frequency and age-of-acquisition. There is still debate as to whether frequency can have effects on naming independent of those of age-of-acquisition.

Target word frequency was therefore considered in this investigation. Of interest was whether frequency of occurrence would be a relevant factor in the lexical access processes of typical language-learning children and whether the size of this effect would change across age groups. It is expected that participants will have an easier time naming words that are higher in frequency than words that are less common in the language.

1.2
Age of acquisition

Some words on average are learned earlier in life than are other words. Judgments regarding the age at which a particular word is acquired have been shown to be correlated with performance on a number of language tasks. Words rated as having been learned earlier are named more rapidly and are more likely to be retrieved on the basis of partial letter or sound cues than are words learned later in life (Barry, Hirsh, Johnston, & Williams, 2001; Carroll & White, 1973a, 1973b; Garlock, Walley, & Metsala, 2001; Gilhooly & Gilhooly, 1979; Lachman, Shaffer, & Hennrikus, 1974; Morrison, Ellis, & Quinlan, 1992). Age of acquisition also affects word reading speeds (Barry et al., 2001) and lexical decision speed (Morrison & Ellis, 1995).

Given these findings with naming speed, it might be expected that there would be effects on the accuracy of word naming, as well. A word that has been learned more recently has had fewer opportunities to be accessed than has a word known for a longer period of time, all other factors being equal. If two words occur equally often in the language, but one was learned two years ago whereas the other was learned only two months ago, the representation of the more recently learned word would be predicted to have been accessed fewer times. This would result in an underdeveloped access path for this more recently-learned word.

Such effects, however, might be expected to decrease over time. That is, the difference between a word learned at age five and a word learned at age six may be a substantial difference for a seven-year-old; for a 12-year-old, these two words may no longer be very different. As stated above, it was predicted that each instance of accessing a word further develops the pathway for future word access. Pathway development is predicted to be greater early in learning than later in learning, so that as a word becomes very well-known, each individual attempt at accessing it will have less of an effect on access path development. Thus, pathway development may be proportional to the amount of pathway strength needed to have automatic word access.

If this model is correct, it would be expected that the same words will show greater age-of-acquisition effects in younger children than in older children (for whom pathways are further developed). Although previous studies have demonstrated that age-of-acquisition effects continue to occur in adults (Gilhooly & Gilhooly, 1979), most have not compared the size of such effects across the lifespan. Thus, the present investigation explored whether the age at which a word is first acquired influences children's lexical access, and whether the size of this effect decreases across childhood.

1.3
Lexical neighborhood

One potential source of lexical access differences comes not from the words themselves, but from their similarity to other words the individual knows. According to the Neighborhood Activation Model (Luce & Pisoni, 1998), words in the phonological lexicon are organized according to their phonological similarity to other words. For example, the word 'cat' is located in a dense neighborhood, as there are many other words in English that are similar to it (*bat*, *cot*, and *cap*, among others). The word *vogue* is located in a sparse neighborhood, as it is similar to only four words (*rogue*, *vague*, *vote*, and *vole*). Words within a neighborhood compete with one another during word recognition, such that words from denser neighborhoods tend to be more difficult to recognize. Differences in neighborhood density could presumably influence the relative ease of word retrieval as well.

Effects of lexical neighborhood have been examined in different ways. Some researchers have focused on a global measure, frequency-weighted neighborhood density. This measure is influenced not only by the number of neighbors that a word has, but also by the frequency of usage of those neighbors. That is, neighbors that occur more frequently in the language contribute more to this value than do neighbors that are relatively uncommon. In theory, then, frequency-weighted neighborhood density is a measure not simply of how many neighbors a particular word *has*, but of how often a word's neighbors are encountered. Research has shown that both words and nonwords with higher frequency-weighted neighborhood density are responded to more slowly in lexical decision tasks (Newman, Sawusch, & Luce, submitted).

Other researchers have attempted to separate the different potential components of frequency-weighted neighborhood density, examining neighborhood density (the number of neighbors an item has) separately from the average frequency of occurrence of those neighbors. Perceptual identification tasks demonstrate effects of both neighborhood density and average neighborhood frequency in listeners with normal hearing, as well as in elderly listeners with sensorineural hearing loss (Dirks, Takayanagi, Moshfegh et al., 2001). Both factors also play a role in auditory lexical decision tasks (Luce & Pisoni, 1998). However, while neighborhood density affects word repetition speed (Luce & Pisoni, 1998; Vitevitch, 2002), neighborhood frequency does not (Luce & Pisoni, 1998). Similarly, slips of the tongue appear to be more common for words from sparse neighborhoods but neighborhood frequency does not show an effect (Vitevitch, 2002). Tip-of-the-tongue guesses (Harley & Bown, 1998) also appear to be more common for words with few neighbors, although neighborhood frequency has not been examined.

Still other researchers have examined how word frequency interacts with lexical neighborhood. In speech recognition, a word's neighbors are its potential competitors. Words that are high in frequency, and which have only a few, low-frequency neighbors, might be expected to stand out from among these competitors. In contrast, words that are low in frequency, and which are surrounded by many high-frequency words, would be much harder to activate successfully. Not surprisingly, these lexically "easy" and lexically "hard" words have also been shown to differ in their ease of perceptual recognition by listeners with normal hearing (Cluff & Luce, 1990), hearing-impaired listeners (Dirks, Takayanagi, & Moshfegh, 2001), and cochlear-implant users (Kirk, Pisoni, & Osberger, 1995).

Other researchers have found more complicated interactions between word frequency and neighborhood characteristics. For example, Vitevitch (1997) found that malapropisms (a type of speech error in which one word is substituted for another of similar sound pattern but unrelated meaning) were more common for low-frequency words that occurred in sparse neighborhoods than in dense neighborhoods, but that high-frequency words showed the opposite pattern.

Although different researchers have examined neighborhood effects in different ways and findings vary, what remains clear is that the properties of a word's lexical neighborhood do appear to influence the perception and production of that word.

However, there is mixed evidence regarding the direction of these effects, especially with regard to speech production. Some researchers have argued that the presence of similar-sounding words facilitates lexical access (Vitevitch & Sommers, in press), while others have reported competition from these potentially-confusable words (James & Burke, 2000; Jones, 1989; Luce & Pisoni, 1998; Maylor, 1990; Meyer & Bock, 1992). These differences may be the result of the different ways that neighborhood effects have been examined, or may be indicative of different levels of processing. Research in the area of speech perception has suggested that neighborhood factors can influence word recognition at multiple levels: at the phonological level, these effects are typically facilitative, while at higher levels of processing competition between words plays a stronger role (Vitevitch & Luce, 1998). This combination of opposing tendencies can result in a range of different patterns, depending on the particular properties of the stimuli and task.

There have been few studies examining these neighborhood effects developmentally. Garlock and colleagues (Garlock et al., 2001) reported finding neighborhood density effects in a gating task for older children (aged 7.5 years) and adults, but not for younger children (aged 5.5 years). Similarly, Storkel and Rogers (2000) found that children aged 10 and 13 were more likely to learn new words of high phonotactic probability than of low phonotactic probability, whereas younger children showed no such effect. (Phonotactic probability and neighborhood frequency are highly correlated, since items that have many, frequent neighbors necessarily contain high-frequency phonemes.) These developmental changes may be the result of younger children having sparser lexicons overall (Charles-Luce & Luce, 1990; Charles-Luce & Luce, 1995; but see Dollaghan, 1994). However, in more recent work, Storkel has found effects of phonotactic probability in preschoolers' word-learning (Storkel, 2001), and neighborhood properties have been shown to influence the perception of young infants (Hollich, Jusczyk, & Luce, 2002). These results suggest that neighborhood effects are not limited to individuals with more dense lexicons.

The impact of lexical neighborhood on children's lexical access was examined. We begin by considering neighborhood properties globally, using frequency-weighted neighborhood density as our measure of lexical neighborhood. We then conducted further analyses to examine different aspects of lexical neighborhood that might be contributing to the overall effect.

1.4
Stress

One final distinction has to do with the stress pattern of the words themselves. In English, most bisyllabic words have a strong-weak (or trochaic) stress pattern. A weak-strong (or iambic) stress pattern is far less common. This difference in stress patterns has been shown to influence a number of aspects of speech perception and production. By nine months of age, infants learning English prefer listening to words that follow the predominant stress pattern of the language (Jusczyk, Cutler, & Redanz, 1993), and there is some indication that infants show difficulty in recognizing words that fail to follow this pattern (Jusczyk, Houston, & Newsome, 1999). Adult language-users also show effects of stress (Cutler & Butterfield, 1992; Cutler & Norris, 1988). In addition, malapropisms almost always maintain stress patterns (Fay & Cutler, 1977), which may be an indication of a stress-based organization within the lexicon.

It is unclear how stress information is stored in the lexicon. Levelt and colleagues (Levelt, Roelofs, & Meyer, 1999) have suggested that this information is stored as part of a word's representation only when it cannot be predicted; that is, stress information should be stored for items which have unusual stress patterns, but not for items with the typical stress pattern of the language. It is not quite clear what implications this approach has for word naming, however. There is some evidence to suggest that presenting the stress pattern of the word may help children experiencing a word-finding failure (McGregor, 1994). This may in part be the result of providing word-length information, rather than providing stress information per se, but it is at least suggestive that stress may provide a cue to word access.

In the present investigation, the role of stress in children's lexical access was examined, using both bisyllabic and trisyllabic words. It is predicted that children will find it easier to access words with a more common stress pattern, and that this effect will not change across ages.

1.5 *Summary*

In summary, the present study compares the naming performance of typical language-learning children and children with known word-finding difficulties across primary and intermediate school-age years (7–13 years). Naming performance is compared for words that differ in four features: frequency of occurrence, age-of-acquisition, lexical neighborhood, and stress patterns. By examining these features developmentally, it was possible to consider how the influence of these features might change over time. In addition, the comparison of typical language-learning children with that of children with known word-finding difficulties allowed us to determine if features important for lexical access in typical language-learning children were also important for children with a known challenge. If so, one might assume that the differences in word finding between typical and atypical language learning children are quantitative (number of errors) and not qualitative (different mapping of their lexicon).

Data for this study was collected as part of a large-scale item field testing study of a prominent expressive language assessment for children, the Test of Word Finding, Second Edition (German, 2000).

2 Method

2.1 *Participants*

Three hundred and twenty children participated in this study, 273 typical language-learning children (TL) and 58 children with known word-finding difficulties (WF). The TL children were randomly chosen from a group of 800 students attending schools in the Chicago metropolitan area; the children with WF difficulties were referred from Chicago metropolitan schools and centers by their speech and language pathologists. The sample, from lower-middle to middle socioeconomic class homes (determined by parents' educational level) were distributed approximately equally across grades first through sixth and was composed of approximately equal numbers of boys and girls. Because of missing data (some children did not complete all items), the number of children in each analysis varies between 267 and 273 for typical language-learning children, and between 53 and 58 for children with word-finding difficulties.

TL students had normal speech, language, hearing, and vision; had never received or been referred for special education services; and were judged by teachers to have age-appropriate reading and math achievement (for 7-year-olds) or had grade appropriate achievement scores in reading and math on file (for 8, 9,10, 11, and 12-year-olds). Word finding skills of the WF group were assessed using informal measures consisting of a threefold process that included a speech pathology and author interview, a review of the student's Individualized Education Plan (IEP), and a speech and language pathologist's (SLP) completed word-finding questionnaire. Children in the WF group (a) had been identified by their school SLP as having word finding difficulties; (b) were receiving word-finding intervention with related IEP goals; and (c) had a documentation of word finding difficulties on a teacher-completed Word Finding Referral Checklist (WFRC) (German & German, 1992). The receptive language of the participants in the WF group was judged to be in the average range by their SLP, as documented by at least one or more of the following indicators: (a) age-appropriate language comprehension skills defined by the Peabody Picture Vocabulary Test—Revised (Dunn & Dunn, 1981); (b) no indication of language comprehension problems on their IEP, including no remediation objectives or outcomes specific to language comprehension; and (c) the presence of specific language characteristics that indicate appropriate receptive language skills, that is, "Knows the word he or she wants to retrieve, but can't think of it." and "Has good understanding of oral language used in class."—as reported on the SLP-completed classroom observation survey.

2.2 *Materials*

For purposes of this investigation, the naming responses to 43 open-ended sentences (eliciting target words) and 255 colored illustrations of noun (singular and plural) and verb (progressive-ing form) target words were studied. Stimuli consisted of monosyllabic and multisyllabic target words, ranging from low to high in frequency of occurrence, and representing multiple semantic categories. These words were drawn from topics indicated in first-through sixth-grade Ginn Basal Readers; from first-through sixth-grade core and additional reading lists; or were present in a list of picture stimuli shown to be appropriate for children (Cycowicz, Friedman, Snodgrass, & Rothstein, 1997).

An analysis of lexical access must use vocabulary items that one is reasonably sure are within the receptive vocabulary of the children being tested. In addition to drawing vocabulary from known child sources, students' comprehension of words on which they showed naming errors was also assessed.

2.3 *Procedure*

2.3.1 *Instructions*

Picture-naming and open-ended sentence tasks were individually administered by trained examiners. Participants were either asked to name noun and verb items in response to one of three probes: "This is a …"; "What is he/she doing …?"; or "These are all …" (picture naming task) or were asked to say the word that best completes the sentence (open ended sentence task). Accuracy in naming was tallied for each item. Target word comprehension was assessed on erred items. Students were asked to select the erred target word from a three-picture field, including the target word and two decoy items.

2.3.2 *Analysis*

For the purpose of analysis, the target words presented in the picture-naming and open-ended sentence tasks were looked up in an on-line version of the Webster's 20,000-word pocket dictionary, and in the MRC Psycholinguistic database. From these databases, a number of different measures were taken:

Frequency of occurrence: The frequency of occurrence of each target word was determined from word counts generated by Kučera and Francis (1967), and were then transformed into log-frequency values. (Where findings for frequency are reported, raw frequency values are provided, since they may be a more intuitive value than are log-based numbers. However, all divisions into subsets were based on the log-transformed values). Frequency counts were summed for homonyms, as they involve the same phonological form; Dell (1990) has found the frequency of the phonological form, rather than the frequency of the semantic unit, to be the more relevant factor in speech production errors (see also Levelt et al., 1999 for a discussion of this issue).

Age of acquisition: Age-of-acquisition norms were taken from Gilhooly and Logie (1980); they asked listeners to rate the age at which each word was learned, ranging from a one (age 0–2) to a seven (age 13 years and older). These ratings were then multiplied by 100 to produce a range from 100 to 700. Subjective ratings such as these have been shown to be highly correlated with objective measures, and thus appear to be a valid measure of true age-of-acquisition (Gilhooly & Gilhooly, 1980).

Familiarity: Adult familiarity ratings were compared across word sets. Familiarity ratings were taken from Nusbaum, Pisoni and Davis (1984), and were based on a 7-point scale.

Neighborhood density: The number of words in the lexicon which differ from the target word by a single phoneme (either a single phoneme addition, deletion, or substitution). Only words which themselves had familiarities of at least 6.0 on the 7-point scale (Nusbaum et al., 1984) were considered to be neighbors for this analysis.

Mean neighborhood frequency: The mean log frequency of occurrence of all words that differ from the target word by a single phoneme.

Frequency-weighted neighborhood density: The number of words in the lexicon which differ from the target word by a single phoneme, weighted by their frequency of occurrence (an overall neighborhood measure that incorporates both neighborhood density and mean neighborhood frequency).

Obtained values for each studied factor were used to create subsets of words to evaluate each of the issues described above. For all but the stress analyses, only words from picture-naming tasks, and not from open-ended sentence tasks, were selected. For each analysis, factors other than the one being manipulated were held constant.

2.4
Results

Two factor ANOVAs with one repeated measure are reported below. Eta squared values are reported as magnitude-of-effect indicators and represent the proportion of variance in the dependent variable explained or accounted for by the differences in the means for the effect hypothesis tested. The eta squared values range from .00 to 1.00. Values around .01 indicate a "small" effect, values near .06 indicate a "medium" effect, and values in the .14 range or above indicate a "large" effect (Cohen, 1988). More specific details on each issue are presented below.

3 Analysis 1: Word frequency

3.1
Materials / Word lists

To examine issues of word-frequency, two subsets of 52 words each were created, differing in their average log-based word frequency (low frequency mean = 1.43, $SD = 0.41$; high-frequency mean = 2.82, $SD = 0.37$; $t(102) = 17.92$, $p < .0001$). Based on raw frequency values, words in the low-frequency set occurred eight times per million words (*range* 1–16; $SD = 4.44$), while words in the high-frequency set averaged 108 occurrences per million words (*range* 23–913; $SD = 164.05$; $t(102) = 4.57$, $p < .0001$).

These sets of words were well-matched in terms of other factors that might influence lexical access. Word sets did not differ in their familiarity ratings (average ratings of 6.97 ($SD = 0.08$) for low-frequency words, 6.96 ($SD = 0.11$) for high-frequency words, $t(102) = 0.44$, $p > .05$), in their frequency-weighted neighborhood density (average value of 22.53 ($SD = 22.06$) for low-frequency words, and 22.42 ($SD = 19.81$) for high frequency words, $t(102) = .03$, $p > .05$), their neighborhood density (average number of neighbors was 9.7 for both sets of words ($SD = 8.97$ low, 7.91 high), $t(102) = .02$, $p > .05$) or in their mean neighborhood frequency (1.72 ($SD = 0.98$) for low-frequency words, 1.81 ($SD = 0.91$) for high-frequency words, $t(102) = 0.52$, $p > .05$). Finally, for those words for which values were available (37 words), sets were matched for their age-of-acquisition, or AOA (average value of 266 ($SD = 46.6$) for low-frequency words and 261 ($SD = 66.3$) for high frequency words, $t(35) = 0.21$, $p > .05$).

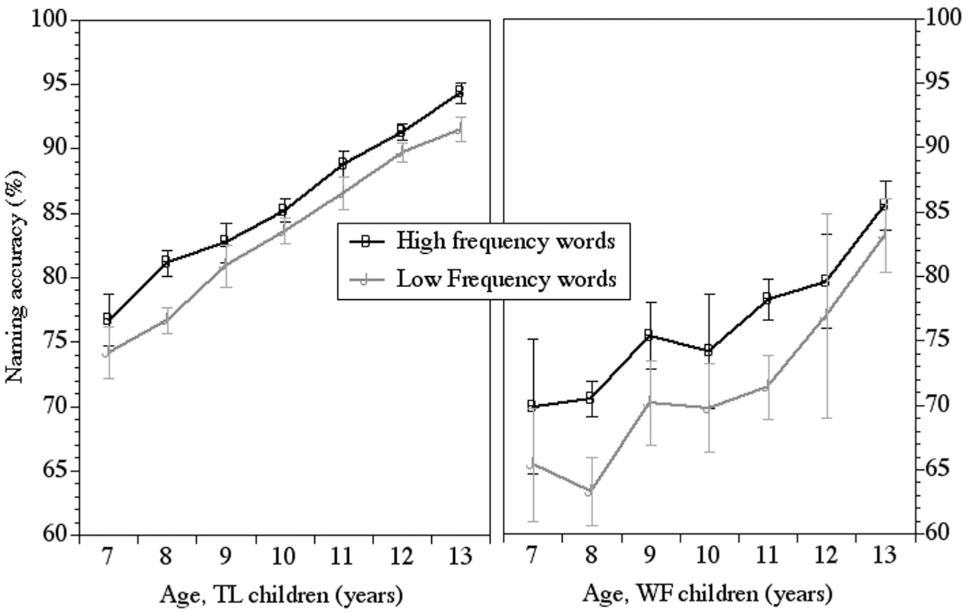
3.2
Findings

Comparison of these two sets of words provides a test of the degree to which word frequency influences lexical access. It was predicted that high-frequency words would be accessed successfully to a greater extent than would low-frequency words. This was in fact the case. A two-factor (age and frequency) ANOVA with one repeated measure (low vs. high frequency) revealed a significant effect of word frequency for both the TL (low frequency mean = 83.9%, high frequency mean = 86.3%, $F(1,260) = 42.53$, $p < .0001$) and WF children (low frequency mean = 71.9%, high frequency mean = 76.7%, $F(1,46) = 16.08$, $p < .0001$). The magnitude of the effects were all "large," .141 for TL children and .259 for WF children.

This indicates that both groups of children were significantly better at naming high-frequency words than at naming low-frequency words. Significant interactions did not emerge for either group (see Fig. 1), suggesting that the effect of word frequency is fairly constant across the ages tested here (TL: $F(6,260) = 1.60$, $p > .10$; WF: $F < 1$; eta-squared values were small, .036 for TL children and .052 for WF children). Thus, the frequency with which a word occurs in the language does appear to influence lexical retrieval in children across a range of ages, supporting findings from earlier child studies.

Figure 1

Frequency effects on naming accuracy for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



4 Analysis 2: Age of acquisition

4.1 *Materials / word lists*

Two sets of 17 words each, differing in their age of acquisition (or AOA) were created (low-AOA average rating = 212, $SD = 35.2$; high-AOA average rating = 331, $SD = 35.9$; $t(32) = 9.78$, $p < .0001$). Word sets did not differ in familiarity ratings (6.96 ($SD = 0.12$) for low-AOA words; 6.99 ($SD = 0.03$) for high-AOA words, $t(32) = 0.96$, $p > .05$), log-based word frequency (2.42 (0.58) vs. 2.29 (0.52), $t(32) = 0.73$, $p > .05$), frequency-weighted neighborhood density (11.56 (9.07) vs. 11.64 (11.52), $t(32) = .02$, $p > .05$), average neighborhood frequency (1.75 (0.93) vs. 1.54 (0.82), $t(32) = 0.71$, $p > .05$) or in neighborhood density (5.4 (4.0) vs. 5.8 (5.1), $t(32) = 0.26$, $p > .05$).

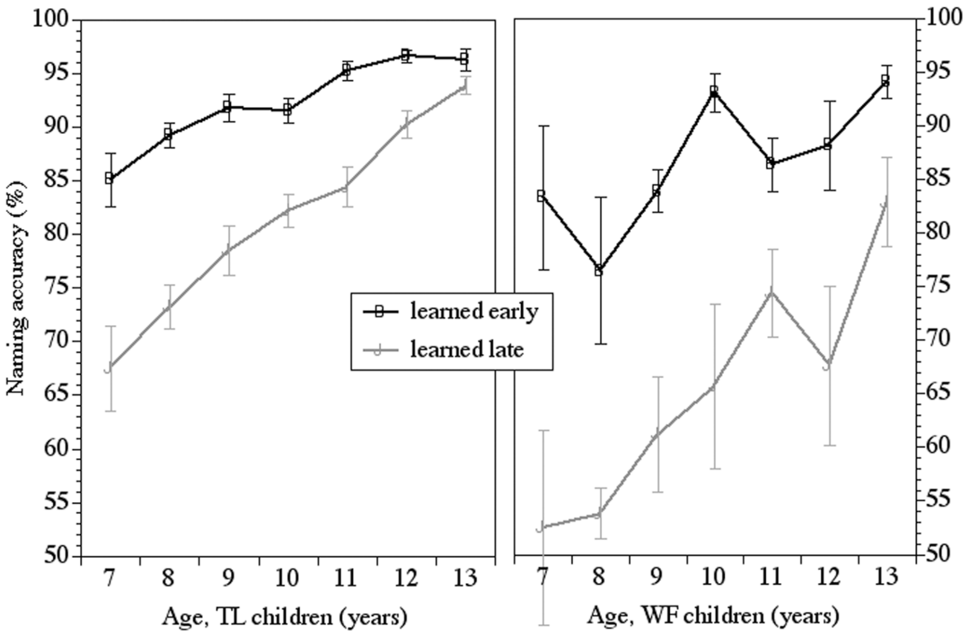
4.2 *Findings*

It was predicted that words learned later (with greater AOA) would be more difficult to name than those learned earlier. However, since all of the target words were learned at a fairly young age (selected to assure comprehensibility), the effect of AOA on these words should decrease as the children get older. That is, as students, through experience, become more automatic in accessing a word, the age at which it was initially learned should no longer influence its access.

Two-factor (age and AOA) ANOVAs with one repeated measure (early vs. late AOA) revealed a significant effect of AOA for both the TL (early AOA mean = 92.8%; late AOA mean = 82.3%; $F(1,260) = 190.21$, $p < .0001$) and WF children (early AOA mean = 86.6%; late AOA mean = 66.8%; $F(1,46) = 86.23$, $p < .0001$). Magnitude of effect sizes were large for both groups (0.422 for TL children; 0.652 for WF children). A significant age by AOA interaction emerged for TL children, $F(6,260) = 6.27$, $p < .0001$, $\eta^2 = .126$, but not for children with word finding difficulties, $F(6,46) = 1.75$, $p > .10$, although the effect size was large ($\eta^2 = 0.186$).

Figure 2

Age-of-acquisition effects on naming accuracy for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



Tukey post hoc analyses indicated that the effect of AOA was present in all TL age groups (7-year-olds, $F = 10.16$, $p < .01$; 8-year-olds, $F = 63.70$, $p < .0001$; 9-year-olds, $F = 35.65$, $p < .0001$; 10-year-olds, $F = 32.78$, $p < .0001$; 11-year-olds, $F = 54.26$, $p < .0001$; 12-year-olds, $F = 26.49$, $p < .0001$; and 13-year-olds, $F = 4.39$, $p < .05$). However, the effect decreased with age, as shown in the left panel of Figure 2. Comparing the different ages for the TL children, ages seven and eight were significantly different from ages 12 and 13 (which do not differ); ages 9 and 11 differ from age 13 only. For TL children, this pattern suggests that while the effect of AOA is present in all ages tested, it is decreasing over time, as predicted.

For the children with word finding difficulties, maturity may not have eroded the AOA effects. The older students appear to be functioning much like their younger TL counterparts with these target words. It may be that their difficulties in retrieval disrupted their development of access pathways and prevented the development of automaticity of usage over time.

5 Analysis 3: Lexical neighborhood

Our investigation of lexical neighborhood begins by examining frequency-weighted neighborhood density. This measure incorporates information both about the number of neighbors an item has and the frequency with which those neighbors occur, and is thus an overall measure of the lexical space in which a word occurs. If there are effects of neighborhood using this overall measure, further analyses would then examine which components of this combined measure might be having the larger effects.

5.1 *Analysis 3.1: Frequency-weighted neighborhood density*

5.1.1 *Materials / Word lists*

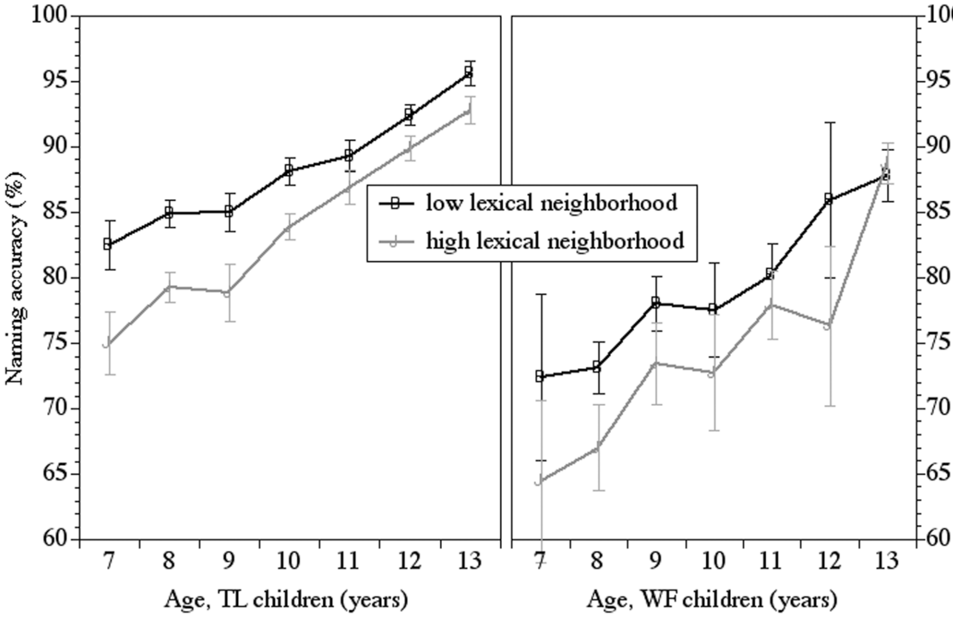
A word's neighbors were considered to include those items which differ by a single phoneme—either a single phoneme substitution, deletion, or addition. Thus, for a word such as *tail*, items such as *ale* (with a one-phoneme deletion), *stale* (with a one-phoneme addition) and *toll* (with a one-phoneme substitution) would all be considered neighbors. Moreover, these one-phoneme changes could occur anywhere in the word; thus *pail*, *toll*, and *tape* are all equivalent neighbors for *tail*. Two subsets of 32 words each, differing in their frequency-weighted neighborhood density, were created (low neighborhood set, average frequency-weighted neighborhood density = 15.18, standard deviation = 6.98; high neighborhood set, average frequency-weighted neighborhood density = 54.41, standard deviation = 8.87; $t(62) = 19.66$, $p < .0001$). Other than the necessary differences between sets on neighborhood density and neighborhood frequency, the sets were matched in terms of factors that might influence lexical access. They did not differ in their familiarity ratings (6.94 ($SD = 0.13$) for low-neighborhood words and 6.98 ($SD = 0.05$) for high-neighborhood words, $t(62) = 1.62$, $p > .05$)[1], log-based word frequency (2.49 ($SD = 0.48$) vs. 2.48 ($SD = 0.56$), $t(62) = 0.07$, $p > .05$), or age-of-acquisition ratings when available (264 ($SD = 51.5$) vs. 252 ($SD = 42.1$), $t(19) = 0.55$, $p > .05$).

5.1.2
Findings

A two-factor (age and lexical neighborhood) ANOVA with one repeated measure (low vs. high frequency-weighted neighborhood density) revealed a significant overall effect of lexical neighborhood for both the TL and WF children (TL: low-neighborhood mean = 88.6%, high-neighborhood mean = 84.5%, $F(1,260) = 75.05$, $p < .0001$; WF: low neighborhood mean = 79.5%, high neighborhood mean = 75.4%, $F(1,46) = 15.64$, $p < .0001$), as seen in Figure 3. Magnitude of effect sizes were large for both groups (0.224 for TL children; 0.254 for WF children). Words which had smaller neighborhood values were easier to name than those with larger values. Significant interactions did not emerge for either group (TL: $F(6,260) = 2.05$, $p > .05$, $\eta^2 = .045$; WF: $F(6,46) = 1.20$, $p > .05$, $\eta^2 = 0.135$), suggesting that frequency-weighted neighborhood density effects remain fairly stable with age.

Figure 3

Effects of frequency-weighted neighborhood density on naming accuracy for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



Given these overall neighborhood results, it seemed important to examine in more depth what aspects of lexical neighborhood in particular might be most relevant to

[1] One word was included for which no familiarity rating was available, 'milk'. We believed this would be a very highly-familiar word, and thus included it despite having no numerical value. For the sake of the statistical analysis, we inserted the average familiarity value of the other members of the set for this cell.

lexical access. Previous work has focused on two possibilities: the density of the neighborhood (or the total number of neighbors), and the average frequency of those neighbors. Each of these were examined separately.

5.2
Analysis 3.2: Neighborhood density:

Density refers to the number of neighbors an item has. A word like *cat* has many neighbors, while a word such as *orange* has very few. This is different from the overall neighborhood factor examined above because it does not take into consideration the frequency of occurrence of those neighbors, only their existence in the language. Thus, it is a measure of the number of neighbors in the mental lexicon, but not of the frequency with which those neighbors are encountered in spoken language.

Previous work has tended to find effects of competition, such that items with many neighbors are recognized less accurately than those with few neighbors (Dirks, Takayanagi, Moshfegh et al., 2001). However, this is task-dependent; Vitevitch (2002) has reported more speech errors for words with sparse neighborhoods. In contrast, given our results from the overall analysis above, we expected that participants would be more likely to make errors when there were other, similar words that might be incorrectly accessed. This implies that items with more neighbors would result in poorer naming performance than those with fewer neighbors.

5.2.1
Materials / Word lists

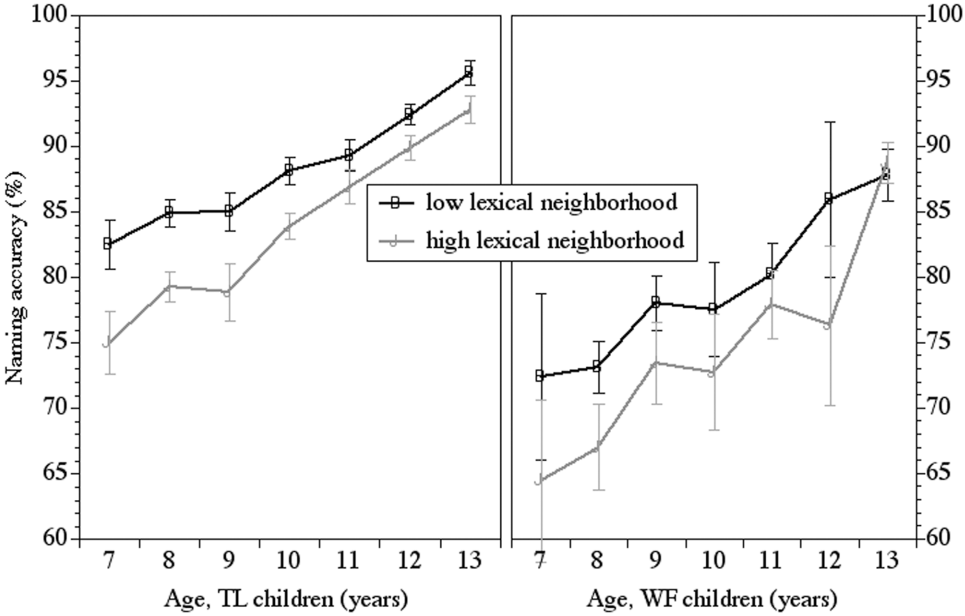
Two subsets of 36 words each, differing in their neighborhood density, were created (low neighborhood set, average neighborhood density = 7.6 ($SD = 0.36$); high neighborhood set, average neighborhood density = 20.8 ($SD = 4.55$); $t(70) = 15.05$, $p < .0001$). The sets did not differ in their log-based word frequency, 2.29 ($SD = 0.59$) versus 2.28 ($SD = 0.59$), $t(70) = 0.06$, $p > .05$, average neighborhood frequency, 2.28 ($SD = 0.36$) versus 2.29 ($SD = 0.27$), $t(70) = 0.02$, $p > .05$, or age-of-acquisition ratings when available, 236 ($SD = 47.5$) versus 264 ($SD = 51.7$), $t(20) = 1.34$, $p > .05$. There was, however, a slight difference in familiarity, such that the high density words were more familiar than the low density words, 6.99 ($SD = 0.03$) versus 6.93 (0.15), $t(70) = 2.32$, $p < .05$. However, this familiarity bias was in the opposite direction of the predicted neighborhood density effect.

5.2.2
Findings

A two-factor (age and neighborhood density) ANOVA with one repeated measure (low vs. high neighborhood density) revealed a significant overall effect of neighborhood density for both the TL and WF children, TL: low-neighborhood mean = 90.4%, high-neighborhood mean = 85.1%, $F(1,260) = 152.73$, $p < .0001$; WF: low neighborhood mean = 81.7%, high neighborhood mean = 75.8%, $F(1,46) = 28.54$, $p < .0001$, with large magnitude of effect sizes (TL: 0.370; WF: 0.383) as seen in Figure 4. Since low-density words were named more accurately than high-density words, despite a lower familiarity rating, the difference in familiarity cannot account for these results. Significant interactions did not emerge for either group, TL: $F < 1$, $\eta^2 = .021$; WF: $F(6,46) = 1.58$, $p > .05$, $\eta^2 = 0.171$, again suggesting that neighborhood density effects remain fairly stable with age.

Figure 4

Effects of neighborhood density on naming accuracy for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



These findings suggest that one of the contributing factors to the overall neighborhood effect is the number of neighbors a given word has. Those words with fewer neighbors are more likely to be named correctly than are those with many neighbors. This implies that one source of word-finding errors is a failure to select the appropriate word-form; when attempting to make the connection from the lemma level to the word-form level, participants are being led astray by the presence of competitors. Apparently both TL and WF children reach the correct part of lexical space; otherwise, the number of neighbors (the number of words in that part of lexical space) would not have any effect. They failed, however, to pick out the correct form from the multiple possibilities present. This suggests that one source of naming failure is competition among similar-sounding words.

5.3
Analysis 3.3: Average neighborhood frequency:

Average neighborhood frequency refers to the frequency with which a word's neighbors occur in the language. Both *met* and *yes* are neighbors to *yet*, but *yes* occurs more frequently in the language. If a word has more neighbors like *yes* than like *met*, it has a higher average neighborhood frequency. If its neighbors are all relatively rare, it has a low average neighborhood frequency.

Rare neighbors are less likely to compete with a word than are frequent neighbors. Thus, it is predicted that words with a low average neighborhood frequency would be named more accurately than those with a higher average neighborhood frequency.

5.3.1
Materials / Word lists

Two subsets of 30 words each, differing in their average neighborhood frequency, were created: low neighborhood set, average neighborhood frequency = 1.95 ($SD = 0.27$), high neighborhood set, average neighborhood frequency = 2.71 ($SD = 0.25$); $t(58) = 11.50$, $p < .0001$. The sets did not differ in their familiarity (6.96 ($SD = 0.10$) versus 6.97 ($SD = 0.07$), $t(58) = 0.38$, $p > .05$), log-based word frequency (2.34 ($SD = 0.65$) vs. 2.34 ($SD = 0.66$), $t(58) = 0.01$, $p > .05$), neighborhood density (14.7 ($SD = 7.7$) vs. 14.8 ($SD = 6.1$), $t(58) = 0.07$, $p > .05$), or age-of-acquisition ratings when available (254 ($SD = 46$) vs. 239 ($SD = 41$), $t(21) = 0.84$, $p > .05$).

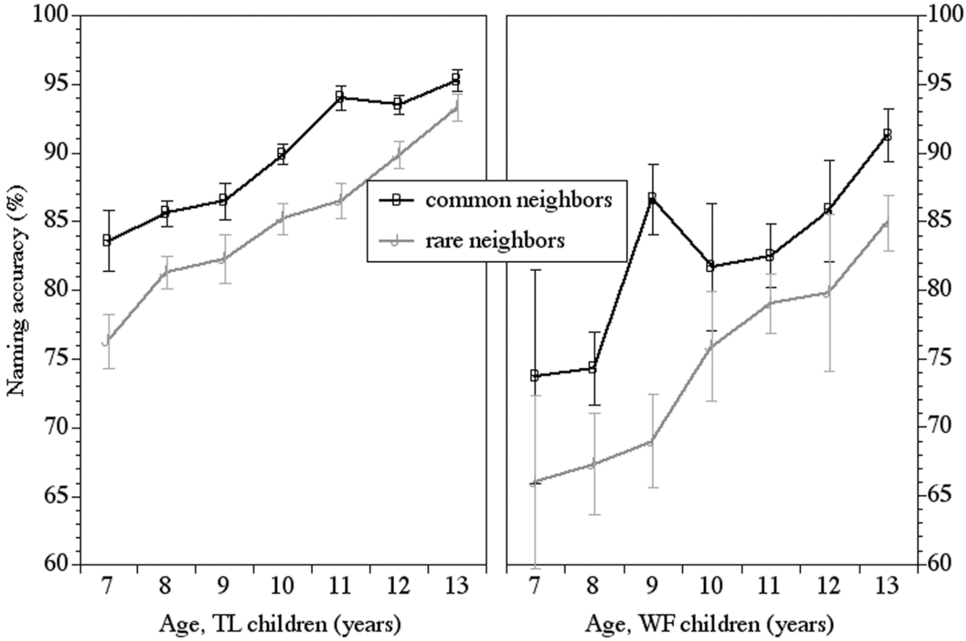
5.3.2
Findings

A two-factor (age and average neighborhood frequency) ANOVA with one repeated measure (low vs. high average neighborhood frequency) revealed a main effect for neighborhood frequency for both groups, TL: low average neighborhood frequency mean = 85.6%; high average neighborhood frequency mean = 90.3%; $F(1,260) = 106.90$; WF: low average neighborhood frequency mean = 74.9%; high average neighborhood frequency mean = 83.0%; $F(1,46) = 35.63$; both $p < .0001$. Both effect sizes were large (eta-squared values were 0.291 for TL children, 0.436 for WF children). Surprisingly, however, the effect was in the opposite direction of that predicted. For both groups of children, words with high average neighborhood frequency were named more accurately than those with low average neighborhood frequency. High-frequency neighbors facilitate performance, rather than inhibiting it.

Both groups of children also showed interactions with age, TL: $F(6,260) = 2.68$, $p < .05$; WF: $F(6,46) = 2.51$, $p < .05$, although the magnitude of the effect was large only for the WF group (for the TL group, $\eta^2 = 0.058$; for the WF group, $\eta^2 = 0.246$). The patterns of these age-related changes can be seen in Figure 5. For TL children, the effect was significant using Tukey post hoc analyses for all ages except the oldest: seven-year-olds, $F(1,14) = 18.19$, $p < .001$; eight-year-olds, $F(1,49) = 14.87$, $p < .0001$; nine-year-olds, $F(1,30) = 15.28$, $p < .0001$; 10-year-olds, $F(1,46) = 28.14$, $p < .0001$; 11-year-olds, $F(1,48) = 50.12$, $p < .0001$; 12-year-olds, $F(1,47) = 11.68$, $p < .001$; 13-year-olds, $F(1,26) = 2.81$, $p < .10$. The only differences among groups occurred between the 11-year-olds and the 13-year-olds ($p < .05$). The interaction with age appears to be the result of an aberrantly large effect among the 11-year-old children.

Figure 5

Effects of the average frequency of a target word's neighbors on naming accuracy for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



For the WF children, the effect of neighborhood was significant for only two of the seven ages, although it approached significance for one other: seven-year-olds, $F(1,5) = 2.88$, $p > .05$; eight-year-olds, $F(1,6) = 5.58$, $p < .10$; nine-year-olds, $F(1,9) = 31.23$, $p < .001$; 10-year-olds, $F(1,5) = 2.95$, $p > .05$; 11-year-olds, $F(1,9) = 1.44$, $p > .05$; 12-year-olds, $F(1,3) = 4.56$, $p > .05$; 13-year-olds, $F(1,9) = 6.32$, $p < .05$. The only differences among groups occurred between the nine-year-olds and the 11-year-olds ($p < .05$). This pattern is difficult to interpret given the small sample sizes in each age group, but again appears to be the result of an unusually large effect in a single age group.

It appears that effects of average neighborhood frequency are fairly constant across the ages tested, although there was some hint of age-related differences. Regardless, the effect is clearly one of facilitation, rather than inhibition. This suggests that frequently activating one portion of phonological space supports future access attempts. Perhaps it is not merely the activation of a single word that is strengthened with use, but is instead the activation of a region of lexical space.

Both average neighborhood frequency and neighborhood density contribute to the overall effects of lexical neighborhood, yet they appear to go in opposite directions: effects of density were competitive, while those of frequency were facilitative. Yet these two effects did not cancel out; overall neighborhood effects were also strongly facilitative. Could there be yet a third factor that contributes to lexical neighborhood? The following section examines one additional possibility.

5.4
Analysis 3.4: Number of neighbors more frequent than the target

Some words are inevitably going to be stronger competitors to a target word than are others. Thus, for the word *fat*, the word *vat* is a potential competitor, but is relatively uncommon in the language. As such, it may be a less strong competitor than is *cat*, which is a far more common word. What may in fact matter is not the overall number of neighbors, or the average frequency of occurrence of these neighbors, but rather the number of neighbors that are strong competitors — those which occur more frequently in the language than the target word itself.

This is a novel suggestion; no studies have specifically focused on the number of neighbors greater in frequency than the target. The present study examines whether this factor could have an additional effect on lexical access, beyond those of neighborhood density and average neighborhood frequency.

5.4.1
Materials / Word lists

For each target word, the number of neighbors that occurred more frequently than the target word itself was determined. Neighbors which were less frequent in occurrence than the target word were ignored. Two subsets of 13 words each, differing in this value (henceforth called more frequent neighbors), were created: low number of more frequent neighbors = 3.2, standard deviation 1.28; high number of more frequent neighbors = 7.2, standard deviation 1.68, $t(24) = 6.84$, $p < .0001$.

In order to ensure that this factor was not confounded with that of any of the other lexical or neighborhood factors examined so far, the sets were matched on these other factors. The words did not differ in their frequency of occurrence ($t(24) = 0.19$, $p > .05$; mean log frequencies of 2.06 ($SD = 0.71$) for words with many more frequent neighbors and 2.11 ($SD = 0.78$) for words with few more frequent neighbors), overall neighborhood density ($t(24) = 0.31$, $p > .05$, with averages of 12 ($SD = 4.1$) and 13 ($SD = 8.0$) neighbors, respectively) their average neighborhood frequency ($t(24) = 1.16$, $p > .05$, with average log-transformed frequencies of 2.29 ($SD = 0.45$) and 2.11($SD = 0.31$)), or in their overall frequency-weighted neighborhood densities ($t(24) = 0.13$, $p > .05$, with values of 27.5 ($SD = 12.23$) and 26.7 ($SD = 17.43$) respectively). There was a marginal difference in familiarity, $t(24) = 2.05$, $p < .06$, but this did not reach significance, and was in the opposite direction (such that the words with more competitors, mean 6.99, $SD = 0.02$, were more familiar than those with fewer competitors, mean 6.88, $SD = 0.19$, rather than less familiar). Age-of-acquisition values were available for only nine words, but these did not differ significantly, $t(7) = 1.61$, $p > .05$, with values of 252 ($SD = 63.0$) and 190 ($SD = 49.8$), and any trend was in the opposite direction (such that words with more competitors were learned earlier).

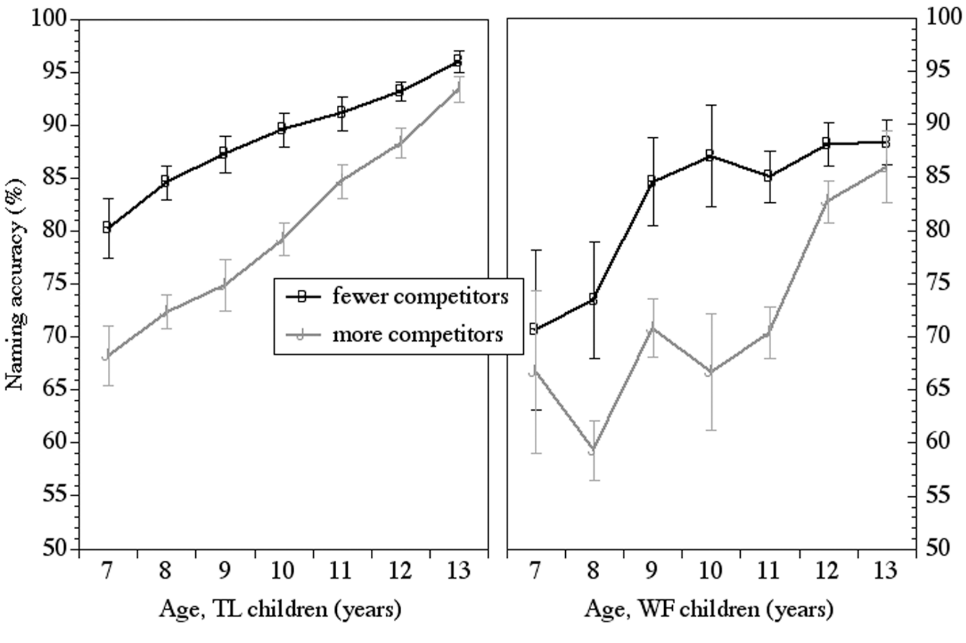
5.4.2
Findings

A two-factor (age and number of more frequent neighbors) ANOVA with one repeated measure (low vs. high number of neighbors higher in frequency than the target word) revealed a significant effect for TL children for number of more frequent neighbors: low number of more frequent neighbors 89.4%; high number of more frequent neighbors 80.9%, $F(1,260)=109.51$, $p<.0001$, with the magnitude of the effect being large ($\eta^2=0.296$).

A significant interaction also emerged, $F(6,260)=3.62$, $p<.05$, although the size of this effect was only moderate ($\eta^2=0.077$). Follow-up tests showed that the effect was present in all age groups except the oldest, for whom there was only a marginal trend, seven-year-olds, $F(1,14)=27.75$, $p<.0001$; eight-year-olds, $F(1,49)=62.78$, $p<.0001$; nine-year-olds, $F(1,30)=19.56$, $p<.0001$; 10-year-olds, $F(1,46)=21.76$, $p<.0001$; 11-year-olds, $F(1,48)=14.74$, $p<.0001$; 12-year-olds, $F(1,47)=7.22$, $p<.01$; 13-year-olds, $F(1,26)=2.92$, $p<.10$. Tukey post hoc analyses indicated significant differences only between the eight-year-olds and 12-year-olds, eight-year-olds and 13-year-olds, and nine-year-olds and 13-year-olds ($p<.05$ for all three pairs). No other age groups differed significantly. This, along with the left panel in Figure 6, suggest that the effect of the number of competitors may be decreasing somewhat as children become older.

Figure 6

Effects of the number of higher-frequency neighbors on naming accuracy for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



A two-factor (age and number of more frequent neighbors) ANOVA with one repeated measure (many more frequent neighbors vs. few more frequent neighbors) also revealed a significant effect for WF children (few more frequent neighbors 82.9%; many more frequent neighbors 72.1%; $F(1,46)=44.92$, $p<.0001$), and a significant interaction, $F(6,46) = 2.71$, $p < .05$, as shown in Figure 6. The size of both the main effect and the interaction were large (main effect, $\eta^2 = 0.494$; interaction, $\eta^2 = 0.261$). Follow-up tests showed the effects to be present in the middle ages, but not in the youngest or the two oldest groups of children: seven-year-olds, $F(1,5) = 1.73$, $p > .05$; eight-year-olds, $F(1,6) = 8.58$, $p < .05$; nine-year-olds, $F(1,9) = 8.40$, $p < .05$; 10-year-olds, $F(1,5) = 22.60$, $p < .01$; 11-year-olds, $F(1,9) = 17.98$, $p < .01$; 12-year-olds, $F(1,3) = 8.94$, $p > .05$; 13-year-olds, $F(1,9) = 0.80$, $p > .05$. However, the only age groups to differ from one another are the 10-year-olds and 13-year-olds ($p < .05$). Small numbers of participants makes interpretation of this data preliminary.

5.4.3
Discussion

Despite the fact that neighborhood density, average neighborhood frequency, and frequency-weighted neighborhood density were all controlled for, these words still demonstrated a neighborhood-based lexical effect. Thus we have demonstrated the existence of yet another neighborhood-based factor that influences lexical access, one that has heretofore received scant attention: the number of neighbors greater in frequency than the target word. Moreover, there are some hints that this effect may decrease with age for some children; This is an interesting result, as it may suggest more fully developed metacognitive (self-monitoring) skills on the part of these older children.

This effect is particularly striking given the opposite effects of average word-frequency. In the prior analysis, words whose neighbors were higher in frequency tended to be *better* named; here, the opposite pattern emerges. What might explain this seemingly paradoxical pattern?

This may be an indication of the multiple levels of processing required for lexical access whereby a word's phonological neighbors play both a primary and secondary role. When a speaker tries to access a word, they first must select the phonological schema that best represents that word's meaning (lemma). At this juncture, a word's phonological neighbors may have a primary influence on the ease with which this lexical access occurs. That is, some sound sequences in the language are more common than are others (e.g., far more words in English begin with /be/ than with /ze/) and, thus, pathways to those schemas are more frequently used. This frequency effect strengthens the access pathways to that region of phonological space, facilitating lexical access. Thus, accessing the appropriate region of lexical space is likely to be easier when the sound pattern in general has been more frequently accessed. This would be the case for words with high-frequency neighbors.

However, once the speaker has reached the appropriate region of phonological space, these same high-frequency phonological neighbors may play a different role. Here the speaker must select one sound sequence from the many possibilities. At this later stage of selecting the word, high frequency neighbors may instead serve as competitors, interfering with the process of selecting a single word. This is especially the case when those neighbors are more frequent than is the target word itself.

Thus, having many, high-frequency lexical neighbors both facilitates lexical access at one level of processing and inhibits it at another; the process of lexical access involves a trade-off of these two, conflicting effects. These different effects have been teased apart experimentally in both behavioral and electrophysiological studies (Pylkkänen, Stringfellow, & Marantz, 2002; Vitevitch & Luce, 1999), and we suspect that our findings are an indication of a similar combination of effects. Words like *cat*, which have many, high-frequency neighbors, also have a phonological pattern that is very common; although the many neighbors compete with the target word, the frequency of that sound pattern simultaneously facilitates accessing the appropriate lexical space.

In theory, this suggests that there should be different error patterns for words that have high neighborhood values and those with low neighborhood values. If a word has few neighbors, accessing that region of lexical space will be more difficult, and individuals are likely to experience a tip-of-the-tongue or produce words with a very different sound pattern. If a word has many neighbors, accessing that general sound pattern is relatively easy, but selecting the appropriate word from among its neighbors will be difficult; thus, speakers should be more likely to produce a neighbor to the target word (in particular, a high-frequency neighbor), resulting in a malapropism or other slip-of-the-tongue type response. Although these error pattern predictions cannot be explored in the current data set, such study is warranted.

5.5
Neighborhood summary

Looking across these subtypes, it appears that lexical neighborhood incorporates a number of different factors, each of which contributes its own, separate effect to lexical retrieval. Words that have fewer neighbors are easier to access than are words that are in dense regions of lexical space. Further, having neighbors which are moderately high in frequency supports lexical access while having neighbors higher in frequency than the target word itself interferes with access.

6 Analysis 4: Stress pattern

Little research has investigated the role of stress on naming. Yet stress has been shown to influence other types of language tasks (Cutler & Norris, 1988). It therefore seemed reasonable to consider whether stress differences would impact lexical access. To that end we examined whether words which have an unusual stress pattern in the language would be harder to access than words with a more typical stress pattern. This analysis was limited to multisyllabic words, and was performed first on bisyllabic words, and second on trisyllabic words. Further, because the set of words studied was small, findings are only preliminary in nature.

6.1
Analysis 4.1: Stress in bisyllabic words

In English, bisyllabic words have a strong tendency to be stressed on their first syllable (Cutler & Norris, 1988). Nouns in particular are unlikely to have stress on their second syllable, and both adults and children use this fact to help them determine the meaning of new words (Kelly, 1996). Words which match the typical stress pattern in the language are predicted to be easier to name than those which do not.

6.1.1
Materials / Word lists

For these analyses target words were drawn from both the picture naming and naming to open-ended sentence tasks administered to the participants. Two sets of five bisyllabic words were created, one consisting of words with a strong-weak (or trochaic) stress pattern, and the other consisting of a weak-strong (or iambic) stress pattern.

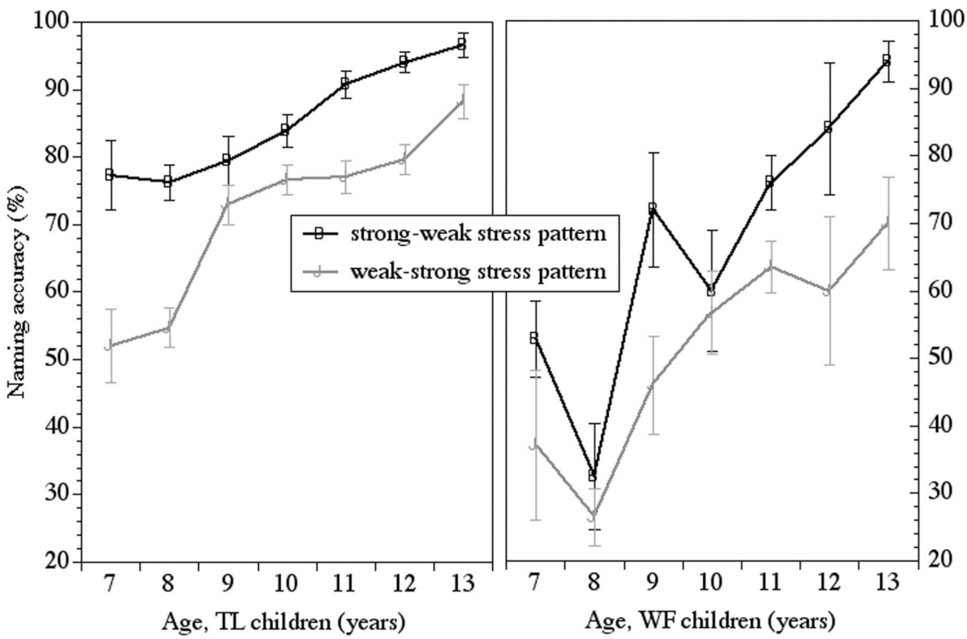
Word sets did not differ relative to familiarity (rating of 7 for all words, standard deviation of 0), log-based word frequency (2.11, $SD = 0.75$ for weak-strong words, and 2.13, $SD = 0.75$, for strong-weak words, $t(8) = 0.04$, $p > .05$), or neighborhood (words in the strong-weak set had four neighbors, while the weak-strong words had three neighbors; overall neighborhood values were 1.31 ($SD = 1.32$) and 1.19 ($SD = 1.63$), respectively; $t(8) = 0.13$, $p > .05$).

6.1.2
Findings

A two-factor (age and stress pattern) ANOVA with one repeated measure (strong-weak vs. weak-strong) revealed a significant effect for TL and WF children. Words with a strong-weak stress pattern (such as *bucket* and *helmet*) were named significantly more accurately than were words with a weak-strong stress pattern (such as *giraffe*

Figure 7

Effects of stress patterns on naming accuracy of bisyllabic words for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



and *canoe*): TL mean strong-weak words = 85.9%, weak-strong words = 72.4%, $F(1,265) = 94.72$, $p < .0001$; WF mean strong-weak words = 67.2%, weak-strong words = 51.0%, $F(1,51) = 18.14$, $p < .0001$. The magnitude of the effect was large for both groups (TL: $\eta^2 = 0.263$; WF: $\eta^2 = 0.262$).

This effect of stress did interact with age for the TL children, $F(6,265) = 3.51$, $p < .005$, but not for the WF children ($F < 1$); effect size for both groups was in the moderate range (TL: 0.074; WF: 0.095). These effects can be seen in the left panel of Figure 7. For the TL children, the effect was significant in all but one of the age groups: for seven-year-olds, $F(1,14) = 16.10$, $p < .001$; for eight-year-olds, $F(1,52) = 44.23$, $p < .0001$; for nine-year-olds, $F(1,30) = 2.63$, $p > .10$; for 10-year-olds, $F(1,46) = 4.98$, $p < .05$; for 11-year-olds, $F(1,49) = 22.50$, $p < .0001$; for 12-year-olds, $F(1,46) = 24.92$, $p < .0001$; for 13-year-olds, $F(1,28) = 6.04$, $p < .05$. The eight-year-olds differed significantly from the nine-year-olds ($p < .05$) and 10-year-olds ($p < .05$), but no other groups differed.

6.2
Analysis 4.2: Stress in trisyllabic words

For long words, English tends to place stress on the antepenultimate syllable. For trisyllabic words, this amounts to placing stress syllable-initially. Words that matched the typical stress pattern in English (stress on the initial syllable) are again predicted to be easier to name than those that followed the atypical pattern (stress on the second syllable).

6.2.1
Materials / Word lists

Two lists, one of Sww (strong-weak-weak) words, the other of wSw (weak-strong-weak) words, were created. Each set contained five words. The sets of words did not differ on their familiarity (average familiarity for Sww words = 6.88 ($SD = 0.22$); average familiarity for wSw words = 6.98 ($SD = 0.04$); $t(8) = -1.01$, $p > .05$), log-based word frequency (Sww words = 1.79 ($SD = 0.41$); wSw words = 1.70 ($SD = 0.43$); $t(8) = 0.31$, $p > .05$), or neighborhood (Sww mean = 1.01 ($SD = 2.26$); wSw mean = 0.63 ($SD = 0.88$), $t(8) = 0.35$, $p > .05$).

6.2.2
Findings

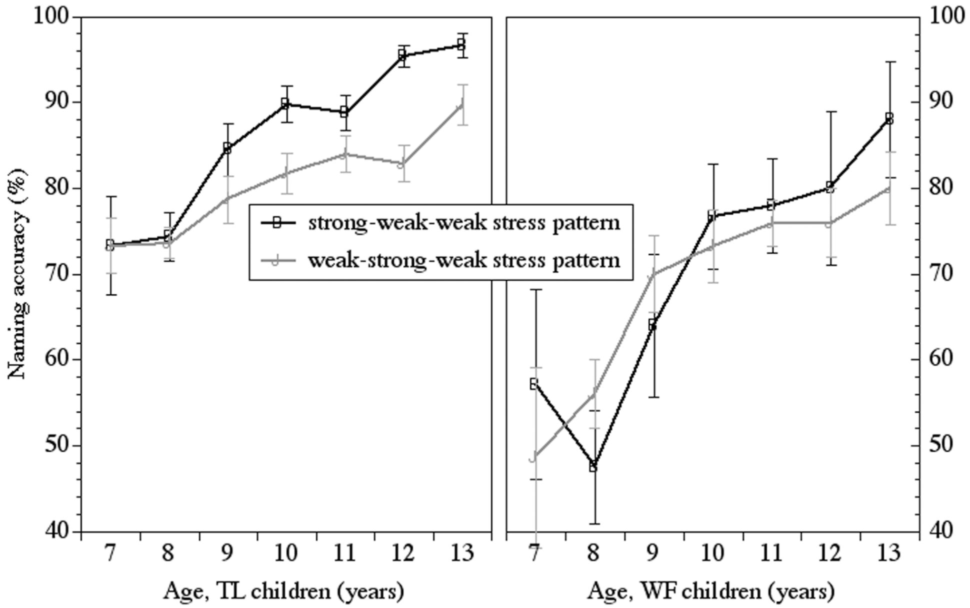
Again a two-factor (age and stress pattern) ANOVA with one repeated measure (Sww vs. wSw) revealed a significant effect of stress pattern for TL children: Sww words, average = 87%; wSw words, average = 81%; $F(1,266) = 18.39$, $p < .0001$. However, the size of the effect was only moderate ($\eta^2 = 0.065$). Words such as *microphone* and *celery*, with stress on their initial (antepenultimate) syllable, were named more accurately than words such as *umbrella* and *banana*, with stress on the middle syllable. There was only a marginal interaction with age, $F(6,266) = 1.88$, $p < .10$, $\eta^2 = .041$.

However, neither a significant main effect nor an interaction for lexical access emerged for children with word-finding difficulties (both $F < 1$; eta-squared values of 0.006 for the main effect and 0.087 for the interaction). This does not appear to be the result of floor effects, for although performance was quite low (less than 70%

correct), it was not near zero, as can be seen in Figure 8. It appears that these children's general difficulty in accessing longer words resulted in errors regardless of stress pattern. This difficulty with longer words could potentially have prevented any benefit of stress pattern from becoming apparent. Children with word-finding difficulties frequently make phonemic substitutions (Lahey & Edwards, 1999), in some cases accessing only the first syllable of a multisyllabic word while being unable to access the entire phonological sequence; in contrast, those TL children who gain access to the first syllable are more likely to successfully access the full word. If the stress pattern of a Sww word helped children successfully access that syllable, this would be more likely to result in successful word retrieval for the TL children. For WF children, it might only lead to successfully accessing the first syllable. As these partial responses were treated as incorrect, the advantage of initial stress would go unnoticed, and significant differences between Sww and wSw words would not emerge. However, future research focusing on the nature of student word-finding errors would be needed to explore this more fully.

Figure 8

Effects of stress patterns on naming accuracy of trisyllabic words for typical language-learning children (left panel) and children with word-finding difficulties (right panel)



Although each of these stress analyses is limited because of small word sets, the two stress-based analyses do offer preliminary evidence suggesting that the stress pattern of a word may influence the likelihood of its successful retrieval. Furthermore, there was no clear pattern of age-related changes, suggesting that such effects might continue into adulthood. As stress has not yet been examined in the word-retrieval of adult language-users, this is another direction for further research.

7 General Discussion

The findings from these analyses suggest that a number of different factors influence the likelihood that a particular word will be accessed successfully. Although some of these effects have been predicted previously, or have even been demonstrated with adult listeners, no prior work has managed to examine each of these effects in isolation from one another. Moreover, this is the first study to examine how these effects change with development. The findings indicate that word frequency, age-of-acquisition, stress pattern, and lexical neighborhood all have independent effects on word retrieval. These findings are summarized below.

Word frequency has been previously shown to be a factor in many different aspects of language processing, but recent papers have suggested that many of these effects may be the result of confounds with age-of-acquisition (Carroll & White, 1973a; Morrison & Ellis, 1995). In contrast, our results suggest that word frequency does appear to influence lexical access. Words which occur more frequently in the language are more likely to be successfully accessed than are less frequent words. This effect does not appear to change with age, at least for the range of ages tested here.

Age-of-acquisition also appears to influence word retrieval, although the size of this effect decreases over time. Words which are learned earlier in life (or which have been known for longer periods of time) tend to be easier to access than words learned more recently. Although previous work has suggested that age-of-acquisition measures and word-frequency measures are often confounded, we have demonstrated that each of these has quite separable effects on the course of lexical access. Moreover, the two factors show different developmental patterns. As it relates to the age-of-acquisition analyses, the age at which a word is initially learned influences the access skills of younger children while having less impact on the access skills of older children. Therefore, it appears that over time, speakers gain lexical competence as pathways for word retrieval mature. This finding is not surprising since one would assume that the longer a word has been known the more complex its lexical network and thus the more opportunities for access. Over time, with successful target word access, one would develop reliable access pathways. However, the same pattern was less distinct for children with word-finding difficulties. For these children, the impact of AOA on access skills generally remained unchanged as they matured. That is, knowing a word over a longer period of time did not seem to improve their access to that word. It may be that these children's word-finding difficulties so interrupted their access attempts that the maturing of pathways and the development of automaticity in word retrieval could not occur as it did for TL children. Therefore, even with high-frequency words, for which they have developed semantic networks, it appears that these student's word-finding difficulties kept them from accessing these words sufficiently to reach their optimum performance over time.

A word's lexical neighborhood can also influence its retrieval. However, this is not a unitary effect, but consists of at least three different (and opposing) tendencies. First, words which have more neighbors tend to be harder to access than words which have fewer neighbors. In addition to this neighborhood density effect, there was also a facilitative effect of average neighborhood frequency.

This study also demonstrated a third type of neighborhood effect, one that has not been explored previously. In addition to the overall effects of neighborhood density and neighborhood frequency, the number of neighbors that are more frequent than the target word also has an effect. That is, relative to the target word, neighbors of moderately high frequency are facilitative, whereas neighbors of higher frequency than the target word compete for selection. The existence of these strong competitors inhibits lexical access. Of interest would be to explore whether this new factor also influences perception as observed here in production.

Finally, this work demonstrates that the stress pattern of the target word also influences the likelihood of successful lexical access. Children were more likely to name words that contained the typical stress pattern for the language than those words that contained less-common stress patterns. This effect of stress on lexical access has not been explored in either the child or the adult lexical-access literature, and has implications for models of lexical organization for both groups. In order for stress to influence the success or failure of naming attempts, stress must either serve as a cue for lexical access (perhaps via a strategy of searching on the basis of common stress patterns first) or words must be organized in a stress-specific way. Further research with child and adult speakers, exploring both naming accuracy and error types, is necessary in order to distinguish between these alternatives.

In addition to examining word-finding in typical language-learning children, this study also investigated how these factors might influence the retrieval performance of children with word-finding difficulties. The pattern of results across the two groups of children was quite similar for both target word frequency and lexical neighborhood, suggesting for the most part that children with word-finding difficulties differ from their peers quantitatively, not qualitatively, relative to these lexical factors. In particular, students with word-finding difficulties typically reached the correct lexical space; otherwise, neighborhood effects would not have been observed. This suggests that target word representations were stored, but failure to access the word was the result of disturbed algorithms for retrieval. However, children with word-finding difficulties performed differently than their same-age counterparts on words differing in their age-of-acquisition. As indicated above, these children's word-finding difficulties may have so interfered with their lexical access that algorithms for retrieval were not able to mature as they did for their TL counterparts. In the same way, their word-finding difficulties with long words may have also interfered with their ability to benefit from the typical stress patterns of trisyllabic words, despite the fact that this stress effect aided production in typical language-learning children. This suggests that children with word-finding difficulties may be doubly disadvantaged—not only do they have frequent difficulties accessing words for spontaneous usage, but their continuous failure to do so may interfere with their lexical access pathways maturing over time.

In conclusion, the findings in this study add to our understanding of factors that may influence lexical access. Moreover, this is the first study to examine how these effects change with development. Interestingly, age-of-acquisition effects appear to demonstrate the most consistent changes across childhood. There were some signs of age-related changes in lexical neighborhood and in effects of stress, but not in effects of word-frequency. Finally, the stability of word-frequency effects across time may help to explain why this particular effect has been the most consistent in the prior literature.

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Appendix 1

Accuracy of naming of the experimental Test of Word Finding, Second Edition (TWF – 2) target words used in this study, averaged across different ages, TL children only.

Word	Accuracy	Word	Accuracy
Animal	0.85	Clap	0.94
Arrow	0.96	Climb	0.97
Axe	0.90	Clothing	0.76
Balance	0.71	Coin	0.57
Banana	1.00	Collie	0.42
Barrel	0.88	Computer	0.88
Bead	0.55	Cone	0.97
Bear	0.94	Crawl	0.97
Beard	0.88	Crib	0.78
Bed	0.86	Crown	0.96
Bird	0.90	Curl	0.76
Blow	0.99	Dairy	0.75
Boat	0.87	Daisy	0.49
Boot	0.90	Dance	0.86
Bucket	0.93	Dime	0.95
Buffalo	0.81	Dive	0.87
Bugs/Insects	0.92	Dog	0.93
Butter	0.80	Doll	0.98
Butterfly	0.96	Drink	0.99
Calculator	0.97	Drive	0.98
Canoe	0.79	Eat	1.00
Cap	0.55	Elbow	0.92
Car	0.97	Elephant	1.00
Card	0.98	Exercise	0.88
Catch	0.90	Fight	0.79
Celery	0.73	File	0.47
Chair	0.83	Fish	0.84
Checkers	0.76	Food	0.53
Cheer	0.63	Fork	0.99
Cheese	1.00	Fruit	0.94
Chop	0.92	Furniture	0.83
Circle	0.97	Game	0.92

Word	Accuracy	Word	Accuracy
Giraffe	0.97	Pedal	0.89
Goat	0.85	Peel	0.43
Guitar	0.88	Penguin	0.99
Harp	0.74	Pick	0.79
Heel	0.67	Pill	0.80
Helmet	0.89	Pin	0.94
Holiday	0.90	Plant	0.79
Hood	0.72	Poodle	0.81
Icicle	0.58	Pour	0.95
Igloo	0.83	Pray	0.96
Instrument	0.91	Quarter	0.98
Juggle	0.97	Rake	0.95
Kick	0.95	Ride	0.79
Kite	0.99	Ring	0.88
Knee	0.97	Ruler	0.92
Knife	1.00	Run	0.96
Lettuce	0.75	Sandal	0.80
Limousine	0.93	Scarecrow	0.95
Lipstick	0.97	Shadow	0.78
Machine	0.31	Shape	0.96
Mail	0.74	Shark	0.93
Mask	0.94	Shepherd	0.32
Measure	0.85	Shoe	0.95
Medicine	0.75	Sing	0.96
Microphone	0.90	Skate	0.99
Milk	1.00	Sky	0.88
Money	0.93	Slipper	0.69
Needle	0.77	Spider	0.95
Net	0.96	Spin	0.89
Octopus	0.96	Spoon	1.00
Oil	0.66	Sport	0.92
Owl	1.00	Spray	0.94
Pack	0.75	Statue	0.67
Paint	0.99	Stem	0.88
Parade	0.66	String	0.57

Word	Accuracy	Word	Accuracy
Submarine	0.82	Toy	0.95
Sweep	0.71	Umbrella	0.99
Swim	0.97	Utensil	0.32
Swing	0.99	Vase	0.77
Tackle	0.76	Water	0.78
Tear	0.98	Web	0.95
Thanksgiving	0.85	Weigh	0.76
Throne	0.53	Write	0.89
Throw	0.96	Yawn	0.93
Tool	0.97	Zebra	1.00
Top	0.80	Zip	0.74
Tow	0.74		

Appendix 2

Words included in the different analyses.

Frequency:

High frequency: animal, balance, barrel, bed, birds, blow, butter, car, card, catch, chair, circle, dance, dive, dog, drink, drive, exercise, file, fish, food, fruit, furniture, instrument, knee, knife, machine, measure, medicine, money, net, oil, paint, pick, plant, quarter, ring, run, shadow, shape, sing, sky, stem, submarine, swing, throne, throw, tool, top, water, weigh, write

Low frequency: banana, bead, boot, bugs, butterfly, calculator, celery, checker, cheer, cheese, chop, clap, collie, cone, curl, daisy, dime, fork, giraffe, goat, harp, icicle, igloo, juggle, kite, lettuce, limousine, lipstick, octopus, owl, peel, penguin, pills, pin, pliers, poodle, rake, ruler, sandal, scarecrow, shark, shepherd, shoe, slipper, spider, tear, tow, toy, vase, yawn, zebra, zip

AOA:

Early age of acquisition: animal, butter, cheese, circle, dog, doll, drink, elbow, elephant, fruit, holiday, money, needle, spoon, swim, toy, water

Late age of acquisition: balance, barrel, canoe, chop, dairy, dive, measure, oil, pedal, quarter, ruler, shadow, shape, statue, submarine, sweep, vase

Neighborhoods:

High overall neighborhood: bear, bed, boats, boot, car, chair, cheer, cone, dime, eat, game, fight, file, heal, hood, kick, knee, mail, net, pack, peel, pick, pills, pin, pour, rake, ride, shoe, tear, tow, vase, write

Low overall neighborhood: beard, blow, climb, crawl, crib, crown, dance, dive, dog, drink, drive, fish, food, knife, milk, oil, paint, plant, pray, shape, sky, sport, spray, stem, string, sweep, swim, swing, throne, throw, top, web

High density: bead, bear, bed, birds, boats, boot, bugs, cap, catch, chair, cheer, chop, clap, cone, dime, dive, game, goat, heel, kick, mail, pack, peel, pick, pills, pin, pour, rake, ride, ring, run, sing, spray, tool, tow, vase

Low density: beard, blow, card, cheese, climb, crawl, crown, curl, dog, drink, drive, fish, food, fork, fruit, harp, knife, mask, oil, owl, paint, plant, pray, shape, shark, sky, sport, stem, string, swim, swing, throne, throw, toy, web, yawn

High average neighbor frequency: bear, beard, bed, birds, chair, cheese, eat, fight, file, fork, game, goat, hood, kite, knee, knife, net, owl, pray, shark, shoe, sport, stem, tear, throw, tool, tow, toy, vase, weigh

Low average neighbor frequency: boot, bugs, car, card, catch, chop, clap, crib, crown, dime, dive, drink, food, fruit, heal, kick, mail, oil, pack, peel, pick, ring, run, sky, spray, sweep, swim, swing, top, zip

Many higher-frequency neighbors: arrow, bed, chair, clap, coin, collie, doll, file, fish, spin, throw, toy, zip

Few higher-frequency neighbors: axe, car, dive, game, mail, pick, pray, sandal, skate, spoon, tackle, web, yawn

Stress:

Strong-weak stress:	balance, bucket, clothing, helmet, quarter
Weak-strong stress:	canoe, giraffe, guitar, machine, parade
Strong-weak-weak stress:	buffalo, butterfly, celery, holiday, microphone
Weak-strong-weak stress:	banana, computer, Thanksgiving, umbrella, utensil