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Effects of word frequency and phonological neighborhood characteristics on confrontation naming in children who stutter and normally fluent peers

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Abstract

In a prior study (Newman & Bernstein Ratner, 2007), we examined the effects of word frequency and phonological neighborhood characteristics on confrontation naming latency, accuracy and fluency in adults who stutter and typically fluent speakers. A small difference in accuracy favoring fluent adults was noted, but no other patterns differentiated fluent speaker responses from those obtained from the adults who stutter. Because lexical organization or retrieval differences might be more easily observed in less mature language users, we replicated the experiment using 15 children who stutter (ages 4;10 16;2) and age- and gender-matched peers. Results replicated the earlier study: the two groups of participants showed strikingly similar patterns of responses based on word frequency and neighborhood characteristics. There were also no differences in naming accuracy overall between the two groups. Given our results and those of other researchers who have explored the impact of neighborhood variables on lexical retrieval in people who stutter, we suggest that differences between language production in PWS and fluent speakers are not likely to involve atypical phonological organization of lexical neighborhoods.

Educational objectives: After reading this article, the reader will be able to: (1) define and illustrate words that have differing frequency and phonological neighborhood characteristics; (2) evaluate whether or not children who stutter appear to organize their mental lexicons differently than those of children who are typically fluent; (3) suggest future areas of research into language processing in people who stutter.

Keywords: Stuttering; Children; Lexical retrieval; Phonology; Language

A number of linguistic regularities characterize stutter events in both adults and children (see Bernstein Ratner, 1997; Bloodstein & Bernstein Ratner, 2008 for review). Given this link between stuttering and linguistic properties, a number of authors (see, e.g., Howell, Au-Yeung, & Sackin, 2000; Karniol, 1995; Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993) have developed models proposing that an underlying cause of stuttering may lie in some weakness that the person who stutters experiences while in the process of retrieving or assembling utterance elements, or in a mismatch

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in developmental trajectory among aspects of the child's developing speech and language system and other abilities (e.g., Conture et al., 2006). The language production process is sufficiently complex that both its developmental and end-stage characteristics are still imperfectly understood (see Griffin & Ferreira, 2006); however, there are a number of proposed and generally agreed-upon stages and tasks that could plausibly give rise to fluency breakdown in a susceptible speaker. Minimally, the broad constructs of phonological encoding, lexical retrieval, and syntactic encoding have each been investigated as specific stages in the speech production process that might be disrupted in stuttering.

In the current study, we examine whether the lexical retrieval abilities of children who stutter can inform the construction of psycholinguistic models of stuttering. Moreover, because representation and access in the mental lexicon reflect multiple attributes of words (such as their semantic, grammatical or phonological features), we explored whether phonological characteristics of words, or the relative frequency of phonologically related forms might differentially affect lexical retrieval in children who stutter and their typically fluent peers.

1. Lexical processing in people who stutter

A large number of lexical factors impact the likelihood of stuttering (see Bloodstein & Bernstein Ratner, 2008 for review). For example, stuttering is more frequently observed on less frequently occurring words in the language (Danzger & Halpern, 1973; Hubbard & Prins, 1994; Palen & Peterson, 1982; Prins, Main, & Wampler, 1997; Ronson, 1976; Soderberg, 1966). Word frequency, however, is not a straightforward predictor of fluency breakdown. Some classes of words attract more stuttering than others. In childhood, high-frequency words, such as function words, are very likely to be stuttered (Bloodstein, 1960; Bernstein, 1981). In adults, when frequency is controlled for, nouns tend to be stuttered less in conversational speech than other content words, such as verbs and modifiers (Quarrington, Conway, & Siegel, 1962). The phonological shape of words does not appear to exert systematic effects on stutter frequency across age groups, languages or ostensibly vulnerable subpopulations of people who stutter, such as children with developmental articulation errors (see summary in Bernstein Ratner, 2005, but also an opposing viewpoint voiced by Howell & Dworzynski, 2005).

The impact of lexical factors on fluency is complemented by the findings of many studies that suggest diminished levels of lexical knowledge in people who stutter. Vocabulary depression or subtle lexical difficulty (such as the ability to resolve lexical ambiguity) has been noted in some studies of adults and children who stutter, using both standardized and experimental tasks (Arnold, Conture, & Ohde, 2005; Byrd & Cooper, 1989; Murray & Reed, 1977; Scripture & Kittredge, 1923; Watson et al., 1994; Westby, 1974). There is also evidence of diminished levels of lexical diversity in spontaneous conversational samples taken from stuttering children (Silverman & Bernstein Ratner, 2002). Finally, Anderson, Pellowski, and Conture (2005) noted unusual gaps between the receptive and expressive lexical abilities of young children who stutter, and correlated the size of such "gaps" with measures of stuttering severity. Such findings suggest the possibility that difficulties with lexical access might be a factor in fluency.

Difficulties with lexical access have been explored in a number of ways. Adults who stutter (AWS) are slower to decide whether an item is a word in the language than are adults who do not stutter (Hand & Haynes, 1983; Rastatter & Dell, 1987). They are also slower to name pictures, even when the stimuli consist of as few as eight familiar nouns and verbs that had been previously pretested to assure their recognition (Prins et al., 1997). PWS also show differences in priming; priming refers to the fact that people are typically faster to respond to a word (such as *cat*) after hearing either a semantically related word (*dog*) or a phonologically related word (*cap*). Pellowski and Conture (2005) found that CWS did not appear to benefit from semantic priming, and Burger and Wijnen (1998) reported that AWS showed weaker phonological priming than AWDNS (but see Burger & Wijnen, 1999, for some contradictory findings). While CWS seem to show generally similar phonological priming patterns to CWDNS (Melnick, Conture & Ohde, 2003), there are some subtle differences (Byrd, Conture, & Ohde, 2007), Likewise, Anderson (2008) found slight differences in identity priming for CWS (speeding response by re-presenting identical stimuli). These results suggest that the phonological representations of target words, or the links between semantic and phonological representations are less well specified in the mental lexicons of children who stutter (Anderson, 2008). This might imply that there would also be differential effects of phonological neighborhood characteristics on the word retrieval abilities of children who do and do not stutter.

The notion that items in the mental lexicons of PWS might be less well specified for phonological and other attributes has support from a number of studies. For example, AWS have also shown slower RTs on tasks requiring monitoring of phonological structure (such as judging whether stimuli rhyme) and lexical analysis (making semantic category judgments; Bosshardt, 1993, 1994; Weber-Fox, Spruill, Spencer, & Smith, 2008), as well as while monitoring for particular phonemes (Sasisekaran, De Nil, Smyth, & Johnson, 2006). Some of these effects are exacerbated under conditions of increased cognitive load (Weber-Fox et al., 2004) Weber-Fox and colleagues noted that the data to date are "consistent with the hypothesis that underlying neural processes mediating lexical access may operate atypically in adults who stutter in the absence of overt speech" (Weber-Fox et al., 2004, p. 1246).

Taken together, the literature on lexical features that impact stutter rate, levels of performance on lexical tasks by people who stutter, and differential responses by PWS to conditions thought to facilitate and impede lexical processing all suggest that lexical representation or network relationships among items in the mental lexicon might distinguish people who stutter from their typically fluent peers. However, the nature of any potential underlying difference in representation or access routes has yet to be clarified.

2. Models of lexical access

How are words represented and accessed during typical lexical access tasks? Contemporary models of word production suggest that lexical access is a partially staged process, including (at a minimum), levels at which conceptual preparation, lemma retrieval, and word form encoding occur (Griffin & Ferreira, 2006; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992). The last stage, word form encoding, is believed to incorporate a variety of distinct substages, including accessing the word form as a whole and accessing sublexical units that make up the word form. While our current thinking about lexical access is based on several models, we base staging of lexical access on a model of single-word retrieval advanced by German (2000). This model was, in turn, based on work by Levelt and colleagues (Levelt, 1989, 1991, 1999). The Levelt model (known as WEAVER++; Roelofs, 2000) is the model that has been most frequently applied to linguistic analyses of stuttering (e.g., Postma & Kolk, 1993; Wijnen & Boers, 1994; Yaruss & Conture, 1996), while the German model has been applied to word retrieval in several clinical populations (German, 2000; German & Newman, 2004, 2007; Newman & German, 2002, 2005). Our work is also strongly influenced by the Neighborhood Activation Model of Luce and Pisoni (1998), which we use to make more explicit predictions about the nature of phonological access in particular, and the spreading activation model of Dell (1986).

The first stage of lexical access involves activation of the conceptual structure or underlying concepts associated with the target word. In a confrontational naming task, that involves identifying the concept that matches a pictured stimulus (Bierswisch & Schreuder, 1991). In the second stage, activation spreads from this conceptual structure to the target word's *lemma* (the representation of its semantic and syntactic features), resulting in selection of that lemma from among potential competing entries in the speaker's semantic lexicon (Garrett, 1991). When this process goes awry, speakers may produce a semantic associate to the target word (for example, producing the word "canoe" when shown a picture of a kayak; see German & Newman, 2004, 2007 for more on specific error type predictions). Activation from the lemma then spreads to the phonological lexicon; if a blockage occurs between the semantic and phonological lexicons, speakers report a "tip-of-the-tongue" error, where they have selected an appropriate lemma but cannot come up with how to say it.

Within the phonological lexicon, activation spreads from the lemma to the target's word form and abstract phonological properties (such as its syllabic structure and embedded phonemic units), so that a fully specified phonological schema for execution can be constructed (Levelt, 1991). We further presume that this phonological lexicon is organized in a manner similar to that proposed in the Neighborhood Activation Model (Luce & Pisoni, 1998), with entries both for complete word forms and for component phonemes, but without semantic or syntactic information. We note that the current model is specifically one of production, not recognition. Within the phonological lexicon, activation spreads to multiple items simultaneously; this results in the partial activation of lexical neighbors (items which are phonologically similar to the target word), and this can lead to phonological errors in production, as well as effects of neighborhood density. Finally, in the last stage, a motor plan is created and forwarded to lower-level articulation processes required to produce the word.

3. Lexical factors in typical speech production

A number of factors appear to organize the mental lexicon and influence ease of lexical retrieval. Some of these factors have previously been identified as affecting stuttering patterns as well, such as the frequency with which a word occurs in the language. Others have been less well investigated in the domain of fluency, such as the similarity of a target's phonological form to other words in the speaker's mental lexicon.

4. Word frequency

We have previously noted that stuttering is reduced on higher frequency target words, and this is consistent with effects of word frequency in typical speakers. For example, studies suggest that 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 older speakers (Vitevitch & Sommers, 2003). This effect of word frequency appears to be relatively constant across adulthood, although it tends to be larger among children than adults (Newman & German, 2005).

5. Lexical/phonological neighborhood

Another potential source of lexical access speed and accuracy differences comes not from how common a word is, but from its similarity to other words that the individual knows. This is sometimes referred to as the *phonological neighborhood characteristics* of a target word. In any given language, some words will be phonologically similar to many other words, whereas other lexical entries will be more unique. According to the Neighborhood Activation Model (Luce & Pisoni, 1998), lexical entries are organized in the mental lexicon according to sound structure. As a result, the process of selecting any given word involves discriminating it from other similar words, and the ease of this task depends on "the number and acoustic–phonetic similarity among the activated lexical items" (Luce & Pisoni, 1998, p. 12), or phonological neighborhood characteristics. A common metric for defining similarity is a one phoneme difference between word pairs. According to this metric, the English word *let* is similar to *bet*, *less*, *lent*, and *light*, among many other items. In contrast, the word *kept* is similar to only three other words, *crept*, *Celt*, and *wept*. We can describe words that have many similar "neighbors" as residing in a dense neighborhood, while those that have few neighbors as residing in sparse neighborhoods.

In speech production, words from dense neighborhoods (those similar to many words) tend to be repeated aloud (named) more slowly than words in sparse neighborhoods (Luce & Pisoni, 1998), presumably as a result of the confusability of the target word and its phonological neighbors, which delays selection of the appropriate target from possible likely options. Both phonological (Vitevitch, 2002) and tip-of-the-tongue (Harley & Bown, 1998) errors by adult speakers appear to be more common for words from sparse neighborhoods than for those from dense neighborhoods, and items involved in malapropisms tend to come from sparse neighborhoods (compared with words chosen at random from the lexicon; Vitevitch, 1997). Newman and German (2005; see also Newman & German, 2002) reported poorer naming performance for words from dense neighborhoods, suggesting that neighbors could cause naming interference in some situations. This effect was greater in children and adolescents compared with young or older adults. Thus, neighborhood density may impact naming more strongly in speakers with weaker or immature lexical systems. This latter possibility suggests that examining neighborhood density effects in atypical populations may be particularly informative.

In addition to this effect of the number of neighbors a word has, the frequency with which those neighbors themselves occur can also influence lexical access. For example, *kept*'s neighbors are not only few in number, but relatively rare words of English. In contrast, the word *weld* has some very high-frequency neighbors, such as *well* and *world*. The factor of neighborhood frequency appears to demonstrate a more variable impact on speech production than simple word frequency, but when effects are found they are generally facilitative, with greater accuracy and faster responding on items with high-neighborhood frequency. Neighborhood frequency was not found to influence word repetition speed (Luce & Pisoni, 1998) in adults. In Vitevitch and Sommers (2003), however, it did influence naming speed in a task in which participants first studied the 54 target words and were then asked to provide them as labels for each picture. Participants responded more quickly and accurately to items with high-neighborhood frequency. Words involved in speech production errors such as malapropisms tend to have a lower neighborhood frequency than do randomly selected words from the lexicon (Vitevitch, 1997). Newman and German (2002) reported a strong effect of neighborhood frequency in children's speech production; words with high average neighborhood frequency were named more accurately than those with low average neighborhood frequency.

6. The impact of frequency and neighborhood factors in stuttering

Studies of the factors that may affect lexical recognition and retrieval have primarily focused on typical, young adult speakers, with small numbers of studies that have examined other age ranges (Newman & German, 2005) and clinical populations, such as adults with aphasia (Boyczuk & Baum, 1999; Gordon, 2002) or children with word retrieval difficulties (Newman & German, 2002). A handful of studies have contrasted the impact of neighborhood factors on RT, fluency, or both in PWS. Arnold et al. (2005) examined picture-naming speech reaction time (SRT) in nine pairs of 3–5-year-old stuttering and fluent children; all participants demonstrated faster and more accurate performance on words from phonologically sparse neighborhoods than on words from phonologically dense neighborhoods, as might be expected. However, the groups did not differ in their patterns of SRT by phonological neighborhood characteristics. In fact, receptive vocabulary was more predictive of SRT than neighborhood characteristics of the stimulus items. The authors noted certain problems that may have obscured possible differences between the groups of children: a relatively small stimulus set and broad variability in children's more limited mental lexicons in this age range.

Anderson (2007) analyzed stuttering children's conversational speech samples and examined the characteristics of the words that led to stuttering episodes as compared to the words produced fluently. Stuttered words were more likely to be low frequency and to have low-neighborhood frequency than fluently produced words. This effect was more marked for what were called "sublexical disfluencies" (sound, syllable repetitions, blocks, and prolongations) than for "lexical disfluencies" common in young children's stuttering (single-syllable, whole-word repetitions). Neighborhood density did not appear to exert a strong effect on either word fluency or stutter-event type. However, because conversational speech samples are naturalistic, they cannot effectively balance or stratify extreme contrasts in neighborhood characteristics. Additionally, because measures were derived from connected speech samples, fluency breakdown could not be unambiguously attributed to the attributes of individual words, as opposed to the larger phrases in which they were embedded. Study of adult SRTs for individual word targets differing in neighborhood characteristics would partially solve this problem, as well as the problem of estimating the actual neighborhood characteristics of children's mental lexicons.

Accordingly, in Newman and Bernstein Ratner (2007), 25 AWS and 25 normally fluent comparison speakers, matched for age and education, participated in a confrontation naming task designed to explore within-speaker performance on naming accuracy, speed, and fluency based on stimulus word frequency and neighborhood density and frequency characteristics. Accuracy, fluency, and reaction time (from acoustic waveform analysis) were computed. In general, AWS demonstrated the same effects of lexical factors on their naming as did adults who do not stutter, suggesting similar profiles of lexical organization, as well as the documented impacts of phonological neighborhood density and frequency for most speakers during lexical access tasks. Frequency effects, however, were larger for the AWS, with low frequency words showing much greater latency and error rates. This finding mirrored others that have found amplified word frequency effects in other clinical populations (Gordon, 2002) and younger speakers (Newman & German, 2002). Stuttering rate was influenced by word frequency as well, but not by other factors. Accuracy of naming was also reduced overall for AWS, suggesting some subtle impairment in lexical access, of unknown origin. The observed error rate suggested that AWS could have a fundamental deficit in lexical representation or retrieval, but the basically similar impact of phonological attributes such as neighborhood density or frequency on both sets of speakers do not suggest differences in abstract phonological representation in people who do and do not stutter.

The stimulus set used in Newman and Bernstein Ratner (2007) was chosen to fit comfortably within adults' and children's estimated mental lexicons. Because studies of children and individuals with word-finding problems have reported amplified effects of frequency and phonological factors on expressive naming patterns, it is possible that underlying differences between PWS and fluent speakers might have been obscured by choice of materials, or sample size limitations. Therefore, we considered it valuable to replicate the paradigm with children, whose lexical representations and organization are still immature, to examine whether differences reflecting use of phonological attributes of words during the lexical access process would emerge.

7. Method

7.1. Participants

Participants included 15 children who stutter (CWS) and 15 children who do not stutter (CWDNS) who were matched for age (within 3 months), vocabulary (standard scores within 15 points on the *Peabody Picture Vocabulary Test-III*), and gender. Each group included 3 females and 12 males; all were native speakers of English. None reported exceptional language or hearing background, with the exception of fluency difficulties; some individuals did have articulation difficulties that had resolved with development. One child in the typically fluent group had been diagnosed with ADHD, although parents of 2 additional CWS indicated that they felt their child had attention difficulties which did not merit a clinical diagnosis. This child's data were retained after *post hoc* analyses that excluded him and his CWS match peer did not yield results differing from analysis that included the pair. CWS ranged in age from 4 years, 10 months to 16 years, 2 months, with a mean of 121.2 months; CWDNS ranged in age from 5 years, 1 month to 16 years, 2 months, with a mean of 121 months. Some CWDNS were siblings of CWS. Data from two additional CWS were removed because the child experienced an excessive number of blocks on the single-word naming, resulting in an inability to measure reaction times. Data from an additional three CWS were lost due to equipment difficulties/poor recordings or for failure to complete the session.

Recruitment of CWS was done primarily through word or mouth/personal contact, by attendance at two national self-help meetings in the local area or through participation in treatment programs at the University of Maryland Speech and Hearing Clinic. Some CWDNS were also recruited from the self-help meeting (friends or siblings of CWS), but most were recruited via a database of families interested in participating in studies on language at the university.

Classification of individuals as being a child who stutters was made by parental report, and was verified by the presence of stuttering in spoken interactions between the examiners and the stuttering child. All children had received therapy for stuttering. Follow-up calls made to families more than a year after conclusion of the study verified that all children could be considered persistent CWS; none had recovered. Fourteen out of 15 parents provided details regarding severity of stuttering and current treatment (a 15th family declined to be interviewed further, but confirmed that the child still stuttered). Five were rated as mild (36%), 2 (14%) were rated as mild-moderate, 2 (14%) were rated as moderate, and 4 (28%) were rated as severe. Seven (50%) were still receiving therapy for their stuttering. The remaining 50% were not in therapy at follow-up: 5 were being followed in an active maintenance program, while two families were looking for an SLP to provide additional intervention for the child's stuttering problem.

7.2. Stimuli: word selection

The stimuli used in this study were taken from a similar study with adult participants (Newman & Bernstein Ratner, 2007). Our goal in the earlier study had been to create a set of stimuli that could be used across a range of ages, and thus all of the words had been selected as being words likely to be known by children as young as 5 years of age. The final words were chosen based on their ability to be pictured clearly, and on the basis of familiarity, neighborhood, and frequency values.

Familiarity ratings were taken from Nusbaum, Pisoni, and Davis (1984), and were based on adult participants' subjective familiarity ratings, with 7 indicating greatest familiarity. Although we did not manipulate familiarity as a factor in this study, we collected this information so that we could ensure that only high-familiarity words were included in our analyses. We then measured the frequency of occurrence of each of our target words using word counts reported in the Carroll, Davies, and Richman (1971) corpus (which is based on occurrences in literature intended for children). These were then transformed into log-frequency values. To determine neighborhood density, each word was first looked up phonologically in a computerized version of Webster's dictionary. All of words in the lexicon that differed from the target word by a single phoneme (either a single phoneme addition, deletion, or substitution) and that had familiarities of at least 6.0 on the 7-point familiarity scale (Nusbaum et al., 1984) were considered to be neighbors for this analysis. However, because we wanted to ensure that these items would be appropriate for young children, we also recalculated neighborhoods in a second manner. The dictionary-based approach includes many items as "neighbors" which young children are unlikely to know. We therefore checked each of these neighbors in the Carroll frequency listing; any item that did not have a *U*-value of at least 1.0 was excluded from consideration as a neighbor for the second analysis. This resulted in only minor changes in values. For neighborhood frequency, we calculated frequency (as above) for each of the neighbors. We then took an average of these values as being the average neighborhood frequency for each word. For this analysis, we used neighborhood frequency values based on the child-set. From these sets of data, three sets of words were chosen for testing. All measurements were performed on the base morpheme (singular form for nouns, the infinitive form for verbs).

The first set of words consisted of two lists differing in word frequency, or the frequency with which the words commonly are encountered. (The list of words, along with mean and standard deviations of their lexical values, is given in Appendix A.) There were 21 items in each list; the low-frequency list had an average log frequency of 0.85, corresponding to a raw value of approximately 10 instances per million (range 1.5–27); the high-frequency list had an average log frequency of 2.68, corresponding to a raw value averaging over 1000 times per million (range 76–4850).

The second set of words consisted of two lists differing in neighborhood density. Neighborhood density refers to the number of items in the lexicon that are similar to the target word. Each list contained 22 words, with an average of 5.18 neighbors in the sparse set, and 22.9 neighbors in the dense set based on the adult neighborhood calculations, and an average of 4.36 neighbors in the sparse set, and 22.5 neighbors in the dense set based on the child neighborhood calculations.

The third set of words consisted of two lists differing in neighborhood frequency, or the frequency with which the neighbors are encountered. This can be thought of as a measure of the frequency with which the sound pattern in general is encountered. (Indeed, for the target words, neighborhood frequency strongly correlated with both biphone-based phonotactic probability and phoneme-based phonotactic probability once the number of phonemes in the words was accounted for; for phonemes, $r = 0.43$, $p < .005$; for biphones, $r = 0.41$, $p < .01$.) Each list contained 22 words, with an average log neighborhood frequency of 0.87 for the low-neighborhood frequency set, and 2.00 for the high-neighborhood frequency set.

For all three sets, the two lists consisted of the same distribution of initial phonemes. Moreover, the lists were matched in terms of the average number of syllables per word, the average number of phonemes per word, and in terms of all factors not being explicitly manipulated (i.e., word frequency, neighborhood density, and neighborhood frequency). See Newman and Bernstein Ratner (2007) for more details on the stimulus selection, matching, and the selection of images to represent these words.

7.3. Stimulus presentation and order

All three word sets were presented to the participants in a combined fashion, with word sets intermixed. Because the different word sets contained some overlap, there were a total of 107 target words tested. Most of the target words were nouns, but a small number (7) were verbs. We subdivided the words into these two groups. Half of the participants were tested on nouns first, and half were tested on verbs first. Order of trials within each set was randomized for each participant. For the nouns, participants were told to name the item they saw on the screen, using a single-word answer. For the verbs, participants were told to identify what the person or people in the picture were doing, again using a single-word answer. Prior to each word type, participants were given a 10-item practice set. (So, prior to being tested on nouns, participants received a practice set of nouns; prior to being tested on verbs, participants received a practice set of verbs.) This allowed us to ensure that participants understood the instructions and were comfortable with the task. Because there were so many nouns, these were randomly subdivided into 5 blocks of 20 words each; the order of trials within each block was randomized for each child.

Thus, from the point of view of participants, there were 8 blocks of words they were asked to name: 1 practice block of nouns, 5 test blocks of nouns, 1 practice block of verbs, and 1 test block of verbs. From our point of view in conducting analyses, there were three sets of words that were examined separately: words differing in frequency, neighborhood density, and neighborhood frequency.

7.4. Procedure

Participants were seated comfortably in front of a computer screen or laptop, facing a Shure SM81 microphone. At the start of each trial, the computer would beep. This occurred simultaneously with the picture appearing on the computer screen. Children were asked to identify the picture as quickly and accurately as possible by saying the word aloud. All responses were recorded on compact disk, using a Marantz CDR300 portable CD recorder. After the participant responded, the experimenter pressed a button on the computer mouse or button box, which advanced the

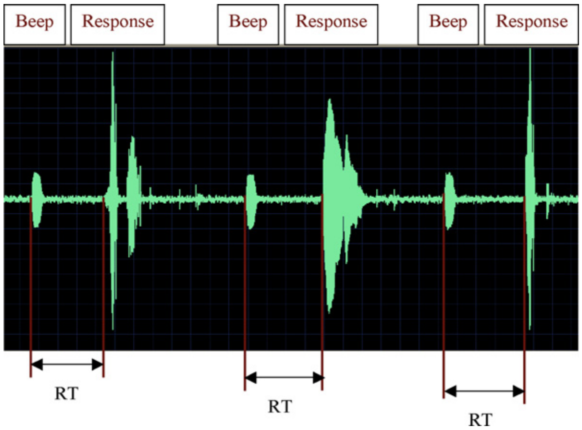

Fig. 1. Image of waveform, with beeps, speech, and reaction times marked.

experiment to the next trial. There was a 1000 ms inter-trial interval between the experimenter's button press and the onset of the following trial.

7.5. Coding and reliability

Experimenters listened to the recordings to determine the accuracy of the participants' responses, and to judge whether the participant stuttered on that response. Stuttering episodes were relatively rare for most of the 15 participants, although two children exhibited initial part-word repetitions on over half of the targets: one had a stuttering episode on 86 trials (out of 107), the other on 51 (out of 107). Thus, reaction time values could not be obtained for these participants. (These are an additional two participants to the ones excluded for constant blocking.) Response times were measured on the digital waveform as the time between the onset of the beep and the onset of the participant's response, using Syntrillium's CoolEdit program (see Fig. 1). Reaction times were only measured when the participant's response matched the one intended. For part-word repetitions, response times were measured to the onset of the first (incomplete) attempt at the response. The same coders measured the reaction times in this study as in the prior study on adults who stutter and a similar study on typically developing children (both of which used the same procedure and target items); reliability for both of the prior two studies had been assessed by having a second individual code a minimum of 10% of the data; average reliability in the two studies ranged from .945 to .96.

In the current study, pictures were identified as intended 86.1% of the time, on average. Other responses were classified as either true word-finding difficulty or response errors, dialectal variants or alternate word choices, elaborations, and visual confusions. Classification of errors was juried. Dialectal variants were responses that were correct, but not the word we had intended; some of these variations may be a result of dialect differences, while others might be considered appropriate synonyms or near-synonyms. Examples include "*garbage*" for "*trash*", "*bicycle*" for "*bike*", and "*puppy*" for "*dog*". Elaborations consisted of multiple word responses, such as "*Christmas bell*" instead of "*bell*", "*baby bottle*" instead of "*bottle*", "*swim goggles*" instead of "*goggles*", in which the correct word was included but was not the first part uttered. Both of these types of responses were considered correct responses for the accuracy analyses; however, no reaction time was generated since the participant did not initially give the intended utterance. Elaborations occurred 1.5% of the time overall; dialectal variants also occurred 1.5% of the time. Visual errors consisted of responses suggesting the person had misperceived the picture itself or what aspect of it they were supposed to name; examples include "*stalagmites*" for "*icicles*", "*argueing*" for "*fighting*", "*man*" for "*beard*". These occurred only 2.6% percent of the time overall, and these trials were excluded from the analysis for that particular individual.

Word-finding errors consisted of any response indicating that the person was having trouble finding the correct word (such as saying, "I don't know", "what's that called again?", or giving an incorrect response and then self-correcting, such as "*shoe*, *I mean socks*!"), giving a related but incorrect response ("*comb*" for "*brush*", or "*mop*" for "*broom*"), or giving a generic response that suggested the picture was correctly perceived (for example, "*bird*" for "*swan*", "*money*" for "*dime*"). In addition, if the individual said "ummmm" or "uhh" more than once on a trial, it was considered an indication of a word-finding problem (this occurred on only 1 trial and was combined with long reaction times, indicating difficulty; see German, 1991). Across words, these word-finding errors occurred 7.7% of the time overall. There were also some items which were named correctly but for which response times were unavailable; generally, these were the result of the participant talking, laughing, or coughing over the start of the trial (indicating they were not ready to respond), or of the beep being inaudible as a result of background noise. Reaction times for 33 trials across the 30 participants (or approximately 1%) needed to be eliminated for this reason; this was no more common in CWS than in CWDNS (19 times vs. 14 times, $t(14) = 0.52$, $p > .05$).

One concern is that elaborations or dialectal responses could have been a means of avoiding difficult words for individuals who stutter. In fact, children who stuttered were marginally more likely to give alternative word choices (a total of 28 vs. 19 such responses; $t(14) = 1.79$, $p < .10$) or to elaborate (a total of 32 vs. 15 such responses, $t(14) = 1.97$, $p < .07$). These differences, however, average to approximately 1 word difference per pair of children, and are thus unlikely to have a major effect on the results (for dialectical differences, averages are 1.87 vs. 1.27 such responses per child; for elaborations, 2.13 vs. 1.0 responses per child). The two groups did not differ on the number of stimulus errors made (total of 38 vs. 44 such responses, $t(14) = 0.59$, $p > .05$).

8. Results

We first report overall patterns of the error data. Next, we looked separately at the analyses of items by frequency, neighborhood density, and neighborhood frequency. These analyses were performed separately on the three types of data collected: reaction times, accuracy, and stuttering episodes.

Reaction time measurements were performed only on responses that matched what was intended. For the reaction time analysis, we removed from analysis any item with an RT more than 2 standard deviations from that individual's mean response time. However, because we were unsure whether this would have a differential effect on the two groups of participants, we also analyzed data without outliers removed, and report any situation in which these provide different values.

8.1. Overall analyses

Although there was a slight tendency for CWS to have overall slower RTs, this difference was not significant. On average, CWS responded in 1.27 s to each stimulus (standard deviation = 185 ms); CWDNS responded in 1.20 s (standard deviation 267 ms), a difference of 66 ms, $t(14) = 1.21$, $p > .20$. Without outliers removed, the difference is 82 ms, still nonsignificant, $t(14) = 1.32$, $p > .20$. Likewise, CWS did not appear to be significantly less accurate than CWDNS; accuracy scores were 90.9% for CWS and 92% for CWDNS, $t(14) = 1.04$, $p > .30$. This is somewhat different from our previous results with AWS; AWS were significantly less accurate than AWDNS on this same set of items (94.3% vs. 97.6%). Thus, while the children were clearly less accurate than adults in general, the naming performance difference between individuals who do and do not stutter appears to increase with age.

8.2. Effects of word frequency

Looking at reaction times, there was no overall effect of group ($F(1,14) = 0.73$, $p > .40$), again suggesting that CWS were no slower than those who do not stutter. As expected, there was an overall effect of word frequency, with slower reaction times to low-frequency words (1.317 s to low-frequency words, 1.203 s to high-frequency words, or a 114 ms difference, $F(1,14) = 20.35$, $p = .0005$), as shown in Fig. 2. This effect of word frequency was significant in both groups separately (CWS: $t(14) = 3.72$, $p < .005$; CWDNS: $t(14) = 4.20$, $p < .001$). There was no hint of an interaction ($F(1,14) = 0.01$, $p > .90$).

Looking at individuals' rates of word-finding errors likewise showed no effect of group ($F(1,14) = 0.15$, $p > .70$) and no interaction ($F(1,14) = 0.55$, $p > .45$). There was a trend towards an effect of word frequency, but this was not significant (11% errors for low-frequency words vs. 7.4% for high-frequency words, $F(1,14) = 2.52$, $p = .135$).

Thus, in general, children were highly accurate with all of the words, but were slower at naming words that are less common in the language. This was the case for both children who stutter and children who do not stutter, with no differences between groups.

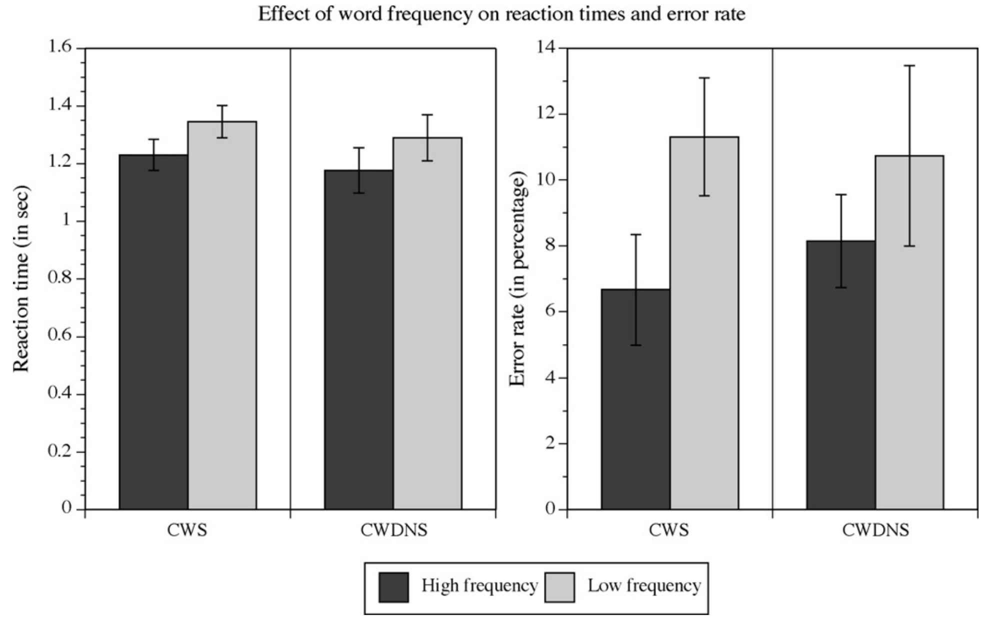

Fig. 2. Effect of word frequency on reaction times (left) and error rate (right) for both CWS and CWDNS; error bars indicated standard error.

8.3. Effects of neighborhood density

Looking at reaction times showed no effect of group ($F(1,14) = 1.18$, $p = .29$), no effect of density ($F(1,14) = 0.002$, $p > .95$), but did show a significant interaction ($F(1,14) = 5.82$, $p < .05$) (see Fig. 3). (This is the one location where removal of outliers mattered, since the interaction was not present when all trials were included, $F(1,14) = 1.53$, $p = .24$.) Children who stuttered showed a slight speed advantage for words from sparse neighborhoods (1.250 s vs. 1.284 s, or a 34 ms difference), while CWDNS showed a slight advantage for words from dense neighborhoods (1.218 s vs. 1.185 s, or a 33 ms difference). However, neither effect was significant in isolation (CWS: $t(14) = 1.48$, $p = .16$; CWDNS: $t(14) = 0.86$, $p = .40$). Thus, while there appears to be a difference between groups, the lack of an effect in either group makes it difficult to assess how consistent these findings might be.

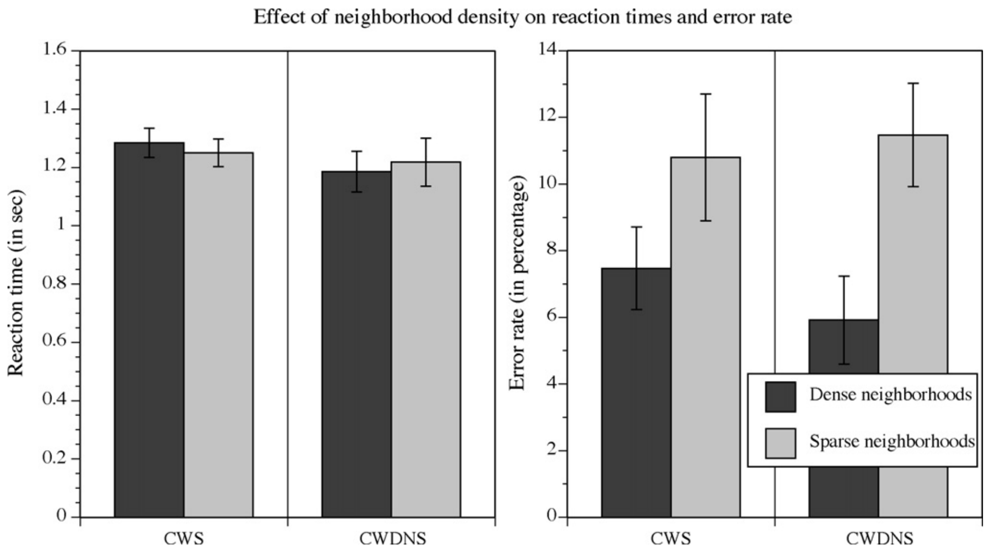

Fig. 3. Effect of neighborhood density on reaction times (left) and error rate (right) for both CWS and CWDNS; error bars indicated standard error.

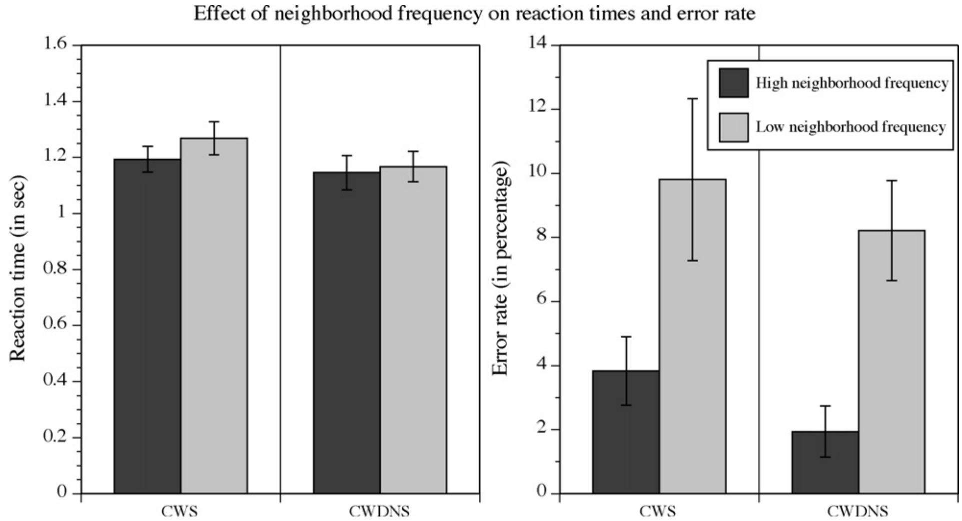

Fig. 4. Effect of neighborhood frequency on reaction times (left) and error rate (right) for both AWS and AWDNS; error bars indicated standard error.

Despite these null results for neighborhood density in the reaction times, the accuracy data show a strong effect of neighborhood density ($F(1,14) = 10.56$, $p = .006$). There was again no effect of group ($F(1,14) = 0.10$, $p > .70$), and there was also no interaction with group ($F(1,14) = 0.52$, $p > .48$). Children erred on words from sparse neighborhoods 11.1% of the time, compared to 6.7% of the time for words from dense neighborhoods. Looking at the two groups separately, we found that CWDNS erred 11.5% of the time to words from sparse neighborhoods, compared to 5.9% to words from dense neighborhoods ($t(14) = 2.75$, $p < .02$); this pattern was similar but not significant in CWS (10.8% vs. 7.5%, $t(14) = 1.60$, $p = .13$). This is similar to the pattern found previously with adult participants (who erred on 6% of words from sparse neighborhoods, but only on 3.3% of words from dense neighborhoods). Thus, as was found with adults, children (regardless of whether they stutter) tend to err on words from sparse neighborhoods.

8.4. Effects of neighborhood frequency

Neighborhood frequency refers to the frequency with which a word's neighbors occur, and can be thought of as roughly a measure of how often the general sound pattern is encountered. The effect of neighborhood frequency was highly significant in the reaction time data, with participants naming words with common sound patterns (high-neighborhood frequency) more quickly than words with rarer patterns (1.218 s vs. 1.169 s, a 49 ms difference, $F(1,14) = 9.25$, $p < .01$), as shown in Fig. 4. There was again no effect of group ($F(1,14) = 1.81$, $p = .20$) nor any interaction between group and neighborhood frequency ($F(1,14) = 2.15$, $p > .15$). Looking at the individual groups shows a similar pattern in both groups, although this was significant only in the CWS (CWS: $t(14) = 2.74$, $p < .02$; CWDNS: $t(14) = 1.02$, $p = .32$). Accuracy data shows a stronger effect of neighborhood frequency, $F(1,14) = 15.18$, $p < .002$, with 9% errors on words with low-neighborhood frequency, and 2.9% errors on words with high-neighborhood frequency (but again no effect of group, $F(1,14) = 1.71$, $p = .21$ and no interaction $F(1,14) = 0.02$, $p > .90$). The effect was significant in both groups (CWS: 9.8% vs. 3.8%, $t(14) = 2.52$, $p < .05$; CWDNS: 8.2% vs. 1.9%, $t(14) = 4.00$, $p < .002$).

8.5. Effects on speech fluency

In the prior study using adult participants (Newman & Bernstein Ratner, 2007), enough response items were stuttered to permit an analysis of word frequency and neighborhood characteristics on stuttering. However, this was not the case in the current study. While children who stutter were heard to stutter during the instructional portion of the activity and during some test items, the number of stuttered productions per stimulus ranged from 0 to 2 events, as judged by two listeners. Stuttered items were discarded for response time analyses, but were not frequent enough to permit any systematic analysis of frequency or neighborhood effects on fluency. (It is worth pointing out, however, that there were two children who exhibited part-word repetitions on the vast majority of their responses; data from these participants, however, had been eliminated from analysis, as described in Section 7.1.)

9. Discussion

In this study, we investigated the effects of three different lexical factors known to affect ease of access in fluent speakers, on the lexical access in children who stutter. We found effects of lexical neighborhood, neighborhood frequency and word frequency in the children's responses, although it varied whether these effects were found in response latency patterns, accuracy patterns, or both. But in most cases, what effects we found occurred for both fluent and stuttering participants. The one exception was neighborhood frequency, which affected the reaction times of CWS but not of CWDNS (although it influenced both groups' data in their accuracy measures). The size of these effects was fairly comparable across groups, suggesting no significant differences in lexical organization between children who stutter and those who do not.

In this regard, the current findings are consistent with those of our earlier study (Newman & Bernstein Ratner, 2007), conducted with a slightly larger cohort of stuttering and fluent adults. However, in that study, discernable differences in accuracy of naming were found; adults who stutter made significantly more frank naming errors than did fluent peers. We anticipated that use of a younger cohort and the same stimulus set might magnify such differences, since children conceivably would find the set more challenging than adults. However, no such difference was found, suggesting that both expressive naming ability for this stimulus set as well as phonological network representation of the stimuli were equivalent across the two study groups.

We note that this study and our earlier study examined single-word production prompted by a relatively small set of concrete, picturable nouns and a smaller set of action verbs. In this regard, it is difficult to draw firm conclusions about the nature of lexical retrieval during naturalistic utterance formulation in PWS from this type of task. Additionally, analysis of the time course of processes involved in lexical retrieval may require use of techniques such as ERP or MEG, rather than analysis of spoken output. In this regard, we encourage further extension of paradigms being used to isolate and plot the time course of lexical encoding in typical populations to people who stutter, as employed, to date, primarily by Weber-Fox and colleagues.

The children in this study also varied widely in age, and were, for the most part, older than those used in Conture and colleagues' priming studies. The fact that phonological priming differentiated some children who stutter from age-matched peers under the age of 10 years should encourage greater emphasis on the use of experimental paradigms in studies of language production in typically developing children with children closer to the onset of stuttering symptoms, although some of the designs used to plot the time course of lexical encoding (cf. Indefrey & Levelt, 2004) may be too sophisticated for use in this age range.

Although we made every attempt to control features of target words across high and low density neighborhoods, inspection of the stimuli in Appendix A might suggest that there is a higher concentration of words in the low density list having consonant clusters. Some work, notably by Howell and colleagues (cf., Dworzynski & Howell, 2004), suggests that phonetic complexity might play a role in precipitating fluency failure in PWS, and thus, might have exerted some effect on accuracy and fluency of word retrieval in our study. However, we note that relatively few stutters were observed in the elicited naming data, and that stuttering did not appear to be influenced by neighborhood characteristics. Next, Howell's rubric is based on spontaneous production data, and it is unclear how well it might capture aspects of lexical organization and storage. Finally, in other work from our laboratory, the limitations of phonetic complexity indices in explaining speech production patterns in both typical speakers as well as individuals who stutter has been discussed at some length (see Bernstein Ratner, 2005).

Given these cautions, it is possible that lexical organization, retrieval and encoding does differ in speed, accuracy or nature between children who do and do not stutter. However, our experimentally controlled task, now administered across a wide age range of individuals who stutter and well-matched fluent peers, as well as that conducted with younger children by Arnold et al. (2005) do not reveal any obvious differences that might be reflected in terms of frequency or neighborhood characteristics of canonical word forms, although such characteristics may exert an exacerbating effect on speech fluency during connected conversational speech (Anderson, 2007).

Given such findings, we believe it is more likely that phonological profiles of stuttered speech are attributable to other concurrent demands on the language formulation system, such as co-occurring motor, memory or cognitive demands during speech production, as suggested by researchers such as Smith, Weber-Fox and their respective colleagues (cf., Smith & Kleinow, 2000; Weber-Fox, 2001) as well as Bosshardt (1999, 2002). Alternatively, other linguistic regularities that have been observed in stuttered speech production may reflect demands imposed by other hypothesized levels of language encoding, such as syntactic or grammatical planning or realization.

CONTINUING EDUCATION

Effects of word frequency and phonological neighborhood characteristics on confrontation naming in children who stutter and normally fluent peers

QUESTIONS

(1) Which of the following is generally NOT true of linguistic features of stuttering across the age span?
  (a) Adults tend to stutter more on content words than function words.
  (b) Children tend to stutter more on function words than content words.
  (c) Across both age groups, nouns attract more stuttering than do verbs or function words.
  (d) Stuttering is more likely on less frequent words of the language.
(2) Which of the following has been observed in experimental studies of naming in people who stutter?
  (a) Adults who stutter may have slower lexical decision times than typically fluent adults.
  (b) Children who stutter do not appear to benefit from any types of priming, which normally facilitates language production in people who do not stutter.
  (c) People who stutter have more difficulty deciding whether stimuli rhyme than people who do not stutter.
  (d) Event-related potentials (ERPs) recorded during experimental tasks are generally similar between people who stutter and typically fluent individuals.
(3) This study involves rapid naming of words that differ in their frequency and neighborhood characteristics. Which of the following is true about lexical frequency and phonological neighborhoods?
  (a) Frequency is the typical pitch that characterizes the phonemes in a word, while neighbors are those words with similar acoustical patterns.
  (b) A phonological neighborhood is the number of words in the language that differ from a target by only one phoneme.
  (c) Neighborhood frequency is the number of words in a language sharing high-frequency spectra, such as fricatives.
  (d) Sparse neighborhoods always contain low frequency words.
(4) The current study is based on a similar, preliminary study in adults. In the prior study, the authors found that:
  (a) Phonological neighborhood and word frequency characteristics do not distinguish adults who stutter from their fluent peers in terms of reaction time (RT).
  (b) Adults who stutter are as accurate in their naming as adults who do not stutter.
  (c) Phonological neighborhood factors have different effects on accuracy and reaction time in people who stutter compared to fluent peers.
  (d) Adults who stutter have more difficulty retrieving words from sparse neighborhoods than do adults who do not stutter.
(5) In the current study, results suggest that:
  (a) Children who stutter show very different patterns on the experimental task than do adults who stutter; they differ from their fluent peers in response to frequency and neighborhood variations.
  (b) Children who stutter are much less accurate in their naming of the experimental stimuli than are their fluent peers.
  (c) The mental lexicons of people who stutter must be organized very differently than those of fluent speakers.
  (d) As with adults who stutter, children who stutter do NOT appear to organize their mental lexicons very differently than do fluent speakers.

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Appendix A.

Listed below are the complete set of words tested for each comparison, along with the summary values for each set. Numbers in parentheses are standard deviations. * indicates a verb.

Low frequency words: Ant, icicle, barn, bike, chin, clap*, dice, dime, phone, goggle, hanger, hose, heel, leash, muffin, mummy, rake, shower, trash, tooth, web

Average log word frequency: 0.851 (0.425).
Average # neighbors: 10.15 (7.42).
Average neighborhood frequency: 1.399 (0.534).

High-frequency words: Apple, eye, boy, bee, chicken, car, door, dog, finger, girl, house, horse, hand, leg, money, man, write*, shoulder, table, tree, witch

Average log word frequency: 2.678 (0.535).
Average # neighbors: 10.20 (8.33).
Average neighborhood frequency: 1.424 (0.452).

Low-neighborhood density words: Box, brush, beard, block, boy, dance*, dress, frog, flag, farm, goose, house, horse, crib, queen, crawl*, clown, climb*, cow, mouth, knife, watch

Average log word frequency: 1.892 (.610).
Average # neighbors: 4.36 (1.84).
Average neighborhood frequency: 1.594 (.394).

High-neighborhood density words: Bell, bear, bowl, boat, bat, dime, deer, fan, fight*, phone, gun, heel, hat, cake, car, kick*, cap, cat, coat, man, net, whale

Average log word frequency: 1.893 (.474).
Average # neighbors: 22.50 (3.78).
Average neighborhood frequency: 1.596 (.224).

Low-neighborhood frequency words: Apple, balloon, broom, box, egg, finger, fly, fence, girl, candle, climb*, car, lamb, necklace, nail, swan, spider, sock, sink, shoulder, tractor, whistle

Average log word frequency: 1.764 (.539).
Average # neighbors: 7.22 (6.86).
Average neighborhood frequency: 0.872 (.376).

High-neighborhood frequency words: Ant, bike, bed, bottle, elephant, frog, flag, feather, glass, crawl*, kite, key, leaves, needle, knee, snail, ski*, smile snow, shoe, turtle, watch

Average log word frequency: 1.769 (.392).
Average # neighbors: 7.32 (6.55).
Average neighborhood frequency: 2.003 (.310).

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