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The Role of Selected Lexical Factors on Confrontation Naming Accuracy, Speed, and Fluency in Adults Who Do and Do Not Stutter

Rochelle S. Newman
Nan Bernstein Ratner
University of Maryland

Purpose: The purpose of this study was to investigate whether lexical access in adults who stutter (AWS) differs from that in people who do not stutter. Specifically, the authors examined the role of 3 lexical factors on naming speed, accuracy, and fluency: word frequency, neighborhood density, and neighborhood frequency. If stuttering results from an impairment in lexical access, these factors were hypothesized to differentially affect AWS performance on a confrontation naming task.
Method: Twenty-five 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 characteristics. Accuracy, fluency, and reaction time (from acoustic waveform analysis) were computed.
Results: In general, AWS demonstrated the same effects of lexical factors on their naming as did adults who do not stutter. However, accuracy of naming was reduced for AWS. Stuttering rate was influenced by word frequency but not other factors.
Conclusions: Results suggest that AWS could have a fundamental deficit in lexical retrieval, but this deficit is unlikely to be at the level of the word's abstract phonological representation. Implications for further research are discussed.

KEY WORDS: stuttering, lexical access, naming

Although the underlying causes of stuttering are not known, there are a number of linguistic regularities that characterize stutter events in both adults and children (see Bernstein Ratner, 1997, for a review). As a result, a number of authors (see, e.g., Howell, Au-Yeung, & Sackin, 2000; Karniol, 1995; Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993) have suggested that its distal or proximate cause may lie in some weakness in retrieving or assembling utterance elements. 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.

It remains unclear whether stuttering moments reflect impairment in linguistic processing or are the result of more generalized capacity limitations that may affect the motoric encoding of linguistic elements (see Bosshardt, Ballmer, & de Nil, 2002; Weber-Fox, Spencer, Spruill, & Smith, 2004, for support for such a multifactorial view of the core deficit in stuttering). However, the notion that the problem could potentially lie in an aspect of phonological, lexical, or syntactic retrieval or encoding suggests that further examination of these stages of processing is warranted. The

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current article focuses particularly on the stage of lexical access. In the sections that follow, we describe both what is known about lexical organization and access, and, in particular, the lexical retrieval skills of individuals who stutter.

Models of Lexical Access

Contemporary models of word production suggest that lexical access consists of a series of distinct stages, including (at least), conceptual preparation, lemma retrieval, and word-form encoding (Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992). The last stage consists of a number of different substages, including accessing the word form as a whole and accessing sublexical units that make up that word form. One adapted model of language production focuses on single-word retrieval (German, 2000). This model is based on work by Levelt and colleagues (Levelt, 1989, 1991, 1999), and contains four stages. During the process of naming a picture, the first stage involves the picture eliciting the conceptual structure or underlying concepts associated with a target word (Bierswisch & Schreuder, 1991). In the second stage, activation spreads from this conceptual structure to the target word's lemma (its semantic and syntactic features), selecting that lemma from among neighboring entries (Garrett, 1991). In the third stage, activation spreads from the lemma to the entry's corresponding abstract phonological properties (its syllabic frame and phonemic units); this results in the creation of a complete phonological schema (Levelt, 1991). Finally, in the fourth stage, a motor plan is created and forwarded to lower level articulation processes in order to produce the word. Although the extent to which this adapted model and its components are fully descriptive of lexical retrieval awaits further investigation, this model has been fruitfully applied to a number of clinical and typical populations (German, 2000; German & Newman, 2004; Newman & German, 2002, 2005).

Although there are competing models of both lexical access and production (Dell, 1986; Luce & Pisoni, 1998), Levelt and colleagues' model (known as WEAVER++; Roelofs, 2000) has most frequently been applied to linguistic analyses of stuttering (e.g., Postma & Kolk, 1993; Wijnen & Boers, 1994; Yaruss & Conture, 1996). We therefore selected this model as an underlying framework for examining factors that might influence lexical access in adults who do and do not stutter.

This model, as well as models based on it, makes certain predictions regarding the impact of lexical factors on the ease of access and production (German, 2000; Levelt, 1999). For example, it should be easier to access a word's phonological form if that word is encountered more frequently in the language. Similarly, words with more common phonological patterns should be easier to access. Both of these effects occur in a stage following lemma activation (Levelt, 1999). They may, however, occur at slightly different stages in processing, because word frequency involves a word's complete form, whereas phonological pattern frequency involves the frequency of sublexical units (see Luce & Pisoni, 1998; Vitevitch & Luce, 1998).

Lexical Factors in Typical Speech Production

A number of factors appear to organize the mental lexicon and influence ease of lexical retrieval. These factors include the frequency with which a word occurs and its similarity in phonological form to other known words.

Word Frequency

Some words occur more frequently in the language than do others, and this influences how easily they are accessed. 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).

Lexical Neighborhood

Another 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), the process of discriminating among possible words is "a function of the number and … acoustic–phonetic similarity among the activated lexical items" (p. 12). Although this model was designed to focus on distinguishing among possible lexical items perceptually, the basic notion is that selecting a particular word will depend not only on properties of that word, but also on its phonological similarity to other known words. Some words will be similar to many other words (e.g., the word *let* is similar to *bet, less, lent,* and *light,* among many others), whereas other words will be similar to far fewer (e.g., the word *kept* is similar to only three other English words, *crept, Celt,* and *wept*).[1] These storage differences can affect how words are accessed. Words from *dense neighborhoods* (those similar to many words) tend to be repeated aloud (named)

[1]Although some past tense forms, such as *capped,* might be considered to be phonological neighbors and indeed, there is ongoing debate on this concept, current research tends to favor a view in which regular past tense and plural markings are decomposed (see Frost, Grainger, & Rastle, 2005). Thus, we presume that the lexicon does not have separate entries for regular past tense or pluralized forms, and such forms do not count as neighbors.

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. However, the accuracy of word retrieval appears to be enhanced by the presence of neighbors, perhaps because they help the speaker reach the appropriate region of lexical space. 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). Some studies suggest that speakers name words more quickly from dense neighborhoods after studying them (Vitevitch, 2002). However, there are some contradictory findings. For example, 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 greatest in children and adolescents than in young or older adults. Some of these differences may be the result of difference in task methodology. For example, Vitevitch's (2002) task, with its prior stimulus studying phase, was designed to measure speed of retrieval in a fluent production, whereas Newman and German's work was designed to elicit errors. Alternatively, it may be the result of differences in the populations tested; perhaps neighborhood frequency 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 occur can also influence lexical access. For example, *kept*'s neighbors are not only few, but those neighbors are very low-frequency words of English. In contrast, the word *weld* has some very high-frequency neighbors, such as *well* and *world*. However, this effect appears to demonstrate a more variable impact on speech production. *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. Likewise, 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). Moreover, 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. Thus, across a number of methodologies, neighborhood frequency has been found to influence naming speed and accuracy. It generally shows a facilitative effect, with greater accuracy and faster responding on items with high neighborhood frequency.

Lexical Processing in People Who Stutter

As early as 1923, well before more recent hypotheses that stuttering might reflect some sort of psycholinguistic impairment, some researchers posited that stuttering reflected a type of word retrieval disability (Scripture & Kittredge, 1923). Is there evidence that people who stutter show differences in lexical ability or processing? We do know that lexical factors affect patterns of fluency in people who stutter. Words that are less common in the language are more likely to be stuttered (Danzger & Halpern, 1973; Hubbard & Prins, 1994; Palen & Peterson, 1982; Prins, Main, & Wampler, 1997; Ronson, 1976; Soderberg, 1966). When frequency is controlled for, nouns tend to be stuttered less in conversational speech than other content words (Quarrington, Conway, & Siegel, 1962). In contrast, few regular and systematic phonological factors appear to be associated with elevated stutter frequency (see Bernstein Ratner, 2005), other than a typical finding that vowels are often stuttered less in adult speech than consonants (see summary in Quarrington et al., 1962).

Given the difficulty of controlling or balancing phonological, lexical, and syntactic factors in spontaneous corpora, a number of studies have relied on standardized tests or laboratory tasks to uncover potential lexical factors that might distinguish adults who stutter (AWS) or influence stuttering frequency (patterns that might implicate the lexicon or access to it as a factor that precipitates fluency breakdown in stuttering). For example, vocabulary depression or lexical difficulty (such as the ability to resolve ambiguity) has been noted in some studies of adults and children who stutter (Arnold, Conture, & Ohde, 2005; Byrd & Cooper, 1989; Murray & Reed, 1977; Scripture & Kittredge, 1923; Watson et al., 1994; Westby, 1974) and on conversational measures of lexical diversity in children (Silverman & Bernstein Ratner, 2002). Another task that has been used is lexical decision, which requires the speaker to indicate, manually or vocally, whether a visual stimulus is a real word of the language. Slower overall lexical-decision times have been noted for AWS (Hand & Haynes, 1983; Rastatter & Dell, 1987).

Other studies have asked AWS to name words aloud, particularly in response to pictures. AWS tested by Prins et al. (1997) showed slower latencies than did fluent speakers on picture naming tasks, even when the set consisted of as few as eight familiar nouns and verbs pretested for recognition. Verb encoding was particularly slowed, as was naming of low-frequency words. Thus, again, AWS appear slower to respond to lexical items, particularly when those items are low in frequency of occurrence.

The organization of the mental lexicon is also thought to be reflected in the effects of priming on the speed of lexical retrieval. In priming studies, baseline measures of lexical decision or word-naming latency are contrasted to conditions in which the target is preceded by a semantically or phonologically similar item. For example, people are faster to respond to the word *cat* after hearing the word *dog* because dog and cat are semantically linked in the mental lexicon. Similarly, phonological priming is demonstrated by faster responding to *cat* after hearing a similar-sounding word, such as *cap*. One study (Burger & Wijnen, 1998) suggested that AWS require larger amounts of phonological priming information (initial consonant + vowel) to speed speech onset compared with consonant-only priming in adults who do not sutter (AWDNS). However, in a follow-up study, although Burger and Wijnen (1999) showed slower reaction times (RTs) in a phonological priming study of single-word naming, they showed no reliable effects that differentiated priming patterns between the groups. Likewise, in a recent study of 3–5-year-old children, Melnick, Conture, and Ohde (2003) did not find patterns of generalized slower RTs to picture naming, nor differential effects of phonological priming across groups. Thus, phonological priming appears to be comparable between individuals who do and do not stutter. Different patterns have been found for semantic priming, however. Pellowski and Conture (2005) found children who stutter to be slower than similarly aged peers in naming both unprimed and semantically primed picture stimuli. Additionally, semantic priming did not appear to speed RTs for the children who stutter, while it facilitated the speech of their fluent peers. These results imply that the mental lexicons of fluent and stuttering speakers may be organized similarly in terms of phonological properties of words, but may differ in terms of semantic organization or activation. This implies that lexical deficits in AWS may be more likely to be found at stages involving concept and word activation than at sublexical or form-based levels. However, these studies differed not only in the type of priming involved, but also in the task and the age groups; this makes any definitive conclusions tentative at best.

AWS also have slower RTs on tasks requiring phonological monitoring (such as judging whether things rhyme) and lexical analysis (semantic category judgment; Bosshardt, 1993, 1994). Most recently, Sasisekaran and colleagues utilized a classic phoneme monitoring paradigm with stuttering and fluent adults, and reported slowed phoneme monitoring in AWS, suggesting delayed phonological encoding ability (Sasisekaran, De Nil, Smyth, & Johnson, in press). Alternatively, because phoneme monitoring task RTs are also affected by nonphonological attributes of words, it is possible that the study's results could reflect slower ability of AWS to access other types of information (such as semantic, syntactic, or frequency of use).

In general, AWS are slower in response to both auditory and visual stimuli, and even show slowed galvanic skin responses to auditory stimuli, raising concerns that slowed absolute latencies of response to verbal tasks may not be specific to linguistic processing or be informative regarding the basis of the presumed deficit (see summary in Starkweather, Franklin, & Smigo, 1984). However, others have argued that slowing is limited to activities requiring vocal responses only (Reich, Till, & Goldsmith, 1981), and some have found no evidence of generalized slowing (McFarlane & Shipley, 1981). McFarlane and Shipley did find relatively slower responses of AWS to auditory cues, but no differences when responding to visual cues, as in the present article. In a recent study using rhyme judgment tasks conducted by Weber-Fox et al. (2004), AWS showed atypically increased RTs under conditions of increased cognitive load, such as incongruence between orthography and phonology (e.g., *gown–own*). In discussion, 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). Because past research had shown aberrant event-related potential (ERP) patterns in AWS for receptive lexical processing (Weber-Fox, 2001), it is possible that it is not speech production, per se, that is aberrant in AWS, but the lexical retrieval and encoding prior to motor action that are impaired. Moreover, other work done by Weber-Fox's colleagues (e.g., Smith & Kleinow, 2000) suggests that language demand can adversely affect motor stability of articulatory patterns in AWS, providing a mechanism whereby potential language weakness could cascade through the motor system during speech production.

In contrast to a number of researchers who have targeted lexical abilities in AWS as a potential underlying source of speech encoding difficulty, Packman, Onslow, Coombes, and Goodwin (2001) rejected lexical retrieval as a primary factor in stuttering, because their 3 participants stuttered during reading of nonword sequences. Thus, they argued, failures of lexical retrieval are not necessary conditions to trigger stutter events. We would agree, but are not sure that their rather unique and limited study can answer questions about how stuttering arises in the language acquisition process, or how lexicalization factors that operate during meaningful sentence generation might trigger stutter events. Au-Yeung and Howell (2002) raised similar concerns about the ability of the study design to rule out any particular stage in the lexicalization process as being critical in fluency breakdown.

The Impact of Frequency and Neighborhood Factors in Stuttering

As noted earlier, most studies of lexical factors in speech production have focused on typical AWDNS, although some have examined other clinical groups, such as individuals with word-finding difficulties. Presumably, an individual who has some difficulty in lexical access might show different effects of these lexical properties on lexical access. As an example, older adults (who tend to demonstrate poorer lexical access) show greater effects of a word's semantic familiarity than do younger adults. Although all individuals are more accurate at naming high-familiarity than low-familiarity words, this difference is greater in older adults, suggesting that age and impairment tend to amplify the effects of lexical factors on naming (Newman & German, 2005). Word frequency and phonological form have also been investigated in individuals with aphasia (e.g., Boyczuk & Baum, 1999; Gordon, 2002). The results of such research led us to expect that linguistic impairment at some stage in processing might result in increased weight on factors that typically serve a facilitative role. If individuals who stutter are particularly impaired at some stage of lexical access, we might similarly expect to find greater effects of lexical factors focused at that stage of processing. For example, we might see greater effects of word frequency in individuals who stutter if they are impaired in accessing the particular word form (i.e., they would show a greater difference between their speed and accuracy for high-frequency words and for low-frequency words than would individuals who do not stutter). Likewise, we might see greater effects of neighborhood frequency if AWS are impaired in accessing sublexical representations. In contrast, if AWS do not have impairments in lexical access, per se, we would expect them to show similar effects of lexical factors as do AWDNS.

We know of only two studies that have contrasted the impact of neighborhood factors on RT, fluency, or both in AWS. Both have been conducted with children. In an experimental study conducted by Arnold et al. (2005) of 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. However, no differences were observed between the two groups on these factors, and a secondary analysis linking SRT to receptive vocabulary scores showed vocabulary to be more predictive of SRT than neighborhood characteristics of the stimulus items. The authors noted that their small set of stimulus items may have made it difficult to obtain statistical differentiation for SRTs among items. They also cautioned that broad variability in lexical abilities of children in this young age range might make it difficult to effectively assess phonological neighborhood effects in individuals who stutter. Study of adult SRTs for pictures differing in neighborhood characteristics would partially solve this problem.

Anderson and Linton (2004) conducted an analysis of frequency and neighborhood characteristics of stuttering children's conversational speech. Stuttered words were more likely to be low frequency and 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, the conversational speech samples could not effectively balance or stratify extreme contrasts in neighborhood characteristics. Thus, it appears that an experimental investigation of the effects of lexical factors on constrained naming tasks could shed greater light on lexical and phonological access in stuttering.

In summary, if individuals who stutter have deficits involving one or more stages of lexical access, this should be reflected in the patterns of lexical effects that they demonstrate. Specifically, we might hypothesize the following: If AWS have either atypical organization of their lexicon or atypical processes of activation, they should show different effects of lexical factors on latency and accuracy of naming than do individuals who do not stutter. In addition we might expect these variables to affect the fluency of their productions.

This hypothesis regarding the role of lexical processing in stuttering might be evaluated by exploring the impacts of a select set of lexical properties on the ease and fluency of single-word naming. If word frequency, neighborhood density, and neighborhood frequency effects differed between AWS and AWDNS, this would provide support for the hypothesis that stuttering reflects some underlying impairment in lexical organization or retrieval.

Method

Participants

Participants included 25 AWS and 25 AWDNS who were matched for age (within 3 years), education level, and gender. Each group included 8 women and 17 men; 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 as children that had resolved with development. AWS ranged in age from 18 to 66, with a mean of 38.2 years; AWDNS ranged in age from 18 to 64, with a mean of 37.8 years. Years of education ranged from 12 years (high school diploma or equivalent) to PhD level; average years of education were 15.6 for AWS and 15.8 for AWDNS. All participants were volunteers who were not paid or reimbursed for their participation. Data from 1 additional pair of participants were removed because 1 member of the pair made an excessive number of multiword, rather than single-word, responses (well over half of the trials).

Recruitment of AWS was done primarily through attendance at a national self-help meeting in the local area and participation in treatment programs at the University of Maryland's Speech and Hearing Clinic. Other participants (both AWS and AWDNS) were recruited by personal contact or by responses to posters placed on campus.

Classification of an individual as being an adult who stutters was initially made by self-report. However, this classification was confirmed individually for each participant, either during the course of the study (by one or more stuttering episodes during the testing or interview portions of the study) or afterward via a conversation with a trained clinician.

Stimuli: Word Selection

Our goal was to create a set of stimuli that could be used across a range of ages. For that reason, we limited ourselves to words likely to be known by children as young as 5 years of age. Using words such as these had the added benefit that for adult participants, therefore, we did not need to be overly concerned with participant vocabulary size; all adult native speakers without cognitive impairments could be expected to know these words. We began by collecting a set of 350 possible target words from books, stories, and other child-friendly sources. We then removed from this list all words unlikely to be clearly picturable, and next calculated familiarity, neighborhood, and frequency values for all words.

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. These were then transformed into log-frequency values. To determine neighborhood density, each word was looked up phonologically in a computerized version of Webster's dictionary. All 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. (We avoided using unfamiliar words on the assumption that these would not necessarily have full lexical representations for our participants.) However, because we were particularly interested in selecting items that could also be used with young children, we also recalculated neighborhoods in a second manner. The dictionary-based approach includes many items as "neighbors" that 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 indicated previously) 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 are commonly encountered. (The list of words, along with mean and standard deviations of their lexical values, is provided in the Appendix.) The low-frequency list had an average log frequency of 0.85, corresponding to a raw value of approximately 10 instances per million (range = 1.5–27.0); the high-frequency list had an average log frequency of 2.68, corresponding to a raw value averaging more than 1,000 times per million (range = 76–4,850). Each list contained 21 words, with the same distribution of onset phonemes in each list. (This matching was necessary to avoid confounds; if an individual had a tendency to stutter on particular onset phonemes, this could not cause an apparent word frequency effect. Each set of 21 words contained 2 words each beginning with /b, d, m, t/; 3 words beginning with /h/; and 1 word beginning with /tʃ, æ, ai, f, g, k, l, r, ʃ, w/.) The two lists were matched in terms of the average number of syllables per word (1.30 vs. 1.35), the average number of phonemes per word (3.25 vs. 3.40), the number of neighbors the words have (10.15 vs. 10.20 based on the child set, 11.0 vs.10.6 based on the adult set), and the average log frequency with which those neighbors occur (1.40 vs. 1.42).

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. As with the frequency set, these two lists contained the same distribution of onset phonemes (6 beginning with /k/, 5 beginning with /b/, 3 with /f/, 2 with /d, h/, and 1 with /g, m, n, w/). Average log frequency was 1.892 for items in the low neighborhood set and 1.893 for items in the high neighborhood set; neighborhood frequency values for the two sets were 1.594 and 1.596, respectively. For the full set of words, see the Appendix.

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, $r = .43$, $p < .005$; for biphones, $r = .41$, $p < .01$). 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. The sets were matched for the number of neighbors (7.2 vs. 7.3 based on the child set, 7.6 vs. 8.2 on the adult set), for average log word frequency (1.76 vs. 1.77), and for the number of phonemes per word (3.96 vs. 3.59). As with the other sets, these two lists contained the same distribution of onset phonemes (4 beginning with /s/; 3 beginning with /b, f, k/; 2 beginning with /n/; and 1 each beginning with /æ, E, g, l, ʃ, t, w/).

We note that while our sets of words were matched in terms of initial phoneme, they were not matched in terms of onsets; the existence of a single versus a cluster onset was not separately controlled for, as this is one of the factors that influences neighborhood properties. The existence of clusters could have its own effect on RTs (see Santiago, MacKay, Palma, & Rho, 2000). This issue is addressed in a later section.

Stimuli: Picture Selection

We then attempted to find pictures appropriate for each of these words. Most pictures were selected from colored line drawings in Nova Development's *Art Explosion*; when there was no appropriate picture from this source, other sources of images were consulted. All images were then piloted by presentation to laboratory members, and next by a set of 22 pilot participants. Pictures that were not identified appropriately by the majority of participants were replaced with alternate pictures. Although all images for the original piloting were colored line drawings, a few items were not sufficiently well identified with this form of picture, and photographic images were needed to avoid confusion (e.g., in order for a picture to be clearly a muffin, and not a cupcake, it needed to be an actual photograph, rather than a line drawing). In total, 11 of the final items (10%) were photographic in nature. To ensure that results were not affected by this difference in picture quality, we performed all analyses two ways: once on the full set of items, and once only on the line drawings. The basic pattern of results remained identical, although some effects that were marginal by one analysis were more clear by the other form; these differences are noted when they occur.

Stimulus Presentation and Order

All three word sets were presented to the participants in a combined fashion, with words intermixed and presented in random order. Because the different word sets contained some overlap, there were a total of 107 target words. Most of the target words were nouns, but a small number (7 words) 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. (Thus, 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 ensured that participants understood the instructions and were comfortable with the task.

Thus, from the point of view of participants, there were two sets of words they were asked to name: one set of nouns, and a second set 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. To ensure that the difference between nouns and verbs did not influence the results, we performed all analyses twice: once with the full set of items, and once with nouns alone. The pattern of results was identical, but some marginal effects disappeared with the smaller number of items; these differences are noted in the text.

Procedure

Participants were seated comfortably in front of a computer screen. They were asked to wear a clip-on Shure MX185 microphone, which recorded their responses. At the start of each trial, the computer would beep. This occurred simultaneously with the picture appearing on the computer screen. Participants 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, which advanced the experiment to the next trial. There was a 1,000-ms intertrial interval between the experimenter's button press and the onset of the following trial.

Coding and Reliability

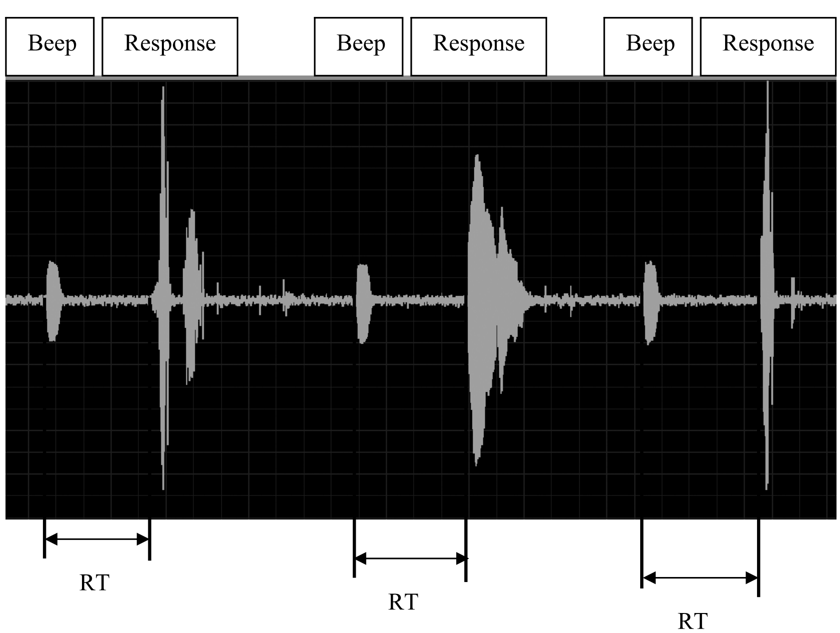
Experimenters listened to the recordings to determine the accuracy of the participants' responses. Experimenters also indicated if they judged the participant to have stuttered on that response. Reliability for identification of stuttering episodes was calculated by having two trained listeners separately assess 6 of the 25 participants (or 24%); the 6 were selected so as not to be outliers (i.e., we avoided selecting those individuals who did not stutter at all, or who made the largest number of stuttering episodes). Across these 6 individuals, there were a total of 642 trials; the two listeners agreed on 627 of the trials (or 97.7%). Any trial on which the two listeners disagreed was juried before use in the final data.

RTs 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 Figure 1). RTs were measured only when the participant's response matched the one intended. Reliability of RT measures was assessed by having a second individual code 6 of the participants (3 who do not stutter and 3 who do). This constitutes 12% of the data. Reliability for the 6 participants ranged from .88 to .997, with an average value of .945. Average difference in RT scores per item was 41 ms, or about 4% of average RT.

In the current study, pictures were identified as intended 89.7% of the time, on average (after the 1 participant who made an excessive number of elaborations was eliminated, as discussed previously). Other responses were classified as (a) true word-finding difficulty or response errors, (b) dialectal variants or alternate word choices, (c) elaborations, and (d) 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, birthday cake* instead of *cake,* and *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 RT was generated because the participant did not initially give the intended utterance. Elaborations occurred 2.8% of the time overall; dialectal variants 1.5% of the time. Visual errors consisted of responses suggesting the person had misperceived the picture itself or what aspect of it he or she was supposed to name; examples include *stalagmites* for *icicles, bruise* for *shoulder, man* for *beard,* and *doll* for *girl*. These occurred only 2.1% 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) or giving an incorrect or generic response that suggested the picture was correctly perceived (e.g.,

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



bird for *swan, cut* for *knife, clock* for *watch*). 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 two trials and was combined with long RTs, indicating difficulty; see German, 1991). Across words, these word-finding errors occurred 3.9% of the time overall.

There were also some items that were named correctly, but for which RTs 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. RTs for 34 trials across the 50 participants (or approximately 0.6%) needed to be eliminated for this reason; this was no more common in AWS than in AWDNS, $t(24) = 0.98$, $p > .05$.

One concern is that particular items may have been problematic, leading to a confound. Alternatively, elaborations or dialectal responses could have been a means of avoiding difficult words for individuals who stutter. We examined this in two ways. First, we compared the percentage of responses of different types for the different groups. In no case did the two groups differ significantly: elaborations, 3.1 versus 2.5, $t(24) = 0.95$, $p > .05$; dialectical variant, 2.0 versus 1.3, $t(24) = 1.76$, $p = .09$; visual errors, 2.20 versus 2.24, $t(24) = 0.09$, $p > .05$.

Second, we looked at each item across participants, to determine if particular items were especially problematic (items that were named in a manner other than intended at least one third of the time). Seven items met these criteria. These items were then removed from the word sets, in pairs, in such a way as to maintain the matching across lists; this involved removing four additional items to maintain matching. All analyses were then conducted both with the full sets of words and with these words excluded; the general patterns of results remained identical, suggesting that these items are not the cause of our effects. We therefore report the data from the full sets in the final analyses.

Results

We first report overall patterns of the error data. Next, we look 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: RTs, accuracy, and stuttering episodes. The latter were examined only for AWS (although there were occasional disfluencies among AWDNS, these were exceedingly rare, occurring in only 4 trials out of 5,350, or less than 0.1%). RT measurements were performed only on responses that matched what was intended. We originally did not remove outliers from the analyses because we were not certain whether this would have a differential effect on the two groups of participants. However, we then reanalyzed the RT data by removing from the analysis any item with an RT more than two standard deviations from that individual's mean RT. Both analyses are reported in all cases. Partial eta-squared measurements are reported as measures of effect size.

Overall Analyses

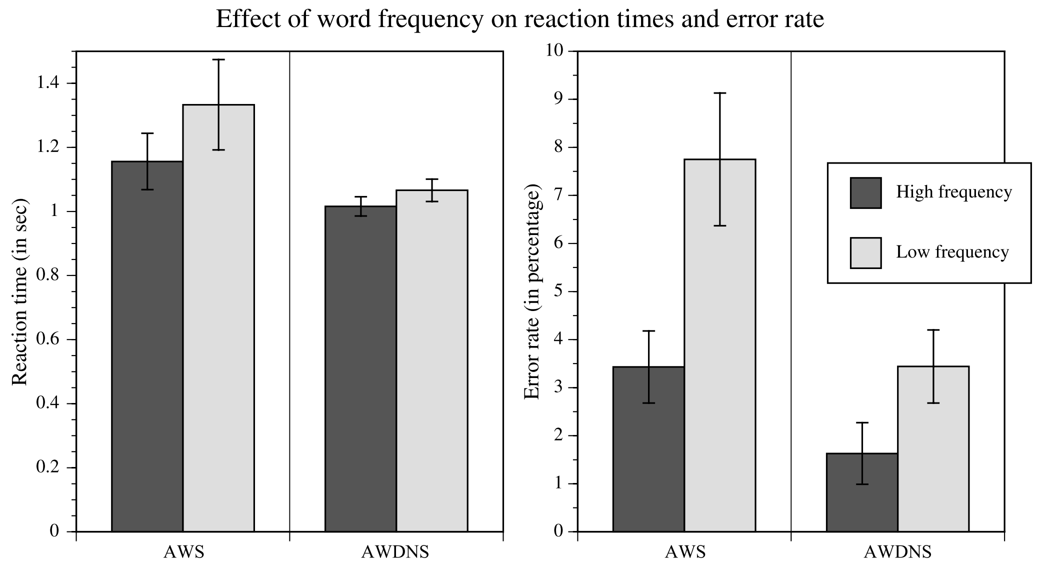
Although there was a tendency for AWS to have overall slower RTs, this difference was not significant. On average, AWS responded in 1.19 s to each stimulus (SD = 427 ms); AWDNS responded in 1.04 s (SD = 153 ms), a difference of 150 ms, $t(24) = 1.75$, $p < .10$, $\eta^2 = .11$. AWS appeared to be more variable in their RT, but not, perhaps, slower on average. This marginal effect disappeared when verbs were excluded, $t(24) = 1.64$, $p > .10$. Likewise, once individual participants' outliers were removed from their average RTs, the difference across groups disappeared as well; AWS responded in 1.11 s (SD = 361 ms), and AWDNS responded in 988 ms (SD = 134 ms), $t(24) = 1.67$, $p > .10$.There was, however, a significant accuracy difference between the two groups, with AWS responding correctly 94.3% of the time (SD = 3.4 %), but AWDNS responding correctly 97.6% (SD = 2.0%) of the time, $t(24) = 3.89$, $p < .001$, $\eta^2 = .39$. This difference in accuracy is particularly striking given the nonsignificant difference in speed of responding, and suggests that AWS were having particular difficulty accessing the words, not simply having difficulty in producing them. This finding supports the original hypothesis that individuals who stutter have some deficit in their lexical processing.

Looking more specifically at the AWS, there did not appear to be any particular pattern with regard to the initial phoneme of the target word and likelihood of that word being stuttered. There was variability; stuttering proportions ranged from 4% of the time for /tʃ/ ("ch") to 16% of the time for /ʃ/. Words beginning with vowels had stuttering episodes 12.8% of the time versus 10.1% for words beginning with consonants. Voiced consonants were stuttered slightly more often than voiceless ones (11.5 vs. 8.4% of the time), and nasals slightly more often than other manners (13.1% vs. 9.3% for stop consonants, 9.4% for fricatives and affricates, and 11.1% for liquids and glides). However, there was a large amount of variability in these tendencies across participants, such that none of these trends represented statistically significant differences across participants. Rather, looking across participants as a group, there appeared to be a relatively even distribution of stuttering across phoneme classes.

Effects of Word Frequency

Looking at RTs, there was no overall effect of group, $F(1, 24) = 2.78$. $p = .11$, $\eta_p^2 = .11$, again suggesting that AWS were no slower than those who did not stutter. As

Figure 2. Effect of word frequency on reaction times (left) and error rate (right) for both adults who stutter (AWS) and adults who do not stutter (AWDNS) . Error bars indicate standard error.



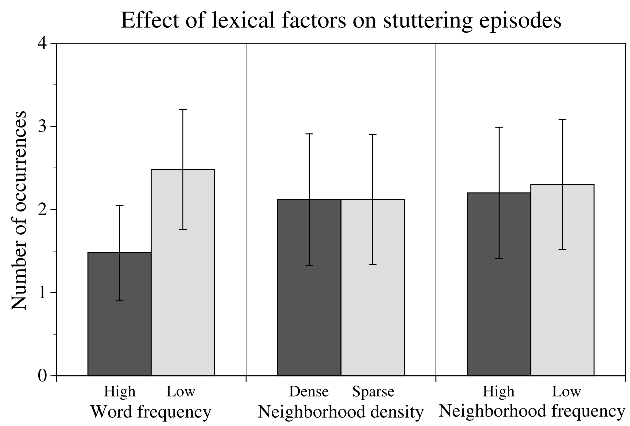
expected, there was an overall effect of word frequency, with slower RTs to low-frequency words (1.19 s to low-frequency words, 1.09 s to high-frequency words, or a 100-ms difference), $F(1, 24) = 12.89$, $p = .0015$, $\eta_p^2 = .34$, as shown in the left-hand panel of Figure 2. This effect of word frequency was significant in both groups separately: AWS, $F(1, 24) = 8.50$, $p = .008$; AWDNS, $F(1, 24) = 7.43$, $p = .011$. Interestingly, there was a marginal interaction between word frequency and group, with AWS showing a larger effect of word frequency than AWDNS: $F(1, 24) = 3.88$, $p = .061$, $\eta_p^2 = .13$; average RTs to low- and high-frequency words were 1.32 s and 1.15 s for AWS, but 1.07 s and 1.02 s for AWDNS. This suggests that AWS may be particularly disadvantaged when attempting to identify low-frequency words. However, this interaction was only marginal, making any such conclusions somewhat tentative.

Once outliers were removed, however, the interaction became significant. There was again no overall effect of group, $F(1, 24) = 2.99$, $p = .097$, $\eta_p^2 = .11$, and a significant effect of word frequency, $F(1, 24) = 18.11$, $p = .0003$, $\eta_p^2 = .43$, but there was also a significant interaction, $F(1, 24) = 4.60$, $p = .04$, $\eta_p^2 = .16$. AWS responded in 1.187 s for low-frequency words but 1.094 s for high-frequency words. AWDNS responded in 1.011 s for low-frequency words but 0.979 s for high-frequency words. The effect was significant in both groups separately: AWS, $F(1, 24) = 14.53$, $p > .0008$; AWDNS, $F(1, 24) = 4.63$, $p = .04$, so the interaction is rather an indication of a change in degree of the effect, rather than a change in the presence of the effect. There was a greater effect of word frequency among AWS. This greater deficit for low-frequency words might be an indication of generally impaired access for word forms in AWS.

Looking at individuals' rates of word-finding errors showed a large effect of group, with AWS making more errors than AWDNS (error rate of 5.80% vs. 2.60%), $F(1, 24) = 11.55$, $p = .002$, $\eta_p^2 = 0.32$, as can be seen in the right-hand panel of Figure 2. There was also a large effect of word frequency, with more errors on low-frequency words (5.60% vs. 2.80%), $F(1, 24) = 11.25$, $p = .003$, $\eta_p^2 = .32$. This supports the findings based on RTs, suggesting that words that occur less often in the language tend to be harder to access. However, there was no significant interaction between these factors, $F(1, 24) = 1.52$, $p = .23$, $\eta_p^2 = .06$. What trend existed mirrored that in the RT data, with AWS showing a larger effect of word frequency than AWDNS (for AWS, errors occurred on 7.75% of trials involving low-frequency words and 3.84% of trials involving high-frequency words; for AWDNS, the values were 3.44% and 1.75%, respectively).

Finally, as has been reported in previous studies (e.g., Hubbard & Prins, 1994; Soderberg, 1966), AWS were more likely to stutter on low-frequency words than on high-frequency words. They averaged 2.5 episodes of stuttering on the low-frequency words (range = 0–14, with 15 individuals having at least one stutter event) but only 1.6 episodes on the high-frequency words (range = 0–14, 11 individuals contributing), a significant difference, $t(24) = 2.72$, $p = .0118$, $\eta^2 = .24$. (This effect was only marginal once photographic items were removed, $t(24) = 1.86$, $p < .08$, perhaps because of the smaller number of items). This effect of word frequency on stuttering occurrences can be seen in the left-hand panel of Figure 3.

Figure 3. Number of stuttering episodes, based on word frequency (left), neighborhood density (center), and neighborhood frequency (right). Error bars indicate standard error.



Effects of Neighborhood Density

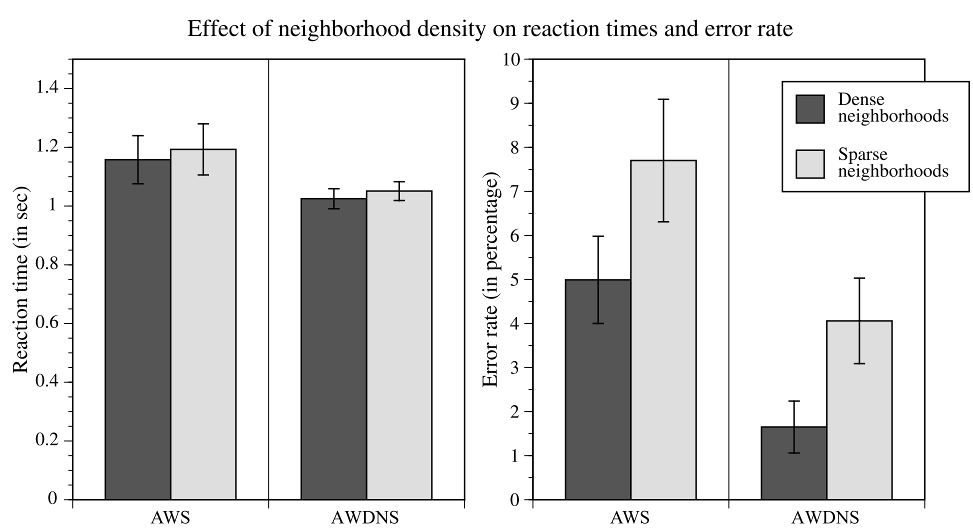
Looking at RTs showed no effect of group, $F(1, 24) = 2.35$, $p = .14$, $\eta_p^2 = .09$, and no Group × Neighborhood Density interaction ($F < 1$), as seen in the left-hand panel of Figure 4. Surprisingly, the effect of neighborhood was itself only marginal, $F(1, 24) = 3.04$, $p = .094$, $\eta_p^2 = .11$, and absent if verbs were excluded ($F < 1$). Nor did this change when outliers were removed from the analysis; with outliers removed, there was no effect of group, $F(1, 24) = 1.96$, $p = .17$, $\eta_p^2 = .08$, no effect of neighborhood ($F < 1$, $\eta_p^2 = .02$), and no interaction, $F(1, 24) = 2.92$, $p = .1002$, $\eta_p^2 = .11$. This lack of significance may be the result of a lack of sufficient power; it is possible the effect would have reached significance with more participants. Participants responded in 1.14 s for words from low-density neighborhoods, and 1.09 s for words from high-density neighborhoods; thus, the trend was for a speed advantage for words from dense neighborhoods. This may be an indication that dense neighborhoods facilitate naming speeds, in the same fashion that they have been shown to increase naming accuracy (Newman & German, 2005; Vitevitch, 2002).

Although the effect of lexical neighborhood density was not significant in the RT data, lexical neighborhood did appear to affect accuracy of naming, as seen in the right-hand panel of Figure 4. Individuals made errors on 6.0% of the words from sparse neighborhoods, but only on 3.3% of words from dense neighborhoods, $F(1, 24) = 7.59$, $p = .011$, $\eta_p^2 = .25$. There was also a significant effect of group, $F(1, 24) = 10.25$, $p = .004$, $\eta_p^2 = .32$, with poorer accuracy for AWS (6.57% vs. 2.75%) but no interaction between these two factors ($F < 1$).

Neighborhood density values did not appear to affect the frequency of stuttering episodes, as seen in the central panel of Figure 3. AWS averaged 2.12 stuttering occurrences on the words from both low-density and high-density neighborhoods, $t(24) = 0.00$, $p > .05$, $\eta^2 = .00$ (range = 0–14 episodes for each condition, with 13 and 11 individuals, respectively, contributing to each condition).

One concern is that the words compared for neighborhood density were matched only for initial phoneme, not for onset; indeed, the low-density set contained many more items containing clusters than did the high-density set. Perhaps this masked an underlying effect going in the opposite direction. Although the issue of clusters is beyond the scope of the current article, we did do a subsequent analysis comparing only a subset of words, those that did not contain clusters. This comparison involved two sets

Figure 4. Effect of neighborhood density on reaction times (left) and error rate (right) for both AWS and AWDNS. Error bars indicate standard error.



of 12 words each, matched on initial phoneme, word frequency, and neighborhood frequency, but differing in the number of neighbors. We found no effects in the RTs: for group, $F(1, 24) = 1.38$, $p = .25$, $\eta_p^2 = .05$; for neighborhood density, $F(1, 24) = 1.41$, $p = .25$, $\eta_p^2 = .05$; and the interaction ($F < 1$). In error rates, we again found an effect of group, with AWS making more errors than AWDNS, $F(1, 24) = 6.16$, $p = .02$, $\eta_p^2 = .20$, but no effect of density, $F(1, 24) = 1.36$, $p = .26$, $\eta_p^2 = .05$, and no interaction ($F < 1$). Thus, while it does not appear that the presence of clusters is masking an opposing effect of neighborhood density, it is possible that the increased error rate on items with sparse neighbors may be due, in part, to the difficulties associated with accessing words with initial clusters (see Santiago et al., 2000).

Effects of Neighborhood Frequency

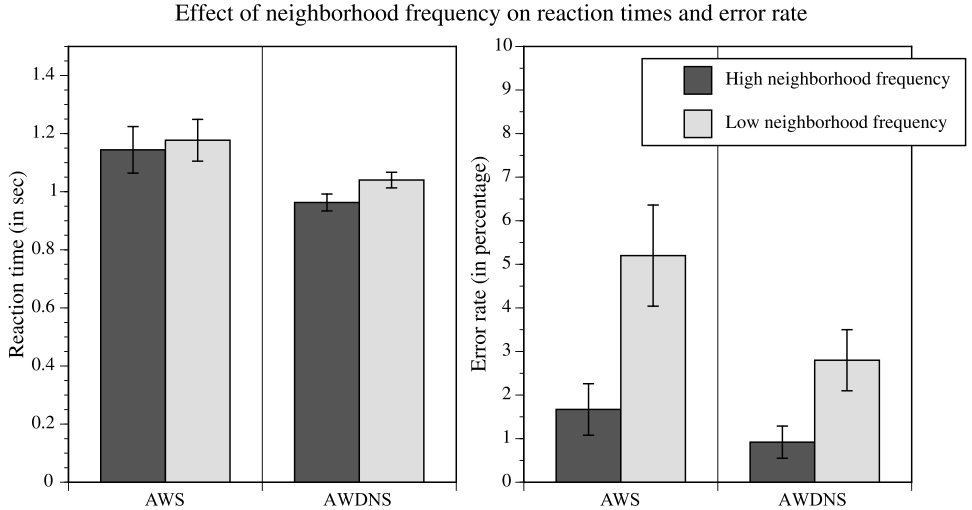
Neighborhood frequency refers to the frequency with which a word's neighbors occur and can be thought of as roughly a measure of how often the general sound pattern is encountered. The effect of neighborhood frequency was highly significant in the RT data, with participants naming words with common sound patterns (high neighborhood frequency) more quickly than words with rarer patterns (1.05 s vs. 1.11 s, a 60-ms difference), $F(1, 24) = 16.38$, $p = .0005$, $\eta_p^2 = 0.41$. This can be seen in the left-hand panel of Figure 5. There was also a marginal effect of group, with a trend toward slower responding in AWS (1.16 s. vs. 1.00 s), $F(1, 24) = 4.16$, $p = .0525$, $\eta_p^2 = .15$. (This marginal effect of group was significant with the photographic items removed, suggesting that there may be some RT differences in this subset of items, $F[1, 24] = 4.36$, $p < .05$).

Most interestingly, there was no interaction between these factors, $F(1, 24) = 1.67$, $p = .21$, $\eta_p^2 = .06$. That said, looking at the groups separately, this effect was present only in the AWDNS, $F(1, 24) = 30.06$, $p < .0001$, not in AWS, $F(1, 24) = 1.33$, $p = .05$. With outliers removed, there was likewise only a marginal effect of group, $F(1, 24) = 2.96$, $p = .099$, $\eta_p^2 = .11$; a significant effect of neighborhood frequency, $F(1, 24) = 39.08$, $p < .0001$, $\eta_p^2 = 0.62$; and no interaction ($F < 1$, $\eta_p^2 = .003$). However, without the outliers, the effect was present in both groups: AWS, $F(1, 24) = 31.38$, $p < .0001$; AWDNS, $F(1, 24) = 8.69$, $p = .007$. Thus, it appears there is an effect of neighborhood frequency in both groups, but outliers masked this when all items were included.

The same pattern of findings occurred in the accuracy data, as seen in the right-hand panel of Figure 5. There was again a significant effect of neighborhood frequency, with more errors on items with rare sound patterns (4.00% vs. 1.39%), $F(1, 24) = 15.51$, $p = .0006$, $\eta_p^2 = .39$. There was a marginal effect of group, $F(1, 24) = 3.14$, $p = .089$, $\eta_p^2 = .11$; this disappeared when photographic items were removed, $F(1, 24) = 2.83$, $p < .11$, or when verbs were removed, $F(1, 24) = 1.08$, $p > .10$, suggesting that it was dependent on having the larger set of items. There was no interaction between these factors, $F(1, 24) = 1.56$, $p = .022$, $\eta_p^2 = .06$.

Neighborhood frequency did not appear to affect the frequency of stuttering episodes, as seen in the right-hand panel of Figure 3. AWS averaged 2.32 stuttering occurrences on the words from low-frequency neighborhoods (range = 0–16 episodes, with 14 individuals contributing) and 2.20 episodes on the words from high-frequency neighborhoods (range = 0–14 episodes, with 13 individuals contributing), $t(24) = 0.43$, $p = .67$, $\eta^2 = .01$.

Figure 5. Effect of neighborhood frequency on reaction times (left) and error rate (right) for both AWS and AWDNS. Error bars indicate standard error.



Discussion

In this study, we investigated the effects of three different lexical factors known to affect ease of access in fluent speakers, on access in AWS. We found effects of lexical neighborhood, neighborhood frequency, and word frequency in response latency patterns of both fluent and stuttering participants, as expected. We also found that the size of the neighborhood effects was fairly comparable across groups, suggesting no basic differences in lexical organization between people who stutter and those who do not. However, even for very simple stimuli, people who stutter made more errors in naming the pictured stimuli. Moreover, adults who stutter showed greater effects of word frequency than did adults who do not stutter. This could suggest a fundamental difference between groups in a basic level of language processing. It is also possible that the difference in errors was caused when individual speakers sought to avoid a moment of stuttering by circumlocuting or providing a synonym. This would be impossible to ascertain post hoc, but is possible for individual participants who were observed to supply very low-frequency responses to relatively common stimuli (e.g., saying "adrogyne" for *boy,* an unusual word even if our stimulus was not a paradigm of masculinity, "pheasant" for *goose,* or "patella" for *knee*). Such responses appeared to be less common in AWDNS, whose errors tended to be more prosaic (e.g., saying "child" for *boy,* "duck" and "bird" for *goose,* and "elbow" for *knee*). To examine whether this was generally the case, we examined the frequency of participants' errors. For this analysis, we only examined real-word errors; responses such as "I don't know" and circumlocutions were ignored. A number of errors needed to be ignored as we were unable to get frequency measures on them; for example, one person, upon seeing a picture of a cat, gave the name of her cat as a response; several individuals called the picture of the mummy a "boogeyman," a word not in our online dictionary. For the remaining words, however, we determined the log frequency value of both the intended word and the error, and calculated a difference score. We then took the means of these values for each participant, and compared these. Difference scores were no greater for AWS than for AWDNS, $t(24) = 0.55$, $p = .59$. Likewise, just looking at the words they erred on, $t(20) = 0.27$, $p = .79$, or just the words erred to, $t(20) = 0.84$, $p = .41$, we found no significant differences. Thus, we found no greater tendency overall for AWS to err to lower frequency words than for AWDNS, and although this may be the case for a small number of participants, it does not seem to be the case in general.

It is also not clear whether circumlocutions are caused by a desire not to stutter, difficulty in accessing a word form, or difficulty in producing a word form. Because the AWS were not significantly slower in general while naming the stimuli, we believe that a look-ahead strategy implemented to avoid anticipated stuttering seems somewhat unlikely. Such a strategy should have contributed to slower overall naming patterns. Potential origins of our observed naming errors would need to be explored in future studies. The pattern of elevated naming errors was maintained in two of the three subset analyses (those for frequency and neighborhood density, with a nonsignificant trend in that direction occurring in the neighborhood frequency analysis). While differences in stuttering adults' naming accuracy for common words is not something we expected to find, they are consistent with a very recent report of elevated RTs in lexical-decision tasks for some otherwise apparently language-normal AWS (Sasisekaran, 2006). We also note that, although AWS seem to make more word-finding errors in general, the pattern of errors they make (or the types of words they find difficult) seems to be the same as for AWDNS. We also found that people who stutter are more likely to demonstrate disfluencies on words that are low frequency, which is not a particularly novel finding. However, neither of the other potential lexical factors that have been shown to affect naming latencies and accuracy in normally fluent speakers exerted any observable effect on precipitating stutter events.

Looking across the lexical factors, we thus find a general pattern emerging. First, those lexical factors reported in the literature appeared to influence speakers in our study, suggesting that our task was sensitive to these factors. Effects of frequency, neighborhood density, and neighborhood frequency were all apparent, generally in both RT and accuracy measures (the one exception being neighborhood density, which was only marginal in the RT measure). Thus, our participants found it easier to name words that were high in frequency and neighborhood frequency, and that were located in dense neighborhoods.

Despite these strong findings for all lexical factors, we generally did not find any interactions between the neighborhood lexical factors and group membership. Thus, it appears that the effects for neighborhood factors are generally quite comparable for AWS and AWDNS. This is supported by prior work demonstrating comparable phonological priming in individuals who do and do not stutter (Burger & Wijnen, 1999; Melnick et al., 2003), and suggests that form-based factors do not have differential effects across groups. In contrast, we found amplified effects of word frequency in individuals who stutter. Comparable findings have been found for both less mature (Newman & German, 2002) and language-impaired (Gordon, 2002) speakers. This similarity in results suggests that adults who stutter may have difficulty accessing lexical word forms. This supports earlier work suggesting a lack of semantic priming in children who stutter (Pellowski & Conture, 2005). However, even if AWS do have difficulty with lexical forms, they do not appear to have difficulty accessing phonological forms, as they did not show greater deficits accessing items low in neighborhood frequency.

It is possible that the limited sample size obscured subtle but real neighborhood differences between our groups that might have emerged with greater power. However, the fact that we found such effects for word frequency suggests that our methodology was sensitive enough to detect group differences when they are large enough. Moreover, despite the need for very large participant pools to identify fine-grained differences in language processing, we note that most studies of AWS utilize samples much smaller than the one reported here. We also note that word frequency, the one small differentiating factor in our findings, has been found to show amplified effects on naming for less mature speakers as well. Thus, it may be useful to further explore this factor in future psycholinguistic investigations of AWS.

Our current results of depressed naming accuracy are consistent with findings of subtly decreased expressive vocabulary ability in children who stutter (CWS; Bernstein Ratner & Silverman, 2000), decreased lexical variability in the conversational speech of CWS (Silverman & Bernstein Ratner, 2002), and atypical discrepancies between expressive and receptive vocabulary skills in CWS (Arnold et al., 2005). Thus, it would also be valuable to replicate this experiment with CWS and children who do not stutter because we could anticipate more obvious differences between groups on our relatively simple stimuli for children who are still solidifying their linguistic abilities.

If such results can be confirmed by further experimental tests of lexical retrieval in AWS, it will be necessary to then narrow down the specific point in lexical processing that appears to cause the most difficulty for people who stutter. In the model we have selected (Levelt, 1999), lexical access involves a variety of stages, such as accessing the lemma, accessing abstract word forms and sublexical units, and creating a motoric output plan. According to such a model, the current findings suggest that lexical processing difficulties in AWS are most likely to occur at the stage of accessing either the lemma or the absract word forms. However, many models of speech production (e.g., Dell, 1986) also acknowledge interactive and bidirectional relations between semantic and phonological features in lexical retrieval for speech. These complicated interactions make it difficult to tease apart the different stages of lexical processing in typically fluent speakers as well as in AWS. Doing so would require not only additional, carefully designed psycholinguistic experiments akin to those used to develop and refine the Levelt model (see summaries in Indefrey & Levelt, 2004; Levelt, 2001), but may also require "chronometric studies of cerebral activation in word production," such as magnetoencephalography and lateralized readiness potentials, which have the potential to isolate and plot the time course of specific stages in lexical encoding (Levelt, 2001, p. 13470). Such sophisticated analysis may be crucial to understanding the prearticulatory processing characteristics of word production in AWS, particularly because speech latencies, even in typical speakers, represent the cumulative effect of multiple successive operations that are difficult to distinguish temporally using behavioral data (Indefrey & Levelt, 2004; Levelt, 2001). With few exceptions (notably the ERP investigations of phonological, semantic, and syntactic encoding in AWS by Weber-Fox and colleagues [Cuadrado & Weber-Fox, 2003; Weber-Fox, 2001; Weber-Fox et al., 2004] and the recent series of phonological, semantic, and syntactic priming studies carried out by Conture and colleagues [Anderson & Conture, 2004; Arnold et al., 2005; Melnick et al., 2003; Pellowski & Conture, 2005]), systematic replication of paradigms that have been used to develop lexical access models has not been frequent in the stuttering literature.

Nonetheless, the current results do provide some clues as to which proposed stages of lexical access might be most fruitful to investigate in future studies of AWS. Given that phonological factors did not appear to exert a greater influence on AWS than they did for AWDNS, degraded phonological representations are unlikely to explain the core deficit in stuttering. In contrast, the Group × Word Frequency interaction suggests the possibility that there may be deficits at the stage of word forms in AWS. However, this does not mean that phonological encoding is as efficient in AWS as in AWDNS; potential problems in the time course and accuracy of phonological encoding, and the possibility that prearticulatory monitoring of the phonetic plan is aberrant in AWS (Vasić & Wijnen, 2005), merit further experimental evaluation, in our opinion, using the major language production models as an organizing framework (Bernstein Ratner, 2005).

Work by Weber-Fox and colleagues (Cuadrado & Weber-Fox, 2003; Weber-Fox, 2001; Weber-Fox et al., 2004), as well as work by Bosshardt and colleagues (Bosshardt, 1999, 2002), also suggests that increases in cognitive load required to complete a phonological (or other language-based) processing task can affect RTs in AWS, and indicate a more general capacity limitation for efficient language formulation and encoding in stuttering. Findings such as this also imply that pre- or postproduction monitoring or attentional processes may play a role in stuttering. This should be considered along with more traditional speech production stages and processes when attempting to describe how disfluencies arise in stuttering. In this vein, it is also interesting that Vasić and Wijnen (2005) discovered that increased concomitant cognitive load during language formulation tasks decreased the frequency of stuttering in AWS. They suggested that this increased load distracted the overly attentive internal monitor, and this decrease in self-monitoring led to the decrease in stuttering behaviors. This pattern of results suggests that competing cognitive, linguistic, and motor programming demands may have differential impacts on the time course of speech encoding, as well as on rate and fluency of output. In summary, this study suggests that paradigms used to study lexical organization and access in AWDNS can be used successfully with AWS to identify areas of relative impairment that appear to be specific to stuttering, at least between these two populations. The paradigms may also be used to rule out less likely bases for the fluency breakdown observed in stuttering. In contrast to studies of spontaneous corpora, laboratory experiments allow us to investigate specific linguistic factors thought to influence ease of speech production while controlling for potential confounds. This, in turn, allows us to evaluate competing models of the level(s) at which the presumed deficit that leads to stuttering arises.

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Contact author: Rochelle S. Newman, Department of Hearing and Speech Sciences, University of Maryland, 0100 Lefrak Hall, College Park, MD 20742. E-mail: rnewman@hesp.umd.edu.

Appendix. Complete set of words tested for each comparison, along with the summary values for each set.

Low frequency words: ant, icicle, barn, bike, chin, clap,[a] dice, dime, phone, goggle, hanger, hose, heel, leash, muffin, mummy, rake, shower, trash, tooth, web
Average log word frequency: 0.851 (0.425)
Average no. of 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,[a] shoulder, table, tree, witch
Average log word frequency: 2.678 (0.535)
Average no. of neighbors: 10.20 (8.33)
Average neighborhood frequency: 1.424 (0.452)

Low neighborhood density words: box, brush, beard, block, boy, dance,[a] dress, frog, flag, farm, goose, house, horse, crib, queen, crawl,[a] clown, climb,[a] cow, mouth, knife, watch
Average log word frequency: 1.892 (0.610)
Average no. of neighbors: 4.36 (1.84)
Average neighborhood frequency: 1.594 (0.394)

High neighborhood density words: bell, bear, bowl, boat, bat, dime, deer, fan, fight,[a] phone, gun, heel, hat, cake, car, kick,[a] cap, cat, coat, man, net, whale
Average log word frequency: 1.893 (0.474)
Average no. of neighbors: 22.50 (3.78)
Average neighborhood frequency: 1.596 (0.224)

Low neighborhood frequency words: apple, balloon, broom, box, egg, finger, fly, fence, girl, candle, climb,[a] car, lamb, necklace, nail, swan, spider, sock, sink, shoulder, tractor, whistle
Average log word frequency: 1.764 (0.539)
Average no. of neighbors: 7.22 (6.86)
Average neighborhood frequency: 0.872 (0.376)

High neighborhood frequency words: ant, bike, bed, bottle, elephant, frog, flag, feather, glass, crawl,[a] kite, key, leaves, needle, knee, snail, ski,[a] smile, snow, shoe, turtle, watch
Average log word frequency: 1.769 (0.392)
Average no.of neighbors: 7.32 (6.55)
Average neighborhood frequency: 2.003 (0.310)

Note. Numbers in parentheses are standard deviations.

[a]Indicates a verb.

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