Life Span Effects of Lexical Factors on Oral Naming

Rochelle S. Newman[1]
Diane J. German[2]

[1] *University of Maryland*
[2] *National-Louis University*

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Abstract

This study investigated how lexical access in naming tasks (picture naming, naming to open-ended sentences, and naming to category exemplars) might be influenced by different lexical factors during adolescence and adulthood. Participants included 1075 individuals, ranging in age from 12 to 83 years. Lexical factors examined included word frequency and familiarity, age of acquisition, neighborhood density, and phonotactic probability. As expected, each of these factors influenced lexical access, and there was a general trend towards less accurate naming with age. More interestingly, word frequency and neighborhood density both showed larger effects for adolescents than for adults, but then showed constant effects on lexical access throughout adulthood. Phonotactic probability showed constant effects across the lifespan. Effects of word familiarity and age of acquisition interacted with age in adulthood; lexical access of older adults was more greatly affected by a word's familiarity and age of acquisition than was the lexical access of younger adults. These lexical factors impact on adult naming so that words that were learned later in life and which are judged to be less familiar are more difficult to retrieve then their counterparts (words learned earlier and judged to be more familiar) as individuals age. This suggests that age of acquisition and familiarity may play a protective role in adult naming. In contrast, word frequency and form-based properties of words appear to have similar effects throughout adulthood. Implications of these findings for theories of aging and for models of lexical access are discussed.

1 Introduction

As individuals age, they experience a number of changes in their ability to perform a variety of cognitive tasks (Cerella, 1985; Salthouse, 1985; but see Kellas, Simpson, & Ferraro, 1988). One cognitive process that has been of high interest in the field of cognitive science has been lexical access, the ability to select from memory a target

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Address for correspondence. Rochelle Newman, Department of Hearing and Speech Sciences, University of Maryland, College Park, MD 20742; phone: (301) 405-4226; fax: (301) 314-2023; e-mail: <rnewman@hesp.umd.edu>.

word from among thousands of possible choices, many of which share features (either semantic or phonological) with the target word. Although failures in accessing known words occur relatively infrequently, there are factors that are likely to influence the ease with which any particular word is accessed. In this study we considered those lexical factors that have previously been identified to interfere with or enhance lexical access of target words.

This investigation is a retrospective, exploratory investigation of the lexical access systems of adolescents and adults without language problems. It is an extension of earlier work in which we considered how the influence of lexical factors might change with a child's development (Newman & German, 2002). The present investigation continues this line of research by examining how these processes might continue to change through the remainder of the lifespan. Of particular interest to us was whether one's lexical access system changes with maturation relative to these lexical factors, and, if so, whether specific components of the lexical system are more or less vulnerable to the aging process.

To explore this topic we considered the stages of lexical access, the nature of the individual, and the nature of target words. Therefore, we first present a theoretical model that differentiates separate components and stages of the lexical access process. We then examine research on how lexical processing changes with age, and the lexical properties of words that might influence the likelihood that individuals experience retrieval errors. We then test experimentally the extent to which these factors influence ease of retrieval in various naming tasks (naming to pictures, open-ended sentences, descriptions and target word exemplars), and the extent to which these factors are sensitive to the age of the individual. Finally, we use these results to hypothesize as to the changes that might occur over time in lexical access.

2 Architectural model and stages of lexical access

Contemporary models of word production distinguish three levels of lexical access: conceptual preparation, lemma retrieval, and word-form encoding (Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992). One such adapted model focuses on single-word retrieval (German, 2000). This model is based on work by Levelt and colleagues (Levelt, 1989, 1991; Levelt, 1999), and contains four stages. In Stage 1, the stimulus (a picture or sentence) elicits the conceptual structure or underlying concepts associated with a target word (Bierwisch & Schreuder, 1991). In Stage 2, this conceptual structure accesses the target word's lemma (its semantic and syntactic features) from among neighboring entries (Garrett, 1991). In Stage 3, the lemma accesses the entry's corresponding phonological properties (its syllabic frame and sound units) to create a complete phonological schema (Levelt, 1991). Finally, in Stage 4, a motor plan is created and forwarded to lower-level articulation processes in order to produce the word. The implied assumption that the semantic and phonological aspects of words are accessed from two independent structures (Stages 2 and 3 above) suggests at least three potential lexical components that could change with maturation: the accessibility of the semantic aspects of a target word, the transmission connections between the semantic aspects and the form aspects, and the subsequent retrieval of the word's phonological features, syllabic structure and segmental sounds units. (This theory separates aspects of retrieval from aspects of production, in contrast to the language-memory hypothesis put forward by MacKay & Abrams, 1996).

Although the extent to which this adapted model and its components are descriptive of adolescents' lexical retrieval awaits further investigation, clinical applications to children have already been informative. In particular, this model has been used as a blueprint for assessing lexical access skills in children with its focus on word-finding error patterns (German, 2000). In addition, German and Newman (2004) reported lexical factor effects on child error patterns as implied in this model, suggesting that disruptions in model stages may underlie children's word-finding blocks. Further, the underlying assumption inherent in this model, that a word's semantic and phonological aspects are accessed from independent structures, is generally assumed in the adult psycholinguistic literature (Garrett, 1991; Gordon, 1997; Levelt, 1989, 1991) and the literature focused on adult aging (Burke, 1997; Burke, MacKay, Worthley, & Wade, 1991). It therefore seemed meaningful to consider this adapted model in our study of lexical factors across the lifespan.

3 The effect of aging on lexical access

Many studies have suggested that older adults tend to have more word-finding problems in general than do younger adults. For example, older adults are more susceptible to tip-of-the-tongue errors (Burke et al., 1991; Cohen & Faulkner, 1986; Heine, Ober, & Shenaut, 1999; Maylor, 1990b; Rastle & Burke, 1996; Schwartz, 2002; but see Dahlgren, 1998; Maylor, 1990a) and show greater deficits in picture naming tasks (Nicholas, Obler, Albert, & Goodglass, 1985; Tabor Connor, Spiro, Obler, & Albert, 2004). Some results suggest that older adults may demonstrate lower amounts of activation within the mental lexicon in general (Cohen & Faulkner, 1986). Yet few studies have examined whether these naming difficulties might be specific to certain types of words (other than those comparing common nouns to proper nouns).

The few studies that have examined naming differences relative to different lexical components in typical aging have reported some age-related differences (Burke et al., 1991; Nicholas, Barth, Obler, Au, & Albert, 1997). In particular, access to the semantic components of words has been reported to be maintained (Burke, 1997; Nicholas et al., 1997), while access to the phonological features of words is reported to be less stable with maturation (Burke et al., 1991; Maylor, 1990a). For example, a number of studies on written word identification and naming (Allen, Madden, & Crozier, 1991; Allen, Madden, Weber, & Groth, 1993; Whiting, Madden, Langley, Denny, Turkington, Provenzale, Hawk, & Coleman, 2003) have found that older and younger adults show similar effects of word frequency, while both Sommers (1996) and Spieler and Balota (2000) report changes in the effects of lexical neighborhoods. Although causes for this asymmetry in development are still debated, most agree that a decline in cognitive processing underlies these observed difficulties in lexical access over the life span (Schwartz, 2002). Specific models put forth to explain this cognitive decline focus on either the semantic, semantic to form, or phonological components of the lexicon. Most noteworthy is the transmission deficit hypothesis (Burke et al., 1991; MacKay & Burke, 1990) and the inhibitory deficit hypothesis (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). Briefly, the transmission deficit hypothesis suggests that with aging there is a reduction in the transmission of priming from the semantic to the phonological lexicon, resulting in a failure to access the form of the target word (Burke, 1997; MacKay & Burke, 1990). In contrast, the inhibitory deficit hypothesis is based on the notion that inhibitory processes decline with age (Hasher & Zacks, 1988). That is, older adults activate more irrelevant information, and are less adept at suppressing such information after it has been activated. Unlike the transmission deficit hypothesis, which is focused on phonological transmission, inhibitory deficits occur throughout the cognitive processing system (Burke, 1997); with regards to lexical access, these deficits would affect processing in both the semantic aspects and the form-based aspects of a word.

The present investigation attempts to explore this asymmetric aging effect in more detail, by considering whether structures of the lexical system, as reported in our adapted model, function differently across the life span. However, we have switched the focus from a study of individuals' naming performance and cognitive functioning to a study of the words that initiate this naming performance. We have theorized that by examining the impact of lexically-controlled target words on participants' naming performance across ages we can hypothesize as to the nature of changes in the lexicon as an individual matures. Our interest is to examine the impact of a word's lexical properties on an individual's word-finding skills across the life span to see if this reverse approach confirms similarities and differences already observed in the language aging studies reported above. Specifically, we have studied individuals' naming performance on words whose lexical properties are thought to correspond to the semantic and phonological processing stages represented in the lexical system described above. It was thought that to the extent that semantic and phonological processes are affected by these lexical factors, one could interpret this effect as an indication of changes (or lack thereof) in the corresponding lexical structures over time.

For the most part, research comparing lexical access performance for different types of words has focused on either children or young adults (e.g., German & Newman, 2004; Newman & German, 2002). Studies with children have suggested that there are changes in lexical access with maturation (Charles-Luce & Luce, 1995; Metsala, 1997; Newman & German, 2002; Storkel, 2001). However, much less work has examined whether these changes might continue throughout adolescence and adulthood, or whether aging itself might alter the accuracy of lexical access. Thus, the current study explores performance for individuals across a range of ages, beginning in adolescence and continuing throughout the lifespan.

4 Lexical properties

Although much of what is known about lexical factors has come from research in the realm of word recognition (Dirks, Takayanagi, Moshfegh, Noffsinger, & Fausti, 2001; Luce & Pisoni, 1998; Newbigging, 1961; Solomon & Postman, 1952), research on these same factors has been conducted on speech production as well. For example, studies focused on word usage have reported that high-frequency words are produced more quickly (Jescheniak & Levelt, 1994; Lachman, Shaffer, & Hennrikus, 1974; Oldfield & Wingfield, 1965) and more accurately (Dell, 1988; Vitevitch, 1997, 2002; Vitevitch & Sommers, 2003) than are low-frequency words. Studies focused on phonological features suggest that words with few lexical neighbors are less likely to be named accurately than are those with more dense neighborhoods (Harley & Bown, 1998; Vitevitch, 1997). In addition, recent studies have begun examining these same lexical factors in children. Newman and German (2002) found that children aged 7 through 12 were more successful at naming words that were more frequent in the language, learned earlier, had more common sound patterns, and which had fewer neighbors. Thus, these lexical factors have been shown to influence performance both in young adults and in children, suggesting that it would be meaningful to study the influence of these lexical factors on the naming skills of individuals over the life span.

To select factors of words that would theoretically map onto the semantic and phonological processing stages identified above, we have assumed that properties having to do with a word's use in the language are linked to semantic and semantic to form processing stages (such properties would include word frequency, age of acquisition, and familiarity). In contrast, those properties associated with a word's phonological features, such as phonotactic probability (phoneme composition) and neighborhood density (phonetic overlap between different words) we assumed to be linked directly to the phonological processing stages in the lexicon. In all, we examined a set of five lexical factors, three of which were assumed to be linked to the semantic and/or semantic to form stages of lexical processing and two believed to be linked to the phonological stages of lexical access. These factors are described below relative to their role in word production tasks.

4.1
Semantic-based factors

Access to the semantic components of words appears to remain intact with age. Studies have reported that neither semantic priming (Light & Burke, 1988; Madden, Pierce, & Allen, 1993) nor semantic organization changes significantly in typical aging (Brown & Mitchell, 1991; Light & Burke, 1988). Yet, even with intact semantic processing, typical-aging adults do report lexical access difficulties. One possibility is that these lexical difficulties may be more related to semantic-form based connections then directly to the access of target word meanings. Most noteworthy is the tip-of-the-tongue (TOT) experience when an individual is unable to produce a word whose meaning is known. These errors have been suggested to be more common among older adults (Burke et al., 1991; Cohen & Faulkner, 1986; Heine et al., 1999; Maylor, 1990b; Rastle & Burke, 1996; Schwartz, 2002; but see Dahlgren, 1998; Maylor, 1990a). Burke and colleagues (1991) suggest the TOT state is the clearest example of a disruption in the connections between the semantic and form features of the target word. To better understand these semantic-to-form based connections, we considered semantic-based factors that were more related to target word usage than target word meaning, for example, target word frequency, age of acquisition, and familiarity. We viewed these lexical factors as those that might impact on either the semantic lexicon directly or the semantic-form based connections that underlie retrieval of the phonological features of the target word. Thus, while we refer to these as semantic factors, they are likely best thought of as impacting the transmission of information from the semantic to the form system. A discussion of the lexical factors in this investigation deemed to potentially impact semantic to form transmission in the lexical process follows.

4.1.1
Word frequency

The frequency with which a word occurs in the language can influence the ease with which it accessed and produced. Less-common words are produced more slowly (Jescheniak & Levelt, 1994; Lachman et al., 1974; Oldfield & Wingfield, 1965) and less accurately (Dell, 1988; Vitevitch, 1997, 2002; Vitevitch & Sommers, 2003) than are more frequent words. This effect of word frequency on production has been found not only in young adults, but also in children (Newman & German, 2002) and in older adults (Spieler & Balota, 2000). For the most part, studies have reported comparable frequency effects across ages (Allen et al., 1993; Bowles & Poon, 1981; Tainturier, Tremblay, & Lecours, 1989), although such comparative work has generally been done using recognition tasks rather than production tasks. In contrast, Morrison and colleagues (Morrison, Hirsh, Chappell, & Ellis, 2002) reported that older adults (mean age 73 years) showed no effect of word frequency, whereas younger adults (mean age 20 years) did show an effect using the same words, and a few studies have shown just the opposite pattern of greater effects of word frequency for older than younger adults (Balota & Ferraro, 1993; Spieler & Balota, 2000).

Many of the studies investigating the effects of word frequency with older adults may be confounded (Balota & Ferraro, 1993; Morrison et al., 2002). Frequency effects may actually be the result of differences in the age at which a word was originally learned (age of acquisition, or AOA). Some studies suggest that effects of word frequency disappear when the age at which a word is first learned is held constant, at least for young adults (Barry, Hirsh, Johnston, & Williams, 2001; Carroll & White, 1973a, 1973b; Garlock, Walley, & Metsala, 2001; Morrison & Ellis, 1995; Morrison, Ellis, & Quinlan, 1992). At least one study using an orthographic naming task has suggested that this may also be the case for older adults (Morrison et al., 2002). In contrast, Newman and German (2002) reported separate effects of word frequency and AOA among elementary-school-aged children using an oral naming task. Whether these might likewise have separate effects among adolescent and older adults is as yet unclear, and is difficult to determine as AOA ratings are not as readily available as frequency ratings. The present study examines effects of frequency, and then looks for separate effects of AOA above and beyond frequency effects.

4.1.2
Age of acquisition

A number of studies have suggested that the age at which a word is first learned can influence the speed and accuracy of lexical access across a number of tasks (Barry et al., 2001; Carroll & White, 1973a, 1973b; Garlock et al., 2001; Gilhooly & Gilhooly, 1979; Lachman et al., 1974; Morrison & Ellis, 1995; Morrison et al., 1992; Walley & Metsala, 1992). Yet recent evidence suggests that these effects decay with age, at least among children (Newman & German, 2002). Newman and German reported that while words learned earlier in life tend to be easier for children to access than are words learned more recently, this has less of an impact on older children than on younger children. They suggested that with each successful instance of accessing a target word, the pathways for future access become stronger; over time, retrieval becomes automatic, and the effect of a word's age of acquisition decreases. Presumably, this effect should continue to decrease throughout adolescence and adulthood, although it may never completely dissipate (Gilhooly & Gilhooly, 1979).

In contrast, Morrison et al. (2002) reported that age of acquisition continued to show a strong effect on naming performance in adults into their 80s. There was a trend towards this effect being smaller in older than younger individuals, but this trend was only marginally significant. They interpret this finding as an indication that age-of-acquisition effects are not the result of cumulative frequency of exposure or of residence time in the lexicon, but are instead the result of "intrinsic properties of lexical representations, which are fixed when those words are first learned and remain relatively unchanged thereafter" (p. 451). Of interest in this investigation was to observe if a target word's age of acquisition has diminishing effects over the adult life span as observed in child studies (Newman & German, 2002).

4.1.3 Familiarity

In addition to effects of a word's frequency and the age at which it is learned, a word's familiarity may also influence lexical access. Familiarity is a subjective measure, which likely includes both word frequency and AOA. But familiarity may include other aspects of a word, as well, such as meaningfulness (Balota, Pilotti, & Cortese, 2001).

All of the words used in this study had high rated familiarities by young adult listeners. But there were differences among the words in terms of how highly-rated the words were. For example, while *acorn* and *leash* both received a familiarity rating of 7 out of 7, *corsage* and *crutch* rated only 6.4, and *veil* only a 6.25. Of interest in this investigation was whether a word's familiarity rating was related to the ease with which the word is accessed.

The measurement of familiarity used here was taken from young adults, and thus may not be fully representative of familiarity ratings from other age groups. Despite that fact, other studies have suggested that different participant age groups tend to show strongly correlated ratings, and tend to use the same information in making their ratings (Balota et al., 2001). This suggests that familiarity ratings may be roughly comparable across generations.

4.2 *Phonologically-based lexical properties*

A few researchers have examined whether phonological properties of words may have different effects across ages. However, these studies have demonstrated quite varying results, most of which may be the result of the use of different tasks and modalities. As an example, Sommers (1996), using an auditory perception task, reported greater effects of lexical neighborhood in older adults, whereas Spieler and Balota (2000), using an oral reading task, report reduced neighborhood effects. Moreover, both tasks involved the *perception* of language (either auditorily or orthographically). As such, they involved not only lexical access, but also required that elders process linguistic input through a potentially weakened perceptual system (Salthouse, 1985). As a result, it is difficult to determine whether these studies show age-related changes of lexical access per se (let alone the direction of such an effect). A discussion of lexical factors considered in this investigation and deemed to affect the phonological system follows.

4.2.1 Lexical neighborhood

One potential source of differences in lexical access comes not from the words themselves, but from their similarity to other words the individual knows. According to the *neighborhood activation model* (Luce & Pisoni, 1998), words in the phonological lexicon are organized according to their phonological similarity to other words. For example, the word *hum* is located in a dense neighborhood, as there are many other words in English that are similar to it (*numb*, *him*, and *hug*, among others). In contrast, the word *void* has very few neighbors (*voice* and *avoid*). Words within a neighborhood compete with one another for both recognition and for selection. However, this competition appears to have a differential impact depending on the nature of the processing task. Whereas a dense neighborhood appears to impair perception in recognition tasks (Luce & Pisoni, 1998), in production tasks it may aid speech performance. Children find it easier to produce and remember words that were similar phonologically to other known words (Gathercole, Frankish, Pickering, & Peaker, 1999; Gathercole, Willis, Emslie, & Baddeley, 1991). German and Newman (2004) reported that lexical density was the single most important factor in determining the likelihood of successful lexical access among children with word-finding difficulties. Words that had many neighbors appeared to lead to successful retrieval while those with few neighbors were particularly problematic. Further, it has been reported that both adults (Harley & Bown, 1998; Vitevitch, 1997; Vitevitch & Sommers, 2003) and children with word-finding difficulties (German & Newman, 2004) produced more semantic and tip-of-the-tongue errors on words from sparse neighborhoods.

A few studies have suggested that there may be age effects on lexical neighborhood. However, other than Newman and German (2002), these studies have focused on perception, rather than production (see, e.g. Charles-Luce & Luce, 1995; Charles-Luce & Luce, 1990; Garlock et al., 2001; Sommers, 1996) or on orthographic rather than phonological neighborhoods (Spieler & Balota, 2000). Even so, given these indications of perceptual age-related changes, we thought it meaningful to continue to examine whether developmental changes altered the impact of lexical neighborhood on oral lexical access in adolescents and adults.

4.2.2 Phonotactic probability

A closely related issue to lexical neighborhood is that of phonotactic probability. Phonotactic probability refers to the frequency with which a sound or sequence of sounds occurs in the language. A standard approach to calculating phonotactic probability is to determine the likelihood of each phoneme and biphone (or pair of phonemes) occurring in that position in a word, and to sum these values (see, e.g., Jusczyk, Luce, & Charles-Luce, 1994; Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997). This procedure reveals that some sounds (such as /t/) are quite frequent in the language, whereas others (such as the medial consonant in *measure*) are quite rare. Similarly, some phoneme combinations occur quite commonly (such as /nt/ in *hint*, *faint*, and *pint*), whereas others (such as the /mt/ in *dreamt*) are infrequent. These probabilities can differ for different locations in a syllable; for example, the final phoneme in *ring* is quite common syllable-finally, but never occurs syllable-initially in English.

Phonotactic probability correlates quite highly with lexical neighborhood, since items that have many, frequent neighbors necessarily contain high-frequency phonemes. However, lexical neighborhood effects tend to be competitive, whereas phonotactic effects are facilitative. In most studies, the two effects are conflated, and which wins out depends on the specific properties of the task (Vitevitch & Luce, 1998, 1999). Adults are faster at repeating words that are high in phonotactic probability (Vitevitch et al., 1997). Children's serial recall also shows effects of phonotactic probability, such that nonwords that include common phoneme sequences are recalled more accurately (Gathercole et al., 1999). In the present paper, we examined neighborhood properties first, to see whether these might influence lexical access. We then attempted to tease apart effects of phonotactics from those of lexical neighborhood by examining effects of both phoneme probability and biphone probability while keeping lexical neighborhood constant. In this manner, we serve to ensure that effects of phonotactic probability are not being driven by lexical neighborhood, per se.

In summary, the present study compares individuals' oral naming performance across the life span. Naming performance is compared for words that differ in both semantic-based lexical factors (such as target word familiarity, frequency of occurrence, and age of acquisition) and form-based factors (lexical neighborhood and phonotactic probability). By examining these features across the lifespan, we are able to consider how the influence of these features might change with maturation.

5 Method

This investigation studied the lexical access skills of adolescents (12 to 19 years) and adults (20 years to 83 years). These participants were administered the experimental *test of adolescent/adult word finding* (TAWF) (German, 1990) by speech and language pathologists. These participants are described below.

5.1 *Participants*

A total of 1,075 individuals (717 adolescents and 358 adults) participated in this investigation. The adolescents were randomly selected from among 7th through 12th grade learners attending schools in Scottsdale, AR; Oakland, CA; Chicago, Oak Park and Wheeling, IL; Brighton, Dorchester, Jamaica Plains, and Roxbury, MA; Ann Arbor, MI; Litchfield, MN; Norwood, NC; Pittsburgh, PA; Coppell, Lake Dallas, and Lewisville, TX; and Racine, WI. The adolescent participants included 401 females and 316 males. They were from four different ethnic groups, residing in lower-middle to middle socioeconomic-class homes (determined by parents' educational level), distributed approximately equally across Grades 7 through 12. All students had normal speech, language, hearing, and vision, and had never received or been referred for special education services. To ensure typical word-finding skills among the participants, learners whose naming scores were two *SD*s below their age mean on the naming measure were excluded. A total of 27 adolescents were thus disqualified, leaving a total of 690 adolescents participating in the investigation, distributed across the following seven age ranges: 12-year-olds ($N = 100$), 13-year-olds ($N = 100$), 14-year-olds ($N = 100$), 15-year-olds ($N = 100$), 16-year-olds ($N = 100$), and 18 and 19 year-olds ($N = 90$).

Adult participants were a subset of 530 adults selected from 600 participants. Participants completed permission forms that provided the following personal information: educational attainment level, occupation, primary language spoken in the home, and remarkable heath history. Based on this self-reporting, adults were assigned to cells representing the stratification variables under consideration (sex, chronological age, race or ethnicity, socioeconomic level). Final participants were randomly chosen from the adults assigned to each cell, with the intent of keeping the number of individuals per cell as even as possible. Further, because adults with brain trauma, neurological disease, cardiovascular strokes, fluency disorder or learning disabilities are typically identified as having a higher-than-expected incidence of word-finding difficulties, adults indicating these difficulties were excluded from this investigation. In addition, to ensure that our sample only included participants with typical word-finding skills, adults whose word-finding scores were more than two *SD*s below the mean of their age and gender group were excluded, post assessment.

Adult participants were distributed across the following seven age ranges: 20-year-olds ($N = 60$), 30-year-olds ($N = 60$), 40-year-olds ($N = 60$), 50-year-olds ($N = 60$), 60-year-olds ($N = 60$), and 70- and 80-year-olds ($N = 58$), with the maximum age being 83 years, 7 months. Gender was evenly represented among groups, except for the two oldest, which contained more females (34 females and 26 males in the group of 60-year-olds, 44 females and 14 males in the group of 70-year-olds). All of the participants had completed high school; 141 had high school only, 95 had some college, and 122 were college graduates. Adults resided in the following cities and states: Scottsdale, AZ; Fort Smith, AR; Oakland, CA; Denver, CO; Bethel and Hartford, CT; Boise, ID; Valparaiso, IN; Iowa City, IA; Boston, Lowell and Roxbury, MA; Litchfield, MN; Joplin, MO; Metuchen and Willingboro, NJ; Utica, NY; Cranston and Newport, RI; Albemarle and Norwood, NC; Fort Smith, OK; Pittsburgh, PA; Nashville, TN; Lake Dallas, Lewisville, and Coppell, TX; Olympia, WA, and Racine, WI.

5.2
Materials

Naming responses, on file, to 148 items from the experimental version of the *test of adolescent/adult word finding* (German, 1990) were used for the present analyses (see appendix). The TAWF requires naming to three different types of prompts: 77 colored illustrations of noun (singular and plural) and verb (progressive *-ing* form) target words; 42 open-ended sentences (e.g., *Hot melted rock flowing from an active volcano is called* _____ [lava]) and definitions (e.g., *What is a permanent picture that is drawn on your skin by putting color in with a needle?* [tattoo]) designed to elicit target words; and 29 3-word items for category identification (e.g., *Mars; Jupiter; Saturn; These are all* ______ [planets]). Target words could be monosyllabic (e.g., *palm*, *crutch*) or multisyllabic (e.g., *harmonica, propeller*), ranged from low to high in frequency of occurrence, and represented multiple semantic categories. Moreover, all test items were chosen to have high item comprehension across a range of participants (i.e., the pictures and descriptions were rarely misinterpreted).

5.3
Procedures

5.3.1
Instructions

Naming tasks were individually administered by trained examiners. Participants were asked to name pictures in response to one of three probes: "*This is a* ..."; "*What is he/she doing*...?"; or "*These are all* ...." Pictures remained available until the participant responded. For open-ended sentences and descriptions participants were asked to name the word that best completed the sentence or matched the definition. Sentences and definitions were repeated upon request. For category identification, participants were given three exemplars and were asked to label the category represented (e.g., *waltz, twist, jitterbug* for 'dances'). For all analyses, approximately equal numbers of items in the pictoral versus verbal naming sections occurred in each group of words. Factor analysis of the scores from the five sections of the TAWF identified a single factor, word finding, with each of the section scores having high and similar loadings on this single factor. This provides support for the similarity of the construct (word finding/naming) being measured by each of the sections, and suggests that it is appropriate to collapse across different means of elicitation in our analyses.

5.3.2
Scoring

Accuracy in naming was tallied for each item for each participant. Naming errors consisted of target word substitutions (semantic and phonological); no response (e.g., a participant responding that he or she did not know the answer (IDK) or failing to respond); and circumlocutions (e.g., participant describing the intended referent rather than naming it).

5.3.3
Target word comprehension

Comprehension was assessed on all items that were not named correctly. Participants were asked to select the appropriate word from a three-picture field, including the target word and two decoy items. Participants' comprehension scores for target words in each naming section ranged from 96% to 100%. This suggests that the words chosen were all well-known to the participants, and that naming errors were unlikely to be the result of lack of knowledge.

5.3.4
Lexical factor analysis

For the purpose of analysis, the 148 target words were looked up in an on-line version of the Webster's 20,000-word pocket dictionary, and in the MRC Psycholinguistic database.[1] Although these databases were not always specific to the age ranges of our participants, they were used because they are putatively age independent; use of databases specific to the age ranges of our participants would have required comparing data obtained from multiple databases. Furthermore, because each of these databases is used frequently in the literature, meaningful comparisons across different studies will be possible. From these databases, a number of different measures were taken:

Frequency of occurrence: The frequency of occurrence of each target word was determined from word counts generated by Kučera and Francis (1967). These frequency values were then transformed into log-frequency values. (Where findings for frequency are reported, raw frequency values are provided, since they may be more intuitive values than are log-based numbers. However, all divisions into subsets were based on the log-transformed values). Frequency counts were summed for homonyms, as they involve the same phonological form; Dell has found the frequency of the phonological form, rather than the frequency of the semantic unit, to be the more relevant factor in speech production errors (Dell, 1990; see also Levelt et al., 1999 for a discussion of this issue). Frequency values were available for 132 of the target words.

Age of Acquisition: Age of acquisition norms were taken from Gilhooly and Logie (1980); they asked listeners to rate the age at which each word was learned, ranging from a 1 (age 0–2) to a 7 (age 13 years and older)[2]. These ratings were then multiplied by 100 to produce scores ranging from 100 to 700. Subjective ratings such as these have been shown to be highly correlated with objective measures, and thus appear to be a valid measure of true age-of-acquisition (Gilhooly & Gilhooly, 1980). AOA values were only available for a subset of the target words (34 words total).

Familiarity: Familiarity ratings were taken from Nusbaum, Pisoni and Davis (1984), and were based on a seven-point scale, with 7 indicating greatest familiarity. Familiarity ratings were available for 132 of the target words.

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

Phonotactic probability: The probability of the phonemes and biphones in the target word when assessed across the language as a whole. This analysis was limited to words of the same length, since formulas for phonotactic probability

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[1] Values for the lexical factors for all words are available upon request from the authors.

[2] These values are based on ratings from British speakers. The AOA corpora based on American ratings were not used because they have far fewer target words (the Snodgrass & Yuditsky (1996) corpus contains only six, and the Carroll and White (1973a) corpus contains 11, while the British corpus we used included 34 of our target words).

sum across the probabilities in each position (thus confounding word length with total probability).

Obtained values for each studied factor were used to create subsets of words to evaluate each of the issues described above. For each analysis, factors other than the one being studied were held constant, with exceptions noted below.

5.3.5
Statistical analyses

ANCOVAs with one repeated measure (the lexical factor) were conducted for each lexical factor. Age was treated as a continuous measure for the initial analyses. However, because we expected age to show a quadratic trend (poorest performance for both the youngest and oldest participants, as shown in the overall analysis below), we used the square of age, rather than age itself, as the regressor in the ANCOVA analyses. When interactions between age and the lexical factor were discovered, follow-up tests were performed in which participants were grouped by age; this allowed us to compare the size of the effect for different age ranges.

6 Analyses

6.1
Overall age effects

Before looking at the effects of specific lexical factors, we first examined overall effects of accuracy across the lifespan. We examined the effect of accuracy with two covariates, age and age-squared, and found significant effects of both (age: $F(1, 1045) = 289.79$, $p < .0001$; age-squared, $F(1, 1045) = 286.82$, $p < .0001$). Follow-up analyses showed that adolescents averaged 82.1% accuracy; young adults (those ranging in age from 20–49) averaged 89.88%, and older adults (aged 50+) averaged 81.98%. There were significant differences between the young adults (the middle-aged group) and the other two groups, who did not differ from one another (young adults vs. older adults, $t(356) = 9.35$, $p < .0001$; young adults versus adolescents, $t(868) = 12.15$, $p < .0001$; adolescents versus older adults, $t(866) = 0.15$, $p > .05$). This pattern of performance shows the expected quadratic trend, with improvement in naming during early development, and then a decline again with aging. (See Tabor Connor et al., 2004 for other studies showing a general decline in naming with age.)

6.2
Impact of word frequency on lexical access across the life span

In the analysis of word frequency, two sets of words were compared; one set consisted of high-frequency words, and the other of low-frequency words. This analysis provides a comparison of the degree to which word frequency influences lexical access across the life span. This lexical factor is thought to focus on word usage. Because frequency of usage could affect strength of connections between the semantic and phonological components of the lexicon, we judge this lexical factor to influence semantic-to-form transmission, the connections between Stage 2 and 3 of our lexical model. It was predicted that high-frequency words would be easier to access than low-frequency words for all age groups. However, the size of this effect could still differ across the lifespan. Word lists and analyses are presented below.

6.2.1 Materials/Word lists

To examine the impact of word-frequency on lexical access, two subsets of 36 words each were created, differing in their average log-based word frequency (low frequency mean = 1.20, $SD = 0.32$; high-frequency mean = 2.53, $SD = 0.49$; $t(70) = 13.55$, $p < .0001$). Based on raw frequency values, words in the low-frequency set occurred two times per million words (range 1 – 10; $SD = 2.14$), while words in the high-frequency set averaged 68 occurrences per million words (range 7 – 382; $SD = 96.65$; $t(70) = 4.11$, $p < .0001$).

These sets of words were matched in terms of other factors that might influence lexical access. Word sets did not differ in their familiarity ratings (average ratings of 6.91 ($SD = 0.16$) for low-frequency words, 6.95 ($SD = 0.12$) for high-frequency words, $t(70) = 1.17$, $p > .05$), in their neighborhood density (average number of neighbors was 3.83 for low frequency words, 4.78 for high frequency words ($SD = 3.98$ low, $SD = 6.10$ high), $t(70) = 0.78$, $p > .05$), or in their length in syllables (1.78 ($SD = 0.76$) for low-frequency words, 1.86 ($SD = 0.90$) for high-frequency words, $t(70) = 0.43$, $p > .05$). Finally, for those words for which values were available (20 words), sets were matched for their age-of-acquisition, or AOA (average value of 356 ($SD = 47.5$) for low-frequency words and 362 ($SD = 69.0$) for high frequency words, $t(17) = 0.17$, $p > .05$). Using sets which were matched in this way allows us to be relatively sure that effects found are the result of differences in word frequency, rather than being the result of these other potential confounds.

6.2.2 Findings

An ANCOVA with one repeated measure (word frequency) and one covariate (age-squared) revealed a significant effect of the lexical factor, $F(1, 1046) = 357.57$, $p < .0001$. In general, participants averaged 81.9% accuracy on low-frequency words, but 87.3% accuracy on high frequency words. There was no overall effect of age ($F < 1$), but there was a significant interaction between the two factors, $F(1, 1046) = 8.52$, $p < .005$. This suggests that the effect of word frequency on naming accuracy changes across the lifespan.[3]

In order to explore this age effect more closely, we performed follow-up ANOVAs, in which age was treated as a between-group discrete (rather than continuous) factor.

[3] Additional analyses tested for interactions between the different lexical factors and participant sex (looking across all participants), and between the lexical factors and level of educational attainment in the adult participants only (among adolescents, age and educational attainment have correlations nearing 1.0). Sex interacted with only one lexical factor, that of word familiarity (males and females performed similarly for low-familiarity words, but had a slight (< 1%) accuracy difference on highly familiar words). Years of education had a marginal interaction with word frequency, with a slightly smaller effect of word frequency among individuals with more education. Further details of these analyses are available from the authors on request, but the results suggest that neither educational attainment nor participant sex have large influences on naming performance for these words.

We divided participants into three groups: adolescents (those aged 12 to 19 years), young adults (those aged 20 to 49 years), and older adults (those aged 50 and higher). There were significant effects of frequency, $F(1, 1045) = 223.68$, $p < .0001$, and of age, $F(2, 1045) = 53.40$, $p < .0001$, with young adults outperforming the other two age groups in naming accuracy (90.3% for young adults vs. 83.3% for adolescents and 84.0% for older adults). Most critically, there was a significant interaction between these two factors, $F(2, 1045) = 9.54$, $p < .0001$. The effect of word frequency was present in all three age groups (for adolescents, $t(689) = 18.65$, $p < .0001$; for young adults, $t(179) = 7.14$, $p < .0001$; for older adults, $t(177) = 6.99$, $p < .0001$), but the size of the effect was larger for adolescents than for the other two age groups, who did not differ from one another (adolescents vs. young adults, $t(868) = 3.33$, $p < .001$; adolescents versus older adults, $t(866) = 3.31$, $p = .001$; young versus older adults, $t(356) = 0.005$, $p > .05$).

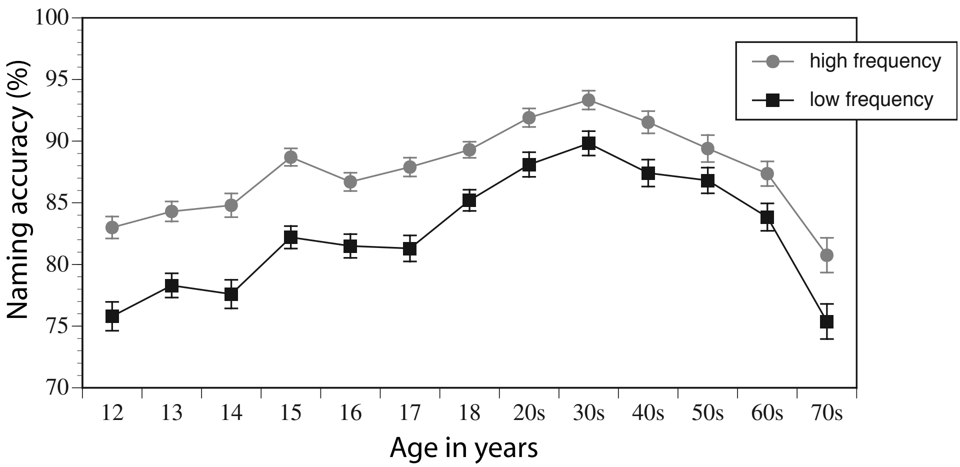
Thus, while it appears that the frequency with which a word occurs in the language influences lexical retrieval across the life span, the size of this effect changes with maturation. Young and older adults performed similarly, while adolescents experienced the greatest impact of this lexical factor on their word-finding skills. These results are compatible with some of the prior research (e.g., Allen, Madden, & Crozier, 1991; Allen, Madden, Weber, & Groth, 1993; Whiting et al., 2003), which has likewise shown that older adults and younger adults showed similar effects of word frequency. However, Spieler and Balota (2000) found that word frequency played a larger role in the recognition performance of older than younger adults, as did Balota and Ferraro (1993). This difference may be the result of task differences; in particular, these two earlier studies measured the speed with which adults were able to read a word aloud. This task involves not only lexical access and speech production, but also reading ability; as the authors themselves note, the greater effect of word frequency in their study may be a result of differences in visual acuity or peripheral processing, rather than lexical access (see Allen et al., 1993 for more on this argument). Another possibility is that because these earlier studies did not control for differences in familiarity, the items they chose may have differed in both familiarity and frequency, rather than in frequency alone.

Explanations for the greater effect of word frequency in adolescents' naming are either retrieval-based or knowledge-based. That is, our adolescents had either not fully established the algorithms for retrieval of the low-frequency words or they simply did not know the word meanings. We would argue the knowledge-based hypothesis is not valid in this case as comprehension of these items was quite high, even for the youngest participants. Moreover, the fact that these words were drawn from elementary-school reading vocabulary lists suggests that the adolescents would have had ample opportunity to learn the meanings of these words. We believe that a more likely explanation would be that our adolescents had less opportunity to use these low-frequency words than our young and older adults, and thus may not have become as automatic in accessing the lemma and/or form attributes of the words for production. Although closure on this issue awaits further study, our findings, in the presence of participants' good comprehension of all target words, suggest that differences in access automaticity need to be considered as well as differences in the richness of adolescents' semantic representations to explain these findings.

In summary, even though older adults show poorer naming performance overall, they did not appear to show any change in the effect of word frequency (see Allen et al., 1991; Allen et al., 1993; Whiting et al., 2003 for similar findings). To some extent this latter finding may be surprising; we might have expected that a word's frequency would serve a protective value as individuals age, such that elderly adults would perform relatively poorly for low-frequency words compared to young adults, but would have similar retrieval abilities for high-frequency words (resulting in a larger effect of word frequency in the older age groups). That was not the case, however; to the extent that age influences lexical access, it appears to have a similar effect on both high-frequency and low-frequency words. Or, to put it another way, even lexical access ability for very high-frequency words may be influenced by aging.

Figure 1

Effect of word frequency on naming accuracy across the lifespan



6.3
Impact of age of acquisition on lexical access across the life span

To examine the second semantic factor, the impact of age of acquisition on lexical access across the life span, two sets of words were compared. These sets of words differed in the age at which they are typically acquired. It was predicted that words learned earlier in life (lower AOA) would be easier to name than would those words learned later in life (high-AOA) for individuals of all ages. However, given that previous work found that the size of the effect decreased during childhood (Newman & German, 2002), we expected that the effect size might continue to decrease slightly during adolescence.

Examining this age effect across the lifespan may help to distinguish between two possible sources of this effect. This lexical factor could focus on either Stage 2 (accessing the semantic representation) or connections between Stage 2 and 3 (transmitting the information from the semantic to the form-based lexicon), as noted in our lexical model. If this lexical factor impacts on lemma access, it is possible that lexical effects may be the result of differences in lexical knowledge. That is, perhaps young children have not stored recently-learned words in as rich a semantic network as adolescents. These poorer representations would then result in poorer access. An alternate possibility is that adolescents have rich representations, but are less efficient in their lexical access. In this case one might hypothesize that AOA effects impact semantic-to-form transmission, connections between Stage 2 and 3 in our model sited above. In either case, children would be expected to show less of an AOA effect as they age. But these two different theories lead to different hypotheses regarding the role of AOA later in life. While older adults might similarly be less efficient at accessing words, there is no reason to believe that their semantic knowledge would decrease. (Indeed, a variety of studies suggest that the lexical knowledge of older adults is higher than that of young adults, and that this may be a contributing factor to their lexical access difficulties; see, e.g., Dahlgren, 1998). Thus, if effects of AOA are the result of differences in knowledge, we would expect that young adults and older adults would perform similarly to one another; the size of the AOA effects would decrease as children and adolescents age and then would eventually plateau, remaining relatively constant thereafter. In contrast, if effects of AOA are the result of differences in efficiency of access, we might expect to see an increase in AOA effects among our oldest participants.

6.3.1
Materials/Word lists

Two sets of 13 words each, differing in their age of acquisition (or AOA) were created (low-AOA average rating = 311, $SD = 27.4$; high-AOA average rating = 411, $SD = 50.5$; $t(24) = 6.31$, $p < .0001$). Word sets did not differ in familiarity ratings (6.98 ($SD = 0.05$) for low-AOA words; 6.90 ($SD = 0.22$) for high-AOA words, $t(24) = 1.23$, $p > .05$), log-based word frequency (2.56 ($SD = 0.73$) vs. 2.25 ($SD = 0.68$), $t(24) = 1.14$, $p > .05$), neighborhood density (3.8 ($SD = 3.88$) vs. 4.2 ($SD = 5.61$), $t(24) = -.24$, $p > .05$), or length in syllables (1.8 ($SD = 0.6$) vs. 2.1 ($SD = 1.0$), $t(24) = 0.71$, $p > .05$).

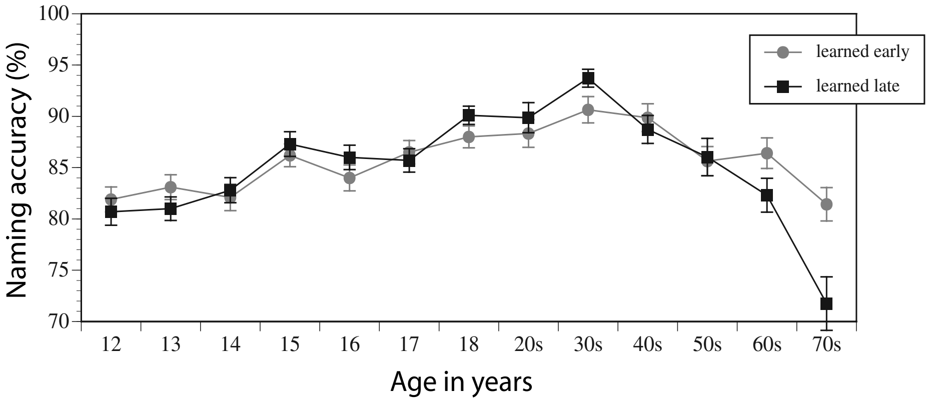
6.3.2
Findings

An ANCOVA revealed a small but significant effect of AOA, $F(1, 1046) = 4.24$, $p < .05$. There was also a significant overall effect of age-squared, $F(1, 1046) = 11.53$, $p < .0001$, and a significant interaction between the two factors, $F(1, 1046) = 23.65$, $p < .0001$.

We performed follow-up analyses to explore the age effect in more detail. As before, we divided participants into adolescents (12–19 years), young adults (20s, 30s, and 40s) and older adults (50s, 60s, 70s). There was a significant effect of age, $F(2, 1045) = 29.46$, with young adults showing the best performance in naming accuracy (90.2% for young adults vs. 84.6% for adolescents and 82.5% for older adults), a marginal effect of AOA, $F(1, 1045) = 3.65$, $p < .06$, but a significant interaction between the two factors, $F(2, 1045) = 9.68$, $p < .0001$. There was no effect of AOA in the adolescents, $t(689) = -0.46$, $p > .05$, or young adults, $t(179) = -1.45$, $p > .10$, but a significant effect in the older adults, $t(177) = 4.29$, $p < .0001$. Older adults had 84.5% accuracy on those items learned earlier in life, but only 80.4% accuracy on those items learned at an older age. Looking even more closely at these older adults, this effect was present in those individuals in their 60s, $t(59) = 3.01$, $p < .005$ and 70s, $t(57) = 4.93$, $p < .0001$, but not for those in their 50s, $t(59) = -0.23$, $p > .05$. Thus, it appears that as individuals reach their 60s, they begin to show a relative decline in their naming accuracy for words learned later in life. This finding suggests that relative to retrieval, the age-of-acquisition semantic property is not resistant to age-related changes. Specifically, age had a significant effect on retrieval of words learned later in life, with less effect on retrieval of words learned earlier in life.

Figure 2

Effect of age-of-acquisition on naming accuracy across the lifespan



These findings may reflect an extension of earlier findings reported for primary- and intermediate-age students. Strong effects of AOA were reported on similar single-word naming tasks for these younger children, but the size of the effect decreased as children became older (Newman & German, 2002). Our present findings combined with those earlier results suggest that AOA effects may reflect a quadratic-shaped function across the life span. That is, it appears that AOA effects are strongest in those individuals who have the poorest lexical access (young children and older adults). As children develop, naming becomes more automatic, and AOA effects decrease. Later in life (60s and 70s), naming again becomes more difficult and AOA effects re-emerge. This may support the notion that effects of AOA are the result of differences in efficiency of access, not simply a result of differences in learning, since the increase in AOA effects was found among the older participants only.

6.4
Impact of word familiarity on lexical access across the life span

A third semantic factor that could potentially influence lexical access is the extent to which a word is judged as familiar to the speaker. Familiarity is highly correlated with a word's frequency, in that more common words tend to be rated as more familiar than are less common words. However, this correlation is not complete; some words are judged as quite familiar to listeners, even though they do not occur very often in the language (as an example, the word *puddle* is considered very familiar, despite being relatively uncommon). Similarly, familiarity is correlated with age of acquisition, but there are again words that are rated as highly familiar which are learned only later in life (such as *transportation*). Some results have suggested that for relatively common words, familiarity ratings may be based primarily on a word's frequency, whereas for relatively rare words, familiarity may be based more on meaningfulness (Balota et al., 2001). That is, when judging familiarity, speakers may be more inclined to focus on whether they know the meaning of the words when the words are relatively uncommon, but may be more likely to be focus on the frequency with which they encounter the word when the word is more common. If this is the case, then familiarity may not be a single factor. However, all of the words in the current study were quite well-known, and thus familiarity judgments for these words might be thought to be less likely to be based on measures of meaningfulness, and more likely to be a third measure related to semantic-to-form transmission (Stage 2 in our model). Therefore, we decided to examine whether familiarity ratings might also play a role in a word's ease of naming, over and above effects of word frequency and age of acquisition.

6.4.1
Materials/Word lists

We created two sets of 39 words each, differing in their rated familiarity. Although all words were rated at least a six on a 7-point scale, the low-familiarity words averaged 6.73 ($SD = 0.19$), whereas all of the words in the high-familiarity set were given a rating of 7 out of 7 ($SD = 0$). (There was no overlap in ratings across the 2 sets.) This difference is significant, $t(76) = 8.67$, $p < .0001$. The sets did not differ in their log-based word frequency, 1.69 ($SD = 0.77$) versus 1.71 ($SD = 0.66$), $t(76) = 0.08$, $p > .05$, number of neighbors, 5.59 ($SD = 7.24$) versus 5.67 ($SD = 7.39$); $t(76) = 0.05$, $p > .05$, length in syllables, 1.74 ($SD = 0.72$) versus 1.89 ($SD = 0.79$), $t(76) = 0.90$, $p > .05$, or age-of-acquisition ratings when available, 348 ($SD = 45.2$) versus 340 ($SD = 69.1$), $t(14) = 0.26$, $p > .05$.

6.4.2
Findings

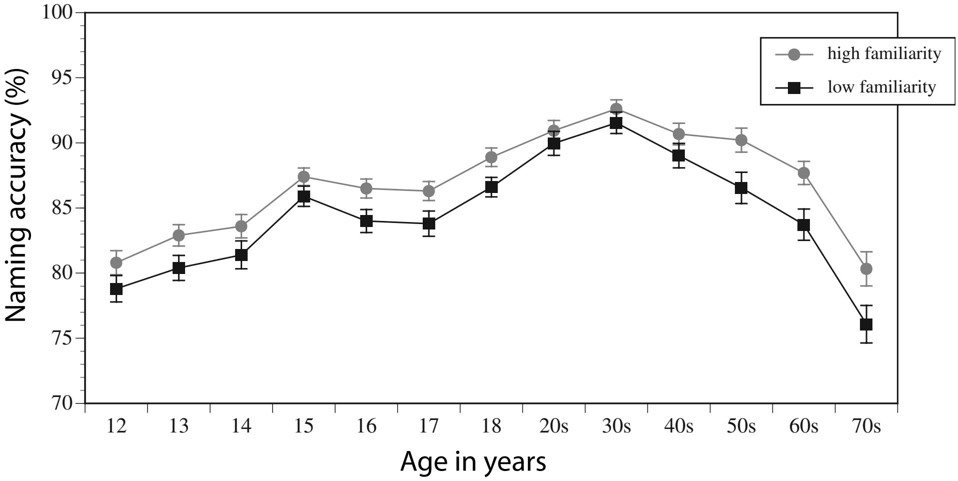
An ANCOVA showed a significant effect of word familiarity (low familiarity words = 84.0% accuracy, high familiarity words = 86.4%; $F(1, 1046) = 47.16$, $p < .0001$. There was no overall effect of age-squared, $F(1, 1046) = 1.64$, $p > .10$, but there was an interaction between age and the lexical factor, $F(1, 1046) = 8.79$, $p < .005$.

Follow-up ANOVAs suggested that young adults did perform better than the other two groups, despite the lack of an overall age effect in the ANCOVA: effect of age in the ANOVA, $F(2, 1045) = 53.54$, $p < .0001$; overall accuracies of 84.0% for adolescents, 84.2% for older adults, and 90.8% for younger adults. It appears that this discrepancy may be the result of a very gradual change in performance throughout the lifespan, with peak performance occurring among individuals in their 30s (see Fig. 3). The interaction between familiarity and age, $F(2, 1045) = 6.63$, $p < .005$, is apparently the result of an increase in the size of the familiarity effect with age. Although the effect was present in all three age groups, adolescents, $t(689) = 7.84$, $p < .0001$; young adults, $t(179) = 2.77$, $p < .01$; and older adults, $t(177) = 6.86$, $p < .0001$, the effect was significantly larger in the older adults, who differed from the other two groups: older versus young adults, $t(356) = 3.73$, $p < .0005$; older adults versus adolescents, $t(866) = 2.78$, $p < .01$; young adults versus adolescents, $t(868) = 1.63$, $p > .10$.

This lexical property had different effects across the lifespan. Naming performance on less familiar words declined with age whereas naming performance on more familiar words did not. Thus, as with AOA, it appears that as we age, words that are less familiar are more difficult to access. Familiarity, like AOA, may serve as a protective factor such that highly familiar words do not show the same decrements in naming performance with aging as do less familiar words.

Figure 3

Effect of word familiarity on naming accuracy across the lifespan



6.5
Impact of lexical neighborhood on lexical access across the life span

Our investigation of lexical neighborhood focuses on the type of neighborhood effect examined most often, neighborhood density. Density refers to the number of neighbors an item has. A word like *cat* has many neighbors, such as *hat*, *cot*, and *cap*, while a word such as *orange* has very few. Since neighborhood density does not take into account the frequency with which those neighbors occur, it can be considered a measure of the number of neighbors in the mental lexicon, but not of the frequency with which those neighbors are encountered in spoken language. We believe this factor to impact lexical access at Stage 3 in our lexical model.

A number of previous studies have reported effects of neighborhood density on lexical access. However, these effects have varied depending on the cognitive process under study and the age and abilities of the participants. For example, Newman and German (2002) reported that school-age students had more difficulty naming words that resided in dense neighborhoods, with the effect being greater for the younger than older children. In contrast, German and Newman (2004) found that children with word-finding difficulties produced more blocked errors (commonly known as “tip-of-the-tongue” errors) on words from sparse neighborhoods. Vitevitch (2002) also reported that adults made more speech errors for words with sparse neighborhoods.

Therefore, we thought that additional data on the impact of neighborhood density on individuals' naming skills as they mature would be helpful in sorting out the influence of neighborhood density on lexical access. We thus studied participants' naming skills on subsets of words differing in their neighborhood density.

6.5.1
Materials/Word lists

Two subsets of 22 words each, differing in their neighborhood density, were created. Words in the sparse neighborhood set had an average of 3.1 neighbors ($SD = 1.44$); those in the dense neighborhood set had an average of 14.8 neighbors ($SD = 8.16$); $t(42) = 6.61$, $p < .0001$. The sets did not differ in their familiarity, 6.94 ($SD = 0.09$) versus 6.92 ($SD = 0.19$), $t(42) = 0.26$, $p > .05$, log-based word frequency, 2.16 ($SD = 0.84$) versus 2.17 ($SD = 0.61$), $t(42) = 0.08$, $p > .05$, or age-of-acquisition ratings when available, 343 ($SD = 47.4$) versus 345 ($SD = 66.3$), $t(12) = 0.05$, $p > .05$. There was, however, a marginal difference in length, such that the dense-neighborhood words were slightly shorter than the sparse-neighborhood words, 1.5 syllables ($SD = 0.51$) versus 1.3 syllables ($SD = 0.46$), $t(42) = 1.87$, $p < .10$.

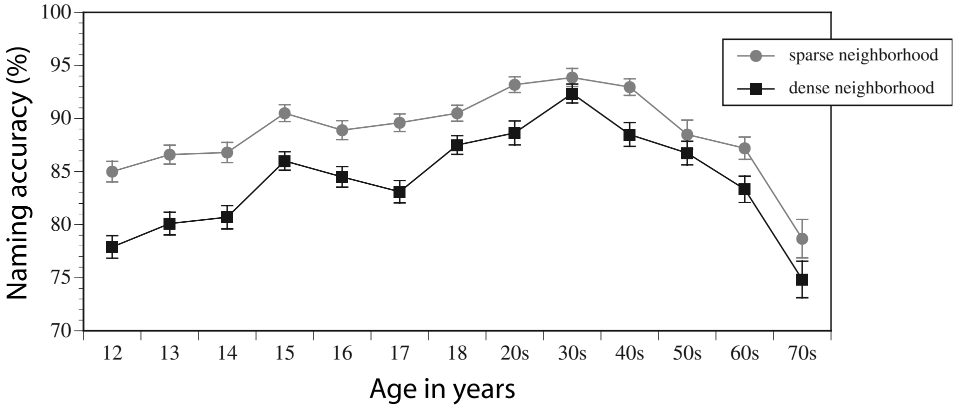
6.5.2
Findings

An ANCOVA revealed a significant effect of neighborhood density, $F(1, 1046) = 209.99$, $p < .0001$, as well as a significant effect of age squared, $F(1, 1046) = 19.72$, $p < .0001$, and an age by neighborhood interaction, $F(1, 1046) = 6.88$, $p < .01$. Looking across the three age groups, an ANOVA revealed once again a significant age effect, with young adults performing best, $F(2, 1045) = 49.97$, $p < .0001$; naming accuracies of 85.5%, 91.6%, and 83.3% for adolescents, young adults, and older adults, respectively. Naming accuracy was higher for words from sparse neighborhoods (88.6% vs. 83.8%), suggesting that the presence of lexical neighbors may have caused interference in naming. This effect was present in all three age groups, adolescents, $t(689) = 14.61$; young adults, $t(179) = 5.87$; and older adults, $t(177) = 4.00$, all $p < .0001$, but was substantially larger in the adolescents than in the other two groups, adolescents versus young adults, $t(868) = 2.51$, $p < .05$; adolescents versus older adults, $t(866) = 2.81$, $p = .005$; older versus younger adults, $t(356) = 0.37$, $p > .05$.

Thus, it appears that the effect of lexical neighborhood is larger amongst the youngest participants. This pattern is bolstered by a closer examination of effects within the adolescents alone. Here, too, there was a significant interaction with age, $F(6, 683) = 2.18$, $p < .05$, and follow-up t-tests suggested that the effect was present among all groups, but largest among the younger adolescents (accuracy differences were 7.1% for 12-year-olds; 6.5% for 13-year-olds, 6.2% for 14-year-olds, 4.6% for 15-year-olds, 4.5% for 16-year olds, 6.5% for 17-year-olds, and 3.0% for 18-year-olds; the oldest group differed significantly from the three youngest, as well as from the 17-year-olds). Thus, effects of neighborhood appear to be steadily declining through the teenage years, but then plateau, remaining relatively constant throughout adulthood.

Figure 4

Effect of neighborhood density on naming accuracy across the lifespan



In general, these results indicate that both adolescents and adults find it easier to name words residing in sparse neighborhoods, that is, words with fewer neighbors. This finding suggests that one source of word-finding errors for individuals may be either a failure to inhibit competition or an inability to resolve blocking brought about by many similar-sounding words. Although speakers have accessed the lemma they fail to access the appropriate word-form of high-density words because neighbors either compete with or block target-word selection.

6.6
Impact of phonotactics on lexical access across the life span

In this analysis we examined whether phonotactics might have an influence on naming across the life span, over and above that of lexical neighborhood. We compared participants' lexical access skills on subsets of words that differed relative to their phoneme and biphone probability. This lexical factor is thought to focus on sublexical features of the target word, noted in our model as subcomponents of Stage 3, accessing the syllabic structure and segmental features of the target word (German, 2000; Levelt, 1991).

6.6.1
Materials/Word lists

Phonotactic probability can refer both to the probability of the particular phonemes occurring (phoneme probability) and the probability of particular pairs of phonemes occurring together, as described earlier (biphone probability). Our materials included both aspects. Two sets of 10 CVC words each were created which differed in terms of high versus low phonotactic probability. These words differed both in phoneme probability and biphone probability. The low phonotactic probability set had an average phoneme probability = 1.13 ($SD = 0.02$); the high phonotactic probability set had an average phoneme probability = 1.19 ($SD = 0.03$); $t(16) = 5.27$, $p < .0001$. The low phonotactic probability set had an average biphone probability = 1.005 ($SD = 0.002$); the high phonotactic probability set had an average biphone probability = 1.008 ($SD = 0.004$);

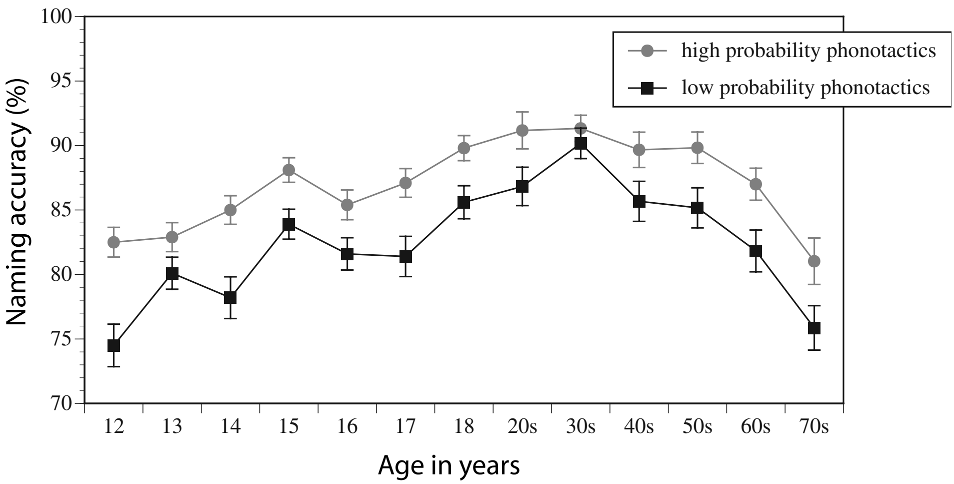
$t(16) = 2.64$, $p < .05$. The sets did not differ in their familiarity, 6.88 ($SD = 0.26$) versus 6.98 ($SD = 0.08$); $t(16) = 1.18$, $p > .05$, log-based word frequency, 2.40 ($SD = 0.59$) versus 2.39 ($SD = 0.50$), $t(16) = 0.02$, $p > .05$, number of neighbors, 18.4 ($SD = 4.90$) versus 20.2 ($SD = 6.03$); $t(16) = 0.71$, $p > .05$, or age-of-acquisition ratings when available, 318 ($SD = 83.9$) versus 340 ($SD = 65.5$), $t(6) = 0.36$, $p > .05$.

6.6.2
Findings

An ANCOVA showed a significant effect of phonotactic probability, $F(1, 1046) = 72.24$, $p < .0001$. However, there was no effect of the square of age ($F < 1$) on these words, and no interaction between phonotactic probability and age ($F < 1$). Although individuals were more accurate at naming words with high phonotactic probability (86.7% vs. 81.9%), this did not appear to change across the lifespan.

Figure 5

Effect of phonotactic probability on naming accuracy across the lifespan



These results support previous findings that phonotactic probability can have effects above and beyond lexical neighborhood. As with previous reports (Vitevitch & Luce, 1999), effects of phonotactics appear to be facilitatory, whereas effects of lexical neighborhood are competitive. That is, a word such as *cat*, which has high-frequency phonemes and phoneme combinations, is accessed more easily than a word with less common phonemes. Yet the fact that it contains high-frequency phonemes also means that it has many lexical neighbors, and those neighbors compete with the target word. Thus there are two separate effects working in opposite directions at different stages of the lexical access process.

In summary, it appears that the impact of phonotactic probability on lexical access remains constant across adolescence and adulthood. Together with neighborhood analyses, these findings suggest that the organization of the phonological lexicon influences individuals' lexical access skills in a similar way throughout adulthood.

7 General Discussion

The current study examined naming performance across the lifespan. In general, our work corroborates prior findings that demonstrate a quadratic effect of age on naming performance (accuracy). Naming performance appears to improve with maturation until the individual reaches adulthood, and then shows declines with further aging beyond that point.

Yet this investigation went beyond exploring this basic pattern of naming, and considered the impact of lexical factors on target word access. Of interest was to observe whether one's lexical access system changes with maturation relative to these lexical factors, and, if so, whether specific components of the lexical system are more or less vulnerable to the aging process. To explore this topic we considered different stages of lexical access: semantic access, semantic-to-form based connections, and phonological processing. We examined lexical factors assumed to be linked to each of these stages. Five lexical factors were studied: three assumed to be linked to either the semantic stage or the transmission between semantic and form stages in lexical access (e.g., word frequency, age of acquisition, and familiarity) and two assumed to be mapped onto stages of phonological processing (e.g., phonotactic probability and neighborhood density). In general, our findings indicated that older adults displayed qualitatively similar effects of semantic and phonological lexical properties as did younger adults and adolescents on our oral naming tasks. However, the weighting of these lexical factors appeared to change with age. Our findings are summarized below.

7.1 *Semantic processing stage*

Generally, research in language and aging has shown that access to meaning of words, as well as semantic retrieval, is relatively stable during the adult years (Burke, 1997; Mayr & Kliegl, 2000). However, this study looked beyond the access of target word meanings, focusing instead on the lexical factors of words that may be associated with semantic-to-form based connections, and found that effects of age were present. In particular, the lexical access performance of older adults was more greatly affected by a word's familiarity and age-of-acquisition than were the lexical access skills of adolescents or younger adults. That is, for older adults, less familiar words and words learned later in life were more difficult to access. Or said in a different way, those words which are highly familiar, or which are learned very early in life, may not suffer the same decrements in naming performance as do other words.

However, there was no similar protective effect for word frequency. That is, a word that was retrieved on a more frequent basis was not necessarily any better protected from age-related declines than were words retrieved less often. Newman and German (2002) likewise found no interactions with age when studying word frequency in young children. This combination of results suggests that even when a word has been encountered very frequently, such that naming would be expected to be fairly automatic, the frequency with which it occurs continues to influence its access.

In contrast, age of acquisition displayed a different developmental pattern. While AOA did influence lexical access, this effect was absent in adolescence, and then increased in size throughout adulthood. Earlier work has suggested that age of acquisition effects decrease during childhood (Newman & German, 2002). This combination of findings suggests that the age-of-acquisition lexical factor may be represented by a quadratic-shaped curve, with a relatively smaller effect during adolescence and young adulthood than in either older adults or child speakers (Newman & German, 2002).

It is also worth noting that this difference in pattern between frequency and AOA suggests that frequency effects are not being driven solely by AOA; that is, were the effects of word frequency that have been shown in the literature truly caused by a confound with AOA, we would expect to find that AOA and word frequency would be affected by age in the same manner. Finding a difference between these two suggests that they are indeed separate factors influencing lexical access.

In addition, a word's rated familiarity also influenced its naming, over and above effects of word frequency and age of acquisition, and this effect increased as participants aged. Words judged to be less familiar were more difficult to access with aging. This suggests that a word's familiarity can protect it from the decreases in access efficiency that normally co-occur with aging: while lexical access in general becomes less efficient with age, words that are highly familiar to the individual do not show greater difficulties.

In one sense, these findings appear to deviate substantially from those found in the prior literature. Prior studies have tended to find similar effects of semantic properties between young and old adults (see, e.g., Allen et al., 1991, 1993; Whiting et al., 2003). However, these prior studies focused particularly on word frequency, which we similarly found to be resistant to age-related changes. Because we expanded the lexical factors studied to include others related to word usage, we are able to both identify changes with maturation as well as to hypothesize as to where these changes might occur. Based on our findings, we postulate that some semantic-to-form related factors may actually show age-related changes.

7.2
Form-based lexical factors

A word's phonological properties also influenced its retrieval and this effect was constant across the life span. Words with few lexical neighbors were named more accurately by our adolescents and adults than those which had many neighbors, suggesting that a word's neighbors may play a competitive or blocking role in lexical access across the life span. This is a different pattern of results than that shown in previous error-type studies of children with word-finding difficulties (German & Newman, 2004), or adults (Vitevitch, 2002). However, this may be no more than a difference in the nature of the error type studied. These prior studies focused on "tip of the tongue blocks" and reported more blocked errors on words from sparse neighborhoods. The discrepancy across studies may suggest a qualitative difference in the phonological processes that underlie different lexical access errors. That is, more "tip of the tongue" blocked errors may occur on words from sparse neighborhoods whereas more slip of the tongue errors may occur on words from dense neighborhoods as a result of competition among words. Clarification of these differences will require further study because this investigation did not examine the nature of the error types produced by our participants.

The present work also demonstrated effects of a word's phonotactic probability, over and above effects of lexical neighborhood. This is particularly interesting, as phonotactic probability and lexical neighborhood are highly correlated factors, and are thus often confounded in investigations. As in other studies that have separated these factors (Vitevitch & Luce, 1999), we found that the effect of lexical neighborhood was competitive, whereas that of phonotactics was facilitative. There also appear to be differences in how the two factors are influenced by maturation, as we found a decline in neighborhood effects among our adolescents, but no effect of age on phonotactic probability. However, the two factors were similar in that neither one appeared to be influenced by the age of the individual once the individual reached adulthood.

One possible explanation for the difference between these two factors comes from the literature on speech perception. While the present study treated both phonotactic probability and neighborhood density as form-related aspects of words, work in the perception literature suggests that these two properties may actually influence two distinct stages of form-based processing (see Pylkkänen, Stringfellow, & Marantz, 2002; Vitevitch & Luce, 1998, 1999). Neighborhood density has been proposed to influence a level of lexical forms, in which different words compete with one another for activation. Phonotactic probability, instead, influences a sublexical level, in which phonemes that occur more frequently in words show stronger activation. Our current findings demonstrate different patterns of age-related changes for neighborhood density as compared to phonotactics, supporting this idea of two different form-based processing stages. These are both represented in Stage 3 of the lexical model described earlier, access of a word's syllabic structure and segmental sound units. It may be that the lexical factor of phonotactic probability is focused on accessing the segmental features of the target word, a substage of form retrieval.

The lack of an age effect for neighborhood density may be seen as somewhat surprising, in that Sommers (1996) reported age-related deficits in the perception of "hard" words (words which had many high-frequency neighbors). This difference may be, in part, a result of the difference in the nature of the cognitive task; older adults may have particular difficulty resolving the fine perceptual details needed to correctly discriminate among near-neighbors perceptually, while not showing deficits in their ability to select the appropriate word from the lexicon in a production-oriented task. One direction for future work would be to test the older adults on the same words for both of these cognitive processes, that is, perception (input) and production (output); this would allow for an explicit test of the prediction that these age-related neighborhood deficits are limited to perceptual tasks.

In summary, despite finding strong effects for our form-based lexical factors, we found no interaction with age among adult speakers. This lack of an interaction suggests the possibility that the effect of form-based properties of words per se may remain relatively constant throughout adulthood. In contrast, lexical factors of AOA and familiarity are vulnerable to maturation changing their influence on lexical access. This may be an indication that AOA and familiarity are implicating a different level of lexical access, interpreted by us as the level of semantic-to-form based transmission. This is further elaborated below.

7.3
Comparisons between semantic and form-based properties

The present findings show very different patterns of age-related effects for the semantic versus form-based properties of words, with one exception. AOA and familiarity both show effects that increase with aging; in contrast, neighborhood density and phonotactic probability do not show this increase with age. Neither does word frequency; in fact, the pattern of findings found for word frequency are quite similar to those found for neighborhood density, despite the fact that they putatively operate at different levels of processing.

One possibility is that the assumption that frequency is a semantic lexical factor may, in fact, be incorrect. Although, theoretically, the frequency with which a word is encountered in the language has a great deal to do with its semantic properties (we talk about *dogs* more often than *zebras* primarily because one species is more common in our environment and more important in our social interactions, not simply because one is a shorter word with more common phonemes), the **effect** of word frequency may well take place at the level of word forms. Indeed, studies looking at homophones suggest that word form frequency plays a much greater role in perceptual studies than does conceptual frequency. These studies suggest that words which are themselves relatively uncommon, but which share a word form with a more common word (e.g., *nun*, which is a homophone for *none*) act as if they are high-frequency words (Dell, 1990). This could suggest that word frequency effects are based at the level of word-forms, and our current finding (showing that word frequency has similar patterns of performance across age as does neighborhood density, but different effects than AOA and word familiarity) supports this notion.

7.4
Implications for models of lexical access and age-related changes

Most current models agree that there are multiple stages of processing during lexical access. For example, Levelt's model of word production (Levelt et al., 1999) suggests there are four levels of processing: a conceptual level, a lemma level, a word-form level, and a motoric output level. Each of these could conceivably contain different substages. Thus, the word-form level might contain both representations of words as a whole and representations of parts of words, as has been instantiated in some connectionist models, for example: TRACE (McClelland & Elman, 1986); NAM (Luce & Pisoni, 1998); and Dell's spreading activation model (Dell, 1986). Although the present data cannot speak to the overall accuracy of these models, they do lend support to some aspects of these models in particular, and make suggestions for how different lexical factors may influence different stages within these models.

First, as noted above, AOA and word familiarity seem to show similar effects, but these appear to differ from effects of word-frequency and lexical neighborhood. This suggests the possibility that these factors are tapping into two distinct stages of processing. Since our participants' comprehension scores were quite high, we presume the individuals were successfully activating the correct concept when seeing the pictures or hearing the sentences and exemplars; this suggests that AOA and familiarity were having an effect not at the conceptual level, per se, but instead at a later stage of processing. This could be at the level of the lemma, or could be occurring in the transition from semantic to form-based processing.

Word frequency effects appear to be similar to effects of lexical neighborhood, although different from AOA and word-familiarity, suggesting that they impact the lexicon in different ways. The lack of an age effect for word frequency supports those theories which suggest that word frequency is an inherent property of lexical organization (as in the model proposed by Forster, 1976). That is, rather than being an aspect of connection strength, it is instead a fundamental part of the representation itself (just as the word's meaning and phonological form are inherent in its representation). In that way, the impact of target word frequency may be similar to the observed stability of target word meanings across the life span, an unchanging factor of lexical influence. In contrast, the age effects revealed for the AOA and familiarity lexical factors may be more related to access issues viewed in this study as reduced strength in the semantic-to-form based connections over the life span. For example, older adults' greater difficulty with less familiar words (familiarity factor) learned later in life (AOA factor) may be related to the reported increase in retrieval disruptions occurring at the juncture point between the semantic and form components of words, commonly known as the tip-of-the-tongue error (TOT) (Burke et al., 1991). If so, these findings would support the transmission deficit hypothesis (MacKay & Burke, 1990) that predicts that with aging there is a reduction in the transmission of priming from the semantic to the phonological lexicon, resulting in increased failures to access the target word's form. This transmission failure may be particularly common for words that are less familiar and learned later in life. Thus, AOA and familiarity may influence the flow of information between Stages 2 and 3 in the adapted model presented earlier, whereas word frequency is part of the lexical organization itself. Given prior findings regarding homonyms (Dell, 1990), and the present similarity between the results for word frequency and those of lexical neighborhood, it appears most likely that word frequency is an inherent part of the organization of words at the level of word forms. Lexical neighborhood, by definition, also would have its effect at this stage, since it reflects the extent to which different word forms are similar to one another.

Phonotactic probability also has to do with word forms, yet it seems to show a third pattern of influence on lexical processing. This finding, in combination with prior work by Vitevitch and Luce (1998; 1999) and by Pylkkännen and colleagues (Pylkkänen et al., 2002), suggests that phonotactic probability may involve a different aspect of word form processing than does lexical neighborhood and word frequency. While all three factors involve the word form (Stage 3 in the model presented earlier), they do not all appear to influence processing in the same way. Since these earlier studies did not involve speech output, it seems unlikely that the phonemic level can be identified with motoric stages of processing. Instead, phonotactics is likely to be occurring at the stage of form access. In the adapted model above, phonotactics is likely to influence the units of syllabic structure and segmental (or phonemic) structure. This suggests the possibility that the word form stage of processing may itself include several substages: one involving whole words, and one involving sublexical representations (such as phonemes).

Thus, the present data seem to support the notion that there are at least three distinct levels of processing in word naming, beyond that of activating an appropriate concept: a lemma stage, a lemma-to-form stage, and a form-based stage. One could hypothesize, then, that AOA and word familiarity have their effects (e.g., easier to access words learned earlier in life, and which are more familiar) at the juncture point between lemma and form access (between Stage 2 and 3 in our model), thus influencing the transmission of lemma-to-form information. Word frequency, lexical neighborhood, and phonotactic probability all have their effects at different points within Stage 3 in our model; specifically, lexical neighborhood and word frequency potentially influencing lexical levels of word-form access, and phonotactic probability influencing sublexical levels.

As noted in the introduction, effects of aging could potentially affect any of these different stages. That is, theoretically, aging could influence the accessibility of the semantic aspects of the target word, the strength of the connections between the semantic aspects and the form aspects, and/or the subsequent retrieval of the word's phonological features, syllabic structure and segmental structure. Based on the current data, it would appear that maturation during childhood influences both lemma-to-form and form-based processes (based both on results from the current study and those of Newman & German, 2002), but that aging effects have the strongest influence at the lemma-to-form stage. That is, the present findings suggest that, as children acquire their native language, both the access pathways between lexical stages and the representations within these stages need to develop. As individuals age, their representations may remain constant. However, the flow of information between stages may change with aging. Those pathways that are stronger are more resistant to this age-related decline, resulting in relative sparing for those words which are either learned earlier in life or which are more familiar to the speaker.

This notion that the greatest change with aging is in the flow of information between processing stages could be incorporated into any of the various theories of aging that have been proposed. However, it would seem intuitively to work best with the transmission deficit hypothesis. This hypothesis suggests that there is a reduction in the transmission of activation from the semantic to the phonological lexicon (Burke, 1997; MacKay & Burke, 1990) and this matches the pattern of results we found here. Our results with lexical neighborhoods suggest that individuals in our study were experiencing competition from other words. However, the amount of this competition did not appear to change with aging; older adults showed no greater effect of lexical neighborhood than did younger adults. This suggests that while a failure to inhibit competitors was a cause of naming failures in this study, there was not a consistent **increase** in this inhibitory failure with age, as the inhibitory deficit hypothesis (Hasher & Zacks, 1988) would suggest. Thus, our findings seem to suggest that there is no overall increase in competition with age, but a failure for information from the semantic lexicon to spread to the phonological lexicon.

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Appendix

Words included in the different analyses

Frequency:

Low frequency: Appliance, badge, binocular, blimp, caboose, claw, costume, croquet, crutch, dart, dimple, diploma, drip, funnel, hamper, hopscotch, jewel, jockey, lava, leash, melt, orphan, parachute, pledge, pliers, robot, sift, siren, spool, squeeze, starfish, tattoo, thimble, thorn, tornado, weld, wink.

High frequency: Aisle, antenna, bang, battery, beg, compass, costume, country, dance, develop, dice, direct, film, forehead, globe, holiday, jack, liquid, march, mask, material, measure, ocean, operate, organ, palm, peak, planet, president, pull, saddle, shelf, squeeze, statue, thread, transportation, weather.

AOA:

Early age of acquisition: Country, gas, holiday, jewel, liquid, measure, metal, ocean, plug, ruler, season, thread, weather.

Late age of acquisition: Canteen, costume, dart, globe, material, muzzle, organ, palm, planet, president, saddle, transportation, veil.

Familiarity:

Rated less familiar: Award, badge, bang, braid, caboose, claw, compass, corsage, croquet, crutch, dance, dimple, equator, forehead, funnel, globe, hopscotch, lava, lick, lullaby, magnet, microphone, passport, pledge, propeller, saddle, season, seed, shelf, tambourine, tattoo, thimble, thorn, tusk, unicorn, veil, weather, weigh, weld.

Rated more familiar: Acorn, aisle, antenna, bandage, battery, blimp, costume, diploma, drip, escalator, fight, hamper, heat, helmet, holiday, jewel, jockey, leash, mask, melt, muzzle, ocean, orphan, palm, paw, peak, planet, pliers, pull, robot, roll, ruler, siren, spatula, spool, starfish, statue, telescope, thermostat.

Neighborhoods:

Sparse neighborhood: Acorn, award, blimp, city, compass, dance, dimple, film, globe, igloo, jockey, march, mask, ocean, planet, pledge, season, shelf, squeeze, statue, tusk, weather.

Dense neighborhood: Aisle, cone, dart, drill, fight, funnel, gas, lake, leash, lick, melt, metal, muzzle, nut, peak, pick, plug, roll, saddle, tackle, veil, wink.

Phonotactics:

Words with low phoneme and biphone probability: Badge, bang, fight, file, heat, jack, leash, lake, nut, veil.

Words with high phoneme and biphone probability: Cone, dice, gas, knit, lick, palm, peak, pick, pull, roll.