

Age-Related Influences on Lexical Selection and Orthographic Encoding

During Homophone Spelling

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Abstract

Two experiments investigated age differences in how semantic, syntactic, and orthographic factors influence the production of homophone spelling errors in sentence contexts. Younger and older adults typed auditorily-presented sentences containing homophone targets (e.g., *blew*) that were categorized as having a regular spelling [EW] or an irregular spelling [UE]. In Experiment 1, homophones were preceded by an unrelated word, a semantic prime that was congruent with the target's meaning in the sentence (e.g., *wind*), or a semantic prime incongruent with the target's meaning (e.g., *sky*) and instead related to the competitor homophone. Experiment 2 manipulated the target's part of speech, where target and competitor homophones shared or differed in part of speech. For both age groups, significant semantic priming occurred, where homophone errors decreased following congruent semantic primes and increased following incongruent primes. However, priming only occurred when homophones shared part of speech. Further, both age groups made more errors on homophones with an irregular than a regular spelling, and this regularity effect was smaller for older adults when homophones shared part of speech. Contrary to many spoken production tasks, older adults made fewer errors overall than younger adults. These findings demonstrate age preservation in lexical selection but age differences in orthographic encoding, resulting in older adults producing fewer errors because of reduced activation to competitor homophones. These findings also illustrate that syntactic factors, such as part of speech, can influence the spellings of individual words.

Keywords: aging, homophone spelling, semantic priming, syntax, language production

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One of the most consistent changes that occur with healthy aging involves speech production, where older adults demonstrate increased word finding problems that result in more tip-of-the-tongue states (e.g., Burke, MacKay, Worthley, & Wade, 1991; James & Burke, 2000; White & Abrams, 2002), increased dysfluencies such as filled pauses, repetitions, and hesitations (e.g., Kemper, 1992), more errors when naming pictures (Feyereisen, 1997), and a greater number of slips of the tongue (e.g., MacKay & James, 2004). One theoretical explanation for these findings comes from the transmission deficit hypothesis (e.g., Burke, MacKay, & James, 2000; MacKay & Burke, 1990), which proposes that as people age, access to phonological representations that underlie speech becomes more difficult because of weakened connections between a word's lexical representation (i.e., lemma) and its sublexical, phonological form. Parallel claims have been made regarding older adults' written production, specifically their ability to produce the correct spellings of words, where the age-related weakening of connections to orthographic nodes results in increased spelling problems with age (e.g., MacKay & Abrams, 1998).

However, findings of age-related declines in the production of a word's orthography have been more variable than those involving the production of a word's phonology, with older adults showing impaired spelling in some studies (e.g., Abrams & Stanley, 2004; MacKay & Abrams, 1998; MacKay, Abrams, & Pedroza, 1999; Stuart-Hamilton & Rabbitt, 1997), but equivalent or better spelling than younger adults in other studies (e.g., Abrams & White, 2010; Kramer, Burke, & Taylor, 2000; Margolin & Abrams, 2007). One explanation for these mixed findings is that older adults' increased vocabularies may lead to greater familiarity with the spellings of rare

words that younger adults have never learned (and therefore cannot spell), masking any potential age difference that might exist due to older adults' weakened orthographic connections (MacKay & Abrams, 1998). Because homophones are commonly-used words that are familiar to all ages, using them to investigate age differences in orthographic retrieval reduces the likelihood that younger and older adults will differ because of lack of familiarity with the correct spellings.

Using a homophone spelling task also creates an opportunity to investigate more generally how aging affects lexical selection, i.e., lemma retrieval. Homophones share sound (phonology) but differ in meaning (semantics), spelling (orthography), and sometimes part of speech (syntax). These differences make them useful tools for investigating whether aging affects the semantic and syntactic connections that drive lemma retrieval, as well as the process of orthographic encoding that occurs after lemma retrieval. The present research investigated age differences in how semantic and orthographic factors (Experiment 1) as well as syntactic factors (Experiment 2) interact to influence the production of homophone spelling errors in sentence contexts. Specifically, (1) semantic factors were assessed by examining whether a semantically-related prime could increase the likelihood of producing a homophone's spelling that was related in meaning; (2) orthographic factors were assessed by examining whether a homophone's sound-to-spelling regularity influenced its likelihood of retrieval; and (3) syntactic influences were assessed by presenting homophones in sentences and comparing the likelihood of producing the wrong homophone when both homophones shared or differed in part of speech.

The present experiments used an experimental method of error elicitation developed by White, Abrams, Zoller, and Gibson (2008) to create processing circumstances that encourage written homophone spelling errors. Specifically, an error occurs when the contextually inappropriate (i.e., competitor) homophone is written in place of the appropriate (i.e., target)

homophone. In White et al. (2008), younger adults wrote auditorily-presented sentences, and homophone spelling errors occurred when the target homophone, e.g., *blew*, was replaced with its competitor, e.g., “The feather *blue* in the wind.” In addition to allowing for the investigation of circumstances that lead to homophone spelling errors, this paradigm also allows for the investigation of spelling errors in sentence contexts, which are more representative of the kinds of everyday tasks involving spelling in which younger and older adults engage (Abrams, Farrell, & Margolin, 2010).

Previous research using this technique has shown that the likelihood of producing a homophone spelling error can be increased via orthographic priming (White, Abrams, McWhite, & Hagler, 2010; White et al., 2008). More errors occurred when a homophone was preceded by a prime (e.g., *glue*) that contained the spelling of the competitor homophone (e.g., *blue*), relative to an unrelated word (e.g., *glass*). This result suggests that homophone errors are dependent on the context in which they are written, particularly if this context includes words that are orthographically similar to a competitor homophone. In the present research, we explored whether homophone errors could be influenced by context that contains a word (i.e., a semantic prime) that is semantically related to a target or to a competitor homophone, and whether these influences would be similar for younger and older adults.

Why would we expect semantic information to influence retrieval of orthography? When writing homophones in sentences, the target homophone (*blew*) is usually produced because it receives activation from the meaning specified by the sentence context. Thus, when the sentence includes a semantic prime (*wind*) that is *congruent* with the target homophone’s meaning, there is a convergence of activation on the target: Activation is transmitted from both the sentence context and also from the semantic prime, increasing the likelihood of retrieving the target’s

lemma and not making a homophone error, relative to an unrelated word (*child*). Conversely, when a semantic prime is presented (*sky*) that is *incongruent* with the target homophone's meaning and is instead related to the competitor homophone (*blue*), the competitor homophone receives activation that it would not receive when the sentence includes an unrelated word (*light*). The additional activation of the competitor homophone allows its lemma to compete more successfully for retrieval, thus increasing the likelihood of a homophone error. Figure 1 displays these predicted patterns of semantic priming among lexical nodes.

Investigations of semantic priming in word recognition studies have demonstrated that older adults experience semantic priming at least to the same degree as younger adults (e.g., Balota & Duchek, 1988; Cerella & Fozard, 1984; Laver & Burke, 1993; Madden, Pierce, & Allen, 1993). In these studies, semantic priming occurs when people are faster to identify a target word (e.g., *doctor*) that has been preceded by a semantically-related prime word (e.g., *nurse*) than by an unrelated word (e.g., *purse*) (Fischler, 1977; Meyer & Schvaneveldt, 1976). Although fewer studies have used semantic priming in word production than in word recognition, older adults similarly appear to show as much (or sometimes more) facilitation from semantically-related words as younger adults (e.g., Balota & Duchek, 1988; White & Abrams, 2004a) as well as similar or greater interference from semantic distractors in picture naming (Taylor & Burke, 2002; Tree & Hirsh, 2003). Preserved or heightened semantic priming effects into old age are explained by the diverse and multiple connections that older adults have in semantic memory as a result of 60+ years of accumulating semantic knowledge (Laver & Burke, 1993). These multiple connections allow for a convergence of activation onto a single lemma and therefore offset potential age-linked declines in the retrieval of semantic information. Intact semantic priming has also been demonstrated in patients with Dementia of the Alzheimer's Type (DAT)

(e.g., Ober & Shenaut, 1995), even when spelling homophones in isolation (e.g., when presented immediately before the homophone, presentation of the prime *father* increased spelling of *son* relative to *sun*) (Fennema-Notestine, Butters, Heindel, & Salmon, 1994). Because older adults (and DAT patients) have preserved access to semantic knowledge, we expected older adults to demonstrate semantic priming effects at least equivalent to younger adults when spelling homophones in sentences. The many-to-one connections between semantic nodes and lemmas help to offset potential age-linked declines in lemma retrieval (e.g., Barresi, Nicholas, Connor, Obler, & Albert, 2000; Cerella & Fozard, 1984; Feyereisen, 1997; Kemper & Sumner, 2001; Mitchell, 1989; Poon & Fozard, 1977)

In contrast to age invariance in lemma retrieval, we anticipated age differences in the process of orthographic encoding. Orthographic encoding, or the selection of specific graphemes, is a sublexical process (i.e., occurs after lemma retrieval and can result in spelling the competitor homophone; White et al., 2010). Orthographic encoding of homophones can be particularly difficult because homophones are sound-to-spelling inconsistent: They have (at least) two spellings, compared to sound-to-spelling consistent, non-homophonic words (e.g., *rust*) that have only one spelling for their phonology (Ziegler, Stone, & Jacobs, 1997). Sound-to-spelling inconsistent words are actually quite common in English, with estimates of approximately 75% of English monosyllabic words found in Kucera and Francis (1967) having sounds that can be spelled in multiple ways (Stone, Vanhoy, & Van Orden, 1997).

MacKay and Abrams (1998) proposed that orthographic encoding depends on the frequency with which spelling patterns correspond to a particular sound. *Regularly-spelled* sounds have a more frequent spelling pattern (e.g., /u/ spelled [EW]) and *irregularly-spelled* sounds have a less frequent spelling pattern (e.g., /u/ spelled [UE]). As illustrated in Figure 1, to

spell a regularly-spelled homophone like *blew*, activation spreads from the target's lemma to its phonology (because a regular homophone is spelled the way it sounds), which activates orthographic nodes via one-to-one lateral connections between phonology and orthography. In contrast, correctly spelling a homophone that has an irregular spelling requires activation of a quasi-irregular node, which then inhibits the regular spelling and activates the orthographic nodes corresponding to the irregular spelling (MacKay & Abrams, 1998). If the quasi-irregular node is not activated, orthographic encoding will proceed via the shared homophone phonology, which will activate the regular spelling and result in an error. Greater frequency of use of homophones with regular spellings results in strong connections between their phonology and orthography. In contrast, homophones with irregular spellings are used less frequently, resulting in weaker connections to the quasi-irregular nodes required to spell them correctly. Therefore, more errors would be expected when spelling homophones with irregular spellings than regular spellings.

Experiment 1

Experiment 1 assessed the influence of semantic priming and homophone regularity on younger and older adults' homophone spelling errors. The relationship between primes and targets was defined as congruent when primes (*wind*) were semantically related to the target (*blew*) and as incongruent when primes (*sky*) were semantically related to the competitor (*blue*). We expected decreased errors following congruent prime-target relationships and increased errors following incongruent prime-target relationships (relative to control words that were unrelated to the target and competitor), with age invariance in these priming effects due to preservation of the semantic system in old age. In contrast, we expected younger and older adults' errors to be differentially dependent on homophone regularity. Specifically, compared to

regularly-spelled homophones, both age groups were expected to produce more errors on irregularly-spelled homophones due to reduced use of those spellings (and therefore weaker connections from lemmas to quasi-irregular nodes). However, aging should exacerbate this regularity effect due to older adults' weakened connections to the less-frequently used quasi-irregular node (MacKay & Abrams, 1998). That is, according to the transmission deficit hypothesis, weakened connections to less-frequently used nodes, particularly those that have single connections to them such as an irregularly-spelled homophone's quasi-irregular node, may be especially weak with age. Because connections to quasi-irregular nodes are weakened due to infrequent use of these irregular spellings, older adults should have a larger effect of regularity when spelling homophones than younger adults, i.e., a larger difference in errors when spelling irregularly-spelled homophones compared to regularly-spelled homophones.

Method

Participants

Fifty-four psychology students (35 females and 19 males) from the College of Charleston were compensated with partial course credit or extra credit for participating in this study. They ranged in age from 18 to 22 years ($M = 19.01$ years, $SD = 0.88$). Fifty-four older adults (31 females and 23 males) from the Charleston community were paid \$10 for participation. Four older adults were excluded from analyses due to scores below 27 on the Mini Mental State Exam (MMSE, Folstein, Folstein, & McHugh, 1975). The remaining 50 older adults ranged in age from 56 to 78 years ($M = 69.98$, $SD = 5.43$). All participants indicated English as their first language, reported demographic information about their age, education, ethnicity, native language, health status, and current medications, and took a 25-item multiple-choice vocabulary test. Table 1 presents means and standard deviations for younger and older adults' various

demographic characteristics. Independent-samples t tests indicated that younger adults had fewer years of education, $t(102) = 5.67, p < .001$ and lower vocabulary scores, $t(102) = 12.76, p < .001$ than older adults. Younger and older adults did not differ on self-reported health, $t(102) = 0.24, p = .814$.

Materials

Sentence Typing Task. Forty homophone pairs (80 total homophones) were categorized as having a subordinate (i.e., lower frequency) target and a dominant (i.e., higher frequency) competitor using normative estimates from White and Abrams (2004b) because these are the only homophones that were normed for dominance using both younger and older adults. Word frequency was also verified through the frequency norms of Zeno, Ivens, Millard, and Duvvuri (1995). Subordinate (target) homophones had a mean raw frequency of 224.13 ($SD = 395.81$) per million, and dominant (competitor) homophones had a mean raw frequency of 11,384.90 ($SD = 52,109.81$). Sentences were created with subordinate homophone targets because people make very few errors when spelling dominant homophones in sentences (White et al., 2008).

The 40 subordinate target homophones were categorized into 20 target homophones that had a regular spelling and 20 target homophones that had an irregular spelling for the shared phonology. Where possible, we used the Ziegler et al. (1997) norms (which reported the number of monosyllabic words with a particular orthography for a shared phonology) to determine whether a target homophone had the regular (i.e., common; e.g., [EW]) or irregular (e.g., [UE]) spelling for the shared phonology (e.g., /u/). Because Ziegler et al.'s norms did not include information for eight of our homophone pairs, we calculated regularity for these homophones by counting the number of words containing each spelling in Francis and Kucera's (1982) corpus. Overall, target homophones categorized as regularly spelled had more words sharing that

spelling ($M = 11.50$, $SD = 3.84$) than target homophones categorized as irregularly spelled ($M = 4.21$, $SD = 3.95$), $t(35) = 5.69$, $p < .001$.

Two types of sentences were constructed for each target (see Table 2). Sentences with a congruent prime-target relationship included either a prime that was a semantic associate of the target or an unrelated control word. Sentences with an incongruent prime-target relationship included either a prime that was a semantic associate of the competitor or a control word. Association strength between primes and homophones was determined by White and Abrams (2004b) free association norms, which provide younger and older adults' most frequently-given associations to homophones. We attempted to use the strongest associate given by both younger and older adults considering constraints on the primes (e.g., the prime could not overlap in orthography with the target or competitor as in *jail-bail*). Mean association strength, measured by the percent of people who gave a particular response when free associating to a homophone, was similar for younger ($M = 31.93\%$, $SD = 12.62\%$) and older adults ($M = 32.51\%$, $SD = 13.97\%$), $t(38) = 3.94$, $p = .696$, and for congruent ($M = 34.24\%$, $SD = 16.82\%$) and incongruent ($M = 30.21\%$, $SD = 17.83\%$) prime-target relationships, $t(38) = 1.04$, $p = .305$. Semantic primes were semantically related but not orthographically similar to either the target or competitor; control words made sense in the sentence context but were not semantically or orthographically related to the target or competitor. Semantic primes and control words preceded homophone targets by one to six words ($M = 2.75$, $SD = 1.33$). The number of words between the prime/control word and the target was the same whether the sentence had a congruent or incongruent prime-target relationship.

Four versions of the sentence typing task were created, with each version containing 20 regularly-spelled and 20 irregularly-spelled homophones. For a given homophone, the prime-

target relationship (congruent, incongruent) and the semantic prime type (semantic prime, control) were counterbalanced across the four versions. Sentences were prerecorded by a female experimenter and were presented to participants through headphones via a program written in Visual Basic 5.0.

Homophone recognition test. A homophone recognition test evaluated participants' comprehension of the spelling and meaning of each homophone pair. Eighty sentences (different from those in the sentence-typing task) were constructed, one for each homophone, and included a blank space where the appropriate homophone belonged. Both homophones were presented directly to the right of the sentence so that participants could circle the one that was contextually appropriate. Four versions of the homophone recognition test were created for counterbalancing of the homophone order within the pair and of the contextually appropriate homophone.

Design and Procedure

This experiment utilized a 2 (age group) x 2 (prime-target relationship) x 2 (semantic prime condition) x 2 (homophone regularity) mixed-factor design, with age group as the only between-subjects variable. Prime-target relationship was determined by whether the semantic prime was related to the target (congruent) or the competitor (incongruent). Semantic prime condition represented sentences containing either a semantic prime or an unrelated control. Homophone regularity was determined by whether the target homophone had a regular spelling or an irregular spelling for the shared homophone phonology. The dependent variable was the percentage of homophone errors made (i.e., when the competitor homophone was typed).

Participants completed the above-mentioned paperwork and all cognitive tests prior to completing the sentence-typing task. The instructions for the sentence-typing task explained that participants were to start typing each sentence as soon as they heard the sentence begin playing

and that they would be given unlimited time to type. Sentences were presented individually in random order and could be repeated once if desired. Participants were instructed to correct any mistakes in each typed sentence using the backspace key to make changes. Two practice sentences oriented participants to the sentence-typing task. After spelling all 40 sentences, participants were given the homophone recognition test.

Results and Discussion

The homophone recognition test was used to determine any homophones that participants were unfamiliar with or of which they did not know the correct spelling. Targets that were incorrectly identified on the recognition test by a participant were removed from analyses (0.67% of the 40 homophone pairs per younger adult and 0.18% per older adult). Targets that were misheard as a different word (2.00% for younger and 4.20% for older adults) or for which no response was given (0.10% for younger and 0.30% for older adults) were also excluded. Finally, targets whose primes were misheard as a different word or not produced (0.03% for younger and 0.09% for older adults) were excluded.

A 2 (age group: younger, older) x 2 (prime-target relationship: congruent, incongruent) x 2 (semantic prime condition: semantic prime, control) x 2 (homophone regularity: regularly spelled, irregularly spelled) repeated-measures analysis of variance (ANOVA) was performed on the mean proportion of homophone errors¹ (see Table 3). A homophone error was defined as writing the entire competitor homophone in its correct spelling (e.g., writing *blue* in place of *blew*). The ANOVA revealed an age group main effect, $F(1, 102) = 80.50$, $MSE = .06$, $p < .001$, $\eta^2 = .44$, with older adults making fewer overall errors ($M = 8.29\%$) than younger adults ($M = 23.81\%$). A main effect of homophone regularity, $F(1, 102) = 69.93$, $MSE = .02$, $p < .001$, $\eta^2 = .07$, was moderated by an Age Group x Homophone Regularity interaction, $F(1, 102) = 12.56$, p

< .001, $MSE = .02$. Planned comparisons of this interaction showed that both younger ($p < .001$, $\eta^2 = .42$) and older ($p < .001$, $\eta^2 = .10$) adults had more errors on irregularly-spelled homophones than regularly-spelled homophones (see Figure 2), but that this effect was larger for younger adults.

Because older adults made fewer errors overall, their regularity effect could have been artificially smaller than younger adults when using raw percent errors as the dependent measure. To account for this possibility, we computed each individual's proportional change in errors as a function of homophone regularity, i.e., the percent increase in errors for irregularly-spelled homophones relative to regularly-spelled homophones, calculated as (

$$\frac{(M_{\text{irregularly spelled}} - M_{\text{regularly spelled}})}{\text{Max}(M_{\text{irregularly spelled}}, M_{\text{regularly spelled}})}$$

). A 2 (age group) x 2 (prime-target relationship) x 2 (semantic prime condition) ANOVA on this proportional change measure revealed a marginal age group effect, $F(1, 102) = 2.82$, $MSE = .38$, $p = .096$, $\eta^2 = .03$, with younger adults ($M = 25.10\%$) having a greater change in errors due to homophone regularity than older adults ($M = 14.88\%$).

A marginal main effect of prime-target relationship, $F(1, 102) = 6.85$, $MSE = .03$, $p = .010$, $\eta^2 = .02$, showed that fewer errors were made in congruent sentences ($M = 14.45\%$) than in incongruent sentences ($M = 17.65\%$). Although there was no main effect of semantic prime condition, $F < 1$, there was a Prime-Target Relationship x Semantic Prime Condition interaction, $F(1, 102) = 9.66$, $MSE = .04$, $p = .002$, showing fewer errors following semantic prime words than control words in congruent sentences ($p = .010$, $\eta^2 = .02$), but more errors following semantic prime words than control words in incongruent sentences ($p = .020$, $\eta^2 = .01$) (see Figure 3). All other interactions were not significant, $ps > .122$.

The results of Experiment 1 support previous research showing that homophone errors can occur at various levels (White et al., 2010), either the lemma level (where the competitor homophone is selected) or during orthographic encoding (whether orthography is activated via homophone phonology or via a quasi-irregular node). New to this experiment was the finding that *semantic* priming influenced lexical selection of homophones, either increasing or decreasing errors in lemma retrieval as a function of the prime's relatedness to the target or competitor homophone, and these semantic influences were preserved in old age. In contrast, the strength of the connections to specific spellings (measured here via homophone regularity) influenced errors made during orthographic encoding, and these homophone regularity effects differed as a function of age group. Specifically, although both younger and older adults made more errors on irregularly-spelled homophones than on regularly-spelled homophones, this regularity effect was smaller for older adults, contrary to our hypothesis (derived from previous research) that older adults have weakened connections to the less-frequently used quasi-irregular node (MacKay & Abrams, 1998). While previous research has sometimes found age-linked declines in the retrieval of irregularly-spelled words that require activation of orthography via a quasi-irregular node (e.g., Abrams & Stanley, 2004; MacKay & Abrams, 1998; MacKay et al., 1999; Stuart-Hamilton & Rabbitt, 1997), the present findings demonstrate that older adults are more successful than younger adults at activating the quasi-irregular node when spelling more familiar words such as homophones.

Experiment 2

Results of Experiment 1 suggest age stability in lemma retrieval during written production but age differences favoring older adults in orthographic encoding. However, recent research has shown that syntactic constraints can also influence younger adults' lemma retrieval

when spelling homophones: White et al. (2010) reported that more errors occurred for homophones that share part of speech (i.e., are syntactically unambiguous; e.g., *feet* and *feat* are both nouns) than for homophones that differ in part of speech (i.e., are syntactically ambiguous; e.g., *ail* is a verb and *ale* is a noun), demonstrating that a homophone's syntax (specifically its part of speech) is critical for predicting when errors will occur. This syntactic constraint is consistent with speech errors where the large majority of whole-word substitutions occur within grammatical class (e.g., Dell, Berger, & Svec, 1997; Fromkin, 1971; Garrett, 1975; Harley & MacAndrew, 2001) and suggests that sentence frames are constructed prior to selection of a particular lemma to fit into a part-of-speech slot. However, the few studies documenting older adults' speech errors (MacKay & James, 2004; Vousden & Maylor, 2006) did not assess whether younger and older adults were similarly affected by syntactic constraints. To address this gap in the literature, Experiment 2 was designed to determine whether older adults' spelling of homophones is influenced by syntactic constraints. We used the same methodology as Experiment 1 (but only included incongruent prime-target relationships because this methodology has also been shown to be effective in studying syntactic constraints in younger adults; White et al., 2010).

Syntactic constraints were expected to influence lemma retrieval, and orthographic encoding of the selected lemma was expected to be influenced by homophone regularity. For unambiguous homophones, both homophones fit into the part-of-speech slot specified by the sentence. If a competitor successfully competes for lemma retrieval, then orthographic encoding of the competitor will lead to errors. Because homophone regularity influences orthographic encoding, we would expect increased errors when competitors have regular spellings because of stronger connections to these regular spellings, relative to competitors with irregular spellings.

However, evidence suggests that older adults may have reduced activation to phonological competitors (e.g., Abrams, Trunk, & Merrill, 2007; Burke et al., 1991; Farrell & Abrams, 2010), which would lead older adults to have fewer errors than younger adults when spelling unambiguous homophones. This reduction in activation to competitors has been observed in spoken production via tip-of-the-tongue (TOT) states, where older adults have fewer alternate words come to mind than younger adults, despite having more TOT states (e.g., Burke et al., 1991). The lemmas for these alternate words get less activation in old age, making retrieval of an alternate less likely. Older adults also are less likely to resolve their TOTs than younger adults following presentation of a phonologically-related word (White & Abrams, 2002; Abrams et al., 2007), suggesting that older adults transmit less activation from a phonological prime to the TOT's lemma to enable retrieval. Recent research (Farrell & Abrams, 2010) has also shown that older adults less effectively transmit activation to phonological competitors than younger adults in a picture-word interference task.

Of additional interest in Experiment 2 was whether semantic priming would differentially influence errors for syntactically ambiguous and unambiguous homophones. We predicted that semantic influences on lemma retrieval would be dependent on a homophone's part of speech (see Figure 4). Specifically, for ambiguous homophones, the competitor homophone receives activation from the semantic prime but not from the sentence context, because the sentence context specifies a part of speech for the to-be-produced homophone that is different from that of the competitor. Selection of the target's or competitor's lemma will be dependent on whether activation from the semantic prime or activation from the sentence context (i.e., part of speech slot) is stronger. For unambiguous homophones, the competitor homophone receives activation from two sources, the semantic prime and the sentence context (which specifies a part of speech

that the target and competitor both have). Thus, compared to ambiguous homophones, increased errors following semantic primes for unambiguous homophones are more likely due to a convergence of activation from semantic primes and from the part-of-speech slot specified by the sentence.

Method

Participants

Fifty-four psychology students from two liberal arts colleges were given partial course credit or extra credit as compensation for participating in this study. The 38 females and 16 males ranged in age from 18 to 22 years ($M = 19.57$ years, $SD = 1.06$). Fifty-four older adults from the Memphis community were paid \$10-15 for participation. The 33 females and 21 males ranged in age from 60 to 82 years ($M = 67.51$, $SD = 5.80$). All participants completed the same demographic information and cognitive tests as in Experiment 1. Table 4 presents means and standard deviations for younger and older adults' various demographic characteristics. Independent-samples t tests yielded similar results as Experiment 1, with younger adults having fewer years of education, $t(106) = 9.38$, $p < .001$ and lower vocabulary scores, $t(106) = 11.10$, $p < .001$, than older adults, but similar self-reported health, $t(104) = 0.78$, $p = .438$.

Materials

Sentence-typing task. Eighty homophones (40 pairs), including 17 from Experiment 1, were used in this experiment. Twenty-three new homophone pairs were added in order to find a sufficient number of homophones that shared and differed in part of speech and fit the criteria described below. As in Experiment 1, Zeno et al.'s (1995) frequency norms were used to categorize the new homophones as subordinate targets (M raw frequency = 536.00, $SD =$

1,170.31) or dominant competitors ($M = 3,596.30$, $SD = 7,630.40$) because normative estimates for these homophones were not available from White and Abrams (2004b).

Of the 40 target homophones, 21 were categorized as syntactically unambiguous (i.e., both homophones having the same part of speech; e.g., *feat* and *feet* are both nouns) and 19 were categorized as syntactically ambiguous (i.e., the homophones having different parts of speech; e.g., *ail* is a verb and *ale* is a noun).² Although target homophones sometimes had more than one dominant part of speech in isolation (e.g., *sail*), the sentence context specified the intended part of speech to be produced. However, competitor homophones were not presented, so we selected competitor homophones that had one primary part of speech according to online web dictionaries. In order to ensure that unambiguous homophones were not more semantically related than ambiguous homophones, semantic relatedness between target and competitor homophones was compared using latent semantic analysis (Landauer & Dumais, 1997). An independent samples t test showed similar degrees of semantic relatedness between ambiguous ($M = 13.33\%$, $SD = 9.58\%$) and unambiguous ($M = 10.52\%$, $SD = 7.73\%$) homophone pairs, $t(37) = 1.01$, $p = .318$. The unambiguous and ambiguous homophone pairs were further divided into target homophones that had a regular spelling and target homophones that had an irregular spelling for the shared phonology. As in Experiment 1, target homophones categorized as regularly spelled had more words sharing that spelling ($M = 13.15$, $SD = 5.06$) than target homophones categorized as irregularly spelled ($M = 5.55$, $SD = 4.45$), $t(38) = 5.04$, $p < .001$.

Sentences were constructed similar to Experiment 1's incongruent sentences. Targets were preceded by incongruent semantic primes only in this experiment to ensure sufficient errors to detect differential semantic priming effects as a function of the homophone's syntactic ambiguity. Each sentence had a semantic prime word or an unrelated control word that preceded

the target homophone by one to six words ($M = 4.05$, $SD = 1.33$). Because many of the new homophones used in Experiment 2 did not have free association norms in White and Abrams (2004b), association strength between primes and competitors was determined by their Backward Association Strength (i.e., target-to-prime) values using the norms of Nelson, McEvoy, and Stehreiber (2004) and Edinburgh Associative Thesaurus (<http://www.eat.rl.ac.uk/>). These norms provide a measure of strength by giving the proportion of participants who gave a certain response to a target on a scale of zero (no participants gave that response) to one (all participants gave that response). Mean association strength values ($M = 31.88\%$, $SD = 24.50\%$) were similar to Experiment 1. Control words were contextually appropriate in the sentence but did not have any semantic or orthographic similarities to the target or competitor. Table 5 includes example sentences for each condition.

Each of the 40 homophones was either regularly- or irregularly-spelled and had either an ambiguous or unambiguous part of speech, characteristics of the items that were fixed. However, two versions of the sentence typing task were created by counterbalancing whether the target's sentence contained the prime or control word. Each of the 40 sentences was prerecorded by a female experimenter and was presented to participants through headphones via a program written in Visual Basic 5.0.

Homophone recognition test. As in Experiment 1, a homophone recognition test was constructed for the 80 homophones used in Experiment 2.

Design and Procedure

This experiment utilized a 2 (age group) x 2 (semantic prime condition) x 2 (homophone regularity) x 2 (homophone part of speech) mixed factor design, with homophone part of speech being the new within-subjects variable in the design relative to Experiment 1. Homophone part

of speech was defined by whether the target shared (i.e., was syntactically unambiguous) or differed in (i.e., was syntactically ambiguous) part of speech with its competitor. The procedure was identical to Experiment 1.

Results and Discussion

Younger and older adults chose the incorrect homophone on the homophone recognition test for 0.30% and 0.15% of the 40 homophones, respectively. As in Experiment 1, any homophone that was incorrectly identified on the recognition test by a particular participant was removed from analyses, as were targets that were misheard as a different word (1.10% for younger and 3.50% for older adults) or that were not produced (0.20% for younger and 2.10% for older adults). Targets whose primes were misheard as a different word or not produced (0.50% for younger and 2.80% for older adults) were also excluded.

A 2 (age group: younger, older) x 2 (semantic prime condition: semantic prime, control) x 2 (homophone regularity: regularly spelled, irregularly spelled) x 2 (homophone part of speech: unambiguous, ambiguous) repeated-measures ANOVA was performed on the mean proportion of homophone errors³ (see Table 6). A main effect of age group, $F(1, 106) = 35.26$, $MSE = .04$, $p < .001$, $\eta^2 = .25$, showed that older adults ($M = 6.9\%$) made fewer errors than younger adults ($M = 14.5\%$). A main effect of homophone regularity also emerged, $F(1, 106) = 25.24$, $MSE = .02$, $p < .001$, $\eta^2 = .03$, which was moderated by an Age Group x Homophone Regularity interaction, $F(1, 106) = 5.31$, $MSE = .02$, $p = .02$. Similar to Experiment 1, both younger ($p < .001$, $\eta^2 = .19$) and older ($p = .058$, $\eta^2 = .03$) adults made fewer errors on regularly-spelled homophones ($M_{\text{younger}} = 10.83\%$; $M_{\text{older}} = 5.46\%$) than on irregularly-spelled homophones ($M_{\text{younger}} = 18.37\%$; $M_{\text{older}} = 8.26\%$) homophones, but this regularity effect was smaller for older adults. All other interactions were not significant, $F < 1$.

As in Experiment 1, the nature of this Age Group x Homophone Regularity interaction was confirmed by a 2 (age group) x 2 (semantic prime condition) x 2 (homophone part of speech) ANOVA on proportional change in errors as a function of homophone regularity. This analysis revealed a marginal effect of age group, $F(1, 106) = 2.88$, $MSE = .34$, $p = .092$, $\eta^2 = .03$, where younger adults ($M = 19.68\%$) had a greater change in errors due to homophone regularity than older adults ($M = 10.18\%$). There was also a main effect of homophone part of speech, $F(1, 106) = 84.68$, $MSE = .02$, $p < .001$, $\eta^2 = .01$, which showed that fewer errors were produced for ambiguous ($M = 11.70\%$) than for unambiguous ($M = 18.10\%$) homophones. A marginal Age Group x Homophone Part of Speech interaction also emerged in this analysis, $F(1, 106) = 2.96$, $MSE = .35$, $p = .088$. For unambiguous homophones only, younger adults ($M = 27.78\%$) had a proportionally larger increase in errors due to homophone regularity relative to older adults ($M = 8.49\%$), $p = .029$. For ambiguous homophones, younger ($M = 11.54\%$) and older adults ($M = 11.85\%$) had similar homophone regularity effects, $p = .966$.

With respect to priming, there was a main effect of semantic prime condition, $F(1, 106) = 9.99$, $MSE = .02$, $p = .002$, $\eta^2 = .01$, which showed more errors following semantic prime words ($M = 12.10\%$) compared to control words ($M = 9.36\%$). However, semantic prime condition interacted with homophone part of speech, $F(1, 106) = 9.57$, $MSE = .01$, $p = .003$ (see Figure 5). Planned comparisons showed significant semantic priming for unambiguous homophones ($p < .001$, $\eta^2 = .13$) but not for ambiguous homophones ($p = .693$, $\eta^2 = .00$).

Analyses were conducted on proportional change scores to verify that the Semantic Prime Condition x Homophone Part of Speech interaction was not due to differences in baseline error rates. A 2 (age group) x 2 (homophone regularity) x 2 (homophone part of speech) ANOVA on proportional change in errors as a function of semantic prime condition revealed a marginal

effect of homophone part of speech, $F(1, 106) = 3.14$, $MSE = .23$, $p = .079$, $\eta^2 = .01$, where proportionally more errors occurred following priming for unambiguous ($M = 10.00\%$) compared to ambiguous ($M = 1.75\%$) homophones.

These results are consistent with Experiment 1: Homophone regularity influenced errors for both age groups, and this effect was larger for younger adults. However, analysis of proportional change scores in Experiment 2 showed that younger adults' regularity effect was only larger than older adults' regularity effect for unambiguous (i.e., shared part of speech) homophones. When younger adults spell unambiguous homophones, competition arises for lemma retrieval because the target and its phonological competitor share part of speech, and this competition increases the likelihood of errors, especially for irregularly-spelled target homophones. If selected, the competitor's lemma is likely to activate its orthography via phonology, rather than through the quasi-irregular node, because it is the regular spelling, resulting in a spelling error. A different pattern emerges for older adults, who are better able to retrieve the target's lemma in the face of competition. This result could be indicative of older adults having reduced activation to the competitor, which is actually adaptive in this situation because it helps older adults to spell the target homophones correctly. In contrast to unambiguous homophones, there is no competition between ambiguous homophones' lemmas because the target is the only homophone that fits the part-of-speech slot, allowing both younger and older adults to equivalently retrieve the target lemma. In this situation, the increased errors from orthographic encoding that arise when spelling irregularly-spelled target homophones are similar for both age groups.

Finding an age-related reduction in activation to phonological competitors contrasts with some studies showing an age-related increase in *semantic* competition, particularly for speeded

naming tasks (e.g., picture naming tasks, LaGrone & Spieler, 2006; Taylor & Burke, 2002). It has been suggested that the age-related increase in semantic-level competition is due to older adults requiring increased time to activate a target's lemma relative to competitors (Burke & Shafto, 2008). The sentence production task used in the present experiments did not require speeded responses, allowing time for target lemmas to reach the critical threshold for retrieval. These results also suggest that phonological competitors are not activated as strongly as targets for older adults, even when there is sufficient time to do so.

Another finding that was consistent with Experiment 1 was that both younger and older adults had more errors following (incongruent) semantic primes relative to unrelated controls. However, Experiment 2 revealed that for both age groups, the semantic priming effect only occurred for syntactically unambiguous homophones, homophones where the target and the competitor had the same part of speech. The lack of age differences in this syntactic constraint provides additional evidence that lemma retrieval, which is governed by both syntactic and semantic influences, is resilient to age in this paradigm. Although previous research has not been able to unequivocally determine whether older adults' speech production deficits reflect weakened connections between lemmas and phonology or a degraded lemma (Mortensen, Meyer, & Humphreys, 2006), lemma retrieval generally appears to be unaffected at least until age 70 (see also, e.g., Barresi et al., 2000; Cerella & Fozard, 1984; Feyereisen, 1997; Kemper & Sumner, 2001; Mitchell, 1989; Poon & Fozard, 1977; although see Hodgson & Ellis, 1998). The present results are consistent with that conclusion and suggest that lemma retrieval may be particularly resistant to age-related declines when using a task that does not require a speeded response (e.g., LaGrone & Spieler, 2006).

General Discussion

The experiments reported here used a homophone spelling error paradigm to assess the independent and combined influences of semantic, syntactic, and orthographic information on younger and older adults' spelling. Our evidence suggests age-related preservation in semantic and syntactic influences on lemma retrieval. First, older adults were equally sensitive to the syntactic constraint that has previously been shown to govern spoken errors and written errors in younger adults (White et al., 2010). The sentence context imposes a syntactic constraint by transmitting activation to the target's part of speech, leading to an increase in errors when homophones are syntactically unambiguous (share part of speech) because the competitor homophone's part of speech also fits this constraint. The present research extends previous research showing age preservation when forming and producing grammatical sentences (e.g., Davidson, Zacks, & Ferreira, 2003) to age preservation in the use of syntax to guide lemma retrieval. Second, finding equivalent semantic priming for both younger and older adults is consistent with previous research in both word recognition (e.g., Laver & Burke, 1993) and production (e.g., Balota & Duchek, 1988, but see White & Abrams, 2004a for an exception) and demonstrates that these priming effects are relatively long-lasting. Whereas previous research has used a brief amount of time between the prime and target (e.g., 200-800 msec used by Balota & Duchek), the present experiments showed that a single semantic prime can precede the target by several words (or several seconds) when embedded in sentences and still influence target retrieval (see also Tree, Hirsh, & Monsell, 2005 for longer semantic priming effects in picture naming with younger adults). Furthermore, demonstrating that semantic primes can both increase and decrease homophone spelling errors suggests that semantic primes can have both interfering and facilitatory effects on written production, similar to their effects on speech production (e.g., Taylor & Burke, 2002; Tree & Hirsh, 2003).

Importantly, semantic priming appears to be limited to influencing retrieval of syntactically unambiguous homophones, such that a convergence of activation from the part-of-speech slot and the semantic prime increases errors (see Figure 4). When producing syntactically ambiguous (different part of speech) homophones, a semantic prime is not strong enough to override activation from the part-of-speech slot, suggesting that the syntactic influences on lemma retrieval are stronger than those from semantics. However, given that production of the competitor occurs considerably less often than production of the target (people spelled homophones correctly more often than not), the entire sentence context may exert a general semantic influence that can be stronger than a part-of-speech slot.

Although these experiments demonstrate age preservation in activation across the lexical (semantic and syntactic) network, age differences were found at the sublexical level. MacKay and Abrams (1998) proposed that older adults have increased transmission deficits to orthographic nodes for irregularly-spelled (i.e., less common) compared to regularly-spelled (i.e., more common) letters within words. In particular, they proposed that activation of a quasi-irregular node would activate an irregularly-spelled component (e.g., *-ar* in *calendar*) and suppress the regularly-spelled alternative (e.g., *-er*). However, the one-to-one connections from the quasi-irregular node to the orthographic nodes result in an increase in spelling errors such that older adults are more likely to produce the regular (more common) spelling over the irregular spelling. Our results suggest that older adults do not always have deficits when spelling less common orthographic components. One explanation is that common words like homophones are very familiar to all ages and have spellings that are repeatedly strengthened over the life course, thus reducing potential age-related deficits that are typically seen for single connections. Of particular interest with respect to orthographic encoding is that older adults' homophone

spelling actually benefits in situations where younger adults are at increased risk of errors due to lexical-level competition. Specifically, when homophones are syntactically unambiguous, competition for selection increases younger adults' likelihood of retrieving the competitor homophone's lemma, but older adults' reduced activation to competitors results in selection of the target's lemma. Consequently, when the target has an irregular spelling, younger adults, but not older adults, are more likely to produce errors. Older adults' reduced competition for retrieval at the lemma level may also explain why they made fewer overall homophone spelling errors than younger adults in both experiments. Alternatively, older adults' superior performance in spelling the subordinate homophones that were used as targets in these experiments may be explained by reports that older adults are more likely than younger adults to spell subordinate than dominant homophones when spelling homophones in isolation (Davis et al., 1990; Gomez, 2002; Rose, Yesavage, Hill, & Bower, 1986). These results suggest that connections to subordinate homophones' orthography may become strengthened with age, minimizing potential errors on subordinate targets presented in our sentences.

Although we have a growing understanding of age-related changes in spoken production, consistent findings in the complementary domain of spelling have been difficult to attain, possibly because of the irregular nature of phonological-to-orthographic mappings (particularly in the English language). The homophone spelling paradigm used in the current study offers a new methodology to investigate age-related differences in spelling by using common words that both cohorts are likely to know. Furthermore, this methodology also allows for comparisons to be made between age-related changes in written production with the more established literature on spoken production. Theoretically, these experiments have demonstrated that younger and older adults use similar contextual and syntactic constraints when selecting lemmas, but that age

differences in spelling errors may be influenced by differential activation of competitors during lemma retrieval as well as influences that occur during orthographic encoding. Future research should explore whether there are ways in which older adults' reduced activation of competitors can be beneficial to phonological encoding and offset some of the consistent age-related changes that occur in speech production.

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Footnotes

¹Due to an error in the computer program, the congruent prime-target version of one homophone (*ail*) was never presented. Also, the congruent prime-target version of *sine* was misheard by 26% of the participants and was therefore removed from analyses.

²One homophone pair (*daze, days*) was inadvertently categorized as syntactically ambiguous when it should have been categorized as syntactically unambiguous, resulting in an unequal number of pairs in each syntax condition.

³One syntactically unambiguous homophone (*cord*) was removed from analyses because of a computer problem in its presentation. Also, the syntactically unambiguous homophone *clique* was removed from analyses after several participants informally indicated a pronunciation (/klik/) that differed from its competitor *click*.

Table 1

Demographic Characteristics for Younger and Older Adults in Experiment 1

Variable	Age Group			
	Younger Adults		Older Adults	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Age*	19.01	0.88	69.98	5.45
Education (years)*	13.47	1.08	15.87	2.80
Vocabulary (max = 25)*	13.26	3.48	20.58	2.30
Health (max = 10)	7.89	1.27	7.95	1.38
MMSE (max = 30)			29.20	0.81

Note. Asterisks indicate significant differences between the age groups, $p < .05$.

Table 2

Example Primed and Control Sentences for Irregularly- and Regularly-Spelled Homophones and for Congruent and Incongruent Prime-Target Relationships.

Homophone Regularity	Prime-Target Relationship	
	Congruent	Incongruent
Irregularly-Spelled	Alex claimed that he was not <i>hurt</i> (upset), but his sister's <u>groan</u> suggested that she was.	The <i>tall</i> (old) man made a <u>groan</u> after bumping his knee.
Regularly-Spelled	The <i>wind</i> (child) at the local park <u>blew</u> the bubbles across the grass.	The bright <i>sky</i> (light) appeared when the curtains <u>blew</u> open and the sun shone in.

Note. Semantic primes are italicized, control words are in parentheses, and target homophones are underlined.

Table 3

Means (and Standard Deviations) for the Percent of Errors Produced by Younger and Older Adults in Experiment 1.

Age Group	Congruent Prime-Target		Incongruent Prime-Target	
	Irregularly Spelled	Regularly Spelled	Irregularly Spelled	Regularly Spelled
Younger Adults				
Semantic Prime	24.23 (19.97)	12.99 (14.39)	35.40 (24.53)	22.01 (20.71)
Control	33.92 (28.13)	16.17 (19.08)	27.50 (24.00)	18.24 (16.08)
Older Adults				
Semantic Prime	7.20 (11.70)	4.67 (10.85)	12.83 (20.15)	9.47 (13.68)
Control	13.10 (17.84)	3.30 (9.72)	10.47 (19.26)	5.27 (11.93)

Table 4

Demographic Characteristics for Younger and Older Adults in Experiment 2.

Variable	Age Group			
	Younger Adults		Older Adults	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Age*	19.57	1.06	67.52	5.80
Education (years)*	13.79	1.56	17.40	2.58
Vocabulary (max=25)*	15.13	2.63	20.76	2.64
Health (max = 10)	7.92	1.30	7.68	1.80
MMSE (max = 30)			29.07	0.89

Note. Asterisks indicate significant differences between the age groups, $p < .05$.

Table 5

Example Primed and Control Sentences for Irregularly- and Regularly-Spelled Homophones and for Syntactically Unambiguous and Ambiguous Homophones.

Homophone Regularity	Syntactic Ambiguity	
	Unambiguous	Ambiguous
Irregularly Spelled	Sally found a <i>tulip</i> (toy) that was covered in <u>flour</u> at the bakery.	I felt a knot in my <i>throat</i> (chest) as I watched the plane <u>soar</u> away.
Regularly Spelled	Since Jane had lost her <i>toes</i> (equipment), it was quite a <u>feat</u> that she was able to climb the mountain.	Tom gave up drinking <i>beer</i> (caffeine) after hearing that his injury would <u>ail</u> him forever.

Note. Semantic primes are italicized, control words are in parentheses, and target homophones are underlined.

Table 6

Means (and Standard Deviations) for the Percent of Errors Produced by Younger and Older Adults in Experiment 2.

Age Group	Syntactically Unambiguous		Syntactically Ambiguous	
	Irregularly Spelled	Regularly Spelled	Irregularly Spelled	Regularly Spelled
Younger Adults				
Semantic Prime	26.79 (19.61)	15.12 (18.10)	14.26 (17.67)	8.33 (10.90)
Control	20.21 (17.59)	12.81 (15.50)	12.22 (17.47)	7.04 (12.50)
Older Adults				
Semantic Prime	15.09 (21.64)	12.04 (19.47)	3.98 (9.33)	1.20 (5.04)
Control	8.76 (13.61)	6.94 (11.98)	5.22 (10.58)	1.67 (5.98)

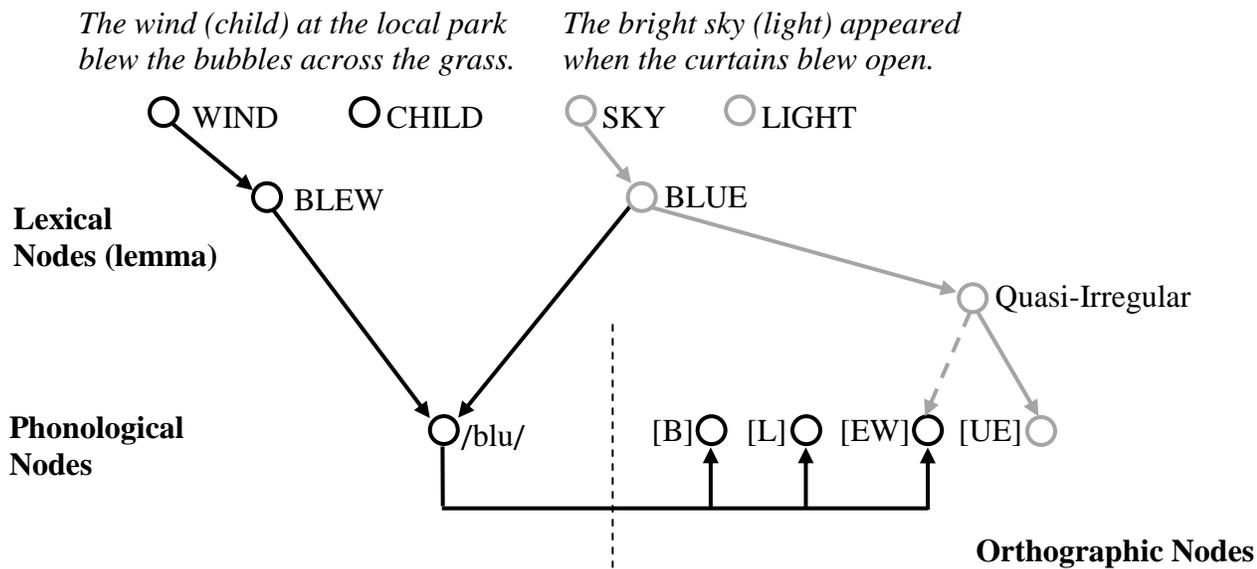


Figure 1. Example of spreading activation among nodes for semantic primes that are incongruent (gray) and congruent (black) with a regularly-spelled target homophone. Sample sentences with incongruent and congruent prime-target relationships are placed above the lexical nodes. When the sentence includes a congruent semantic prime, activation spreads between the prime (*wind*) and target (*blew*), which leads to a reduction in errors. When the sentence includes an incongruent semantic prime, activation spreads between the prime (*sky*) and the competitor (*blue*) and illustrates how semantic priming can lead to an error by activating the quasi-irregular node. Lexical nodes for unrelated control words (in parentheses) are not related to homophones and thus do not activate either the target's or competitor's lexical node.

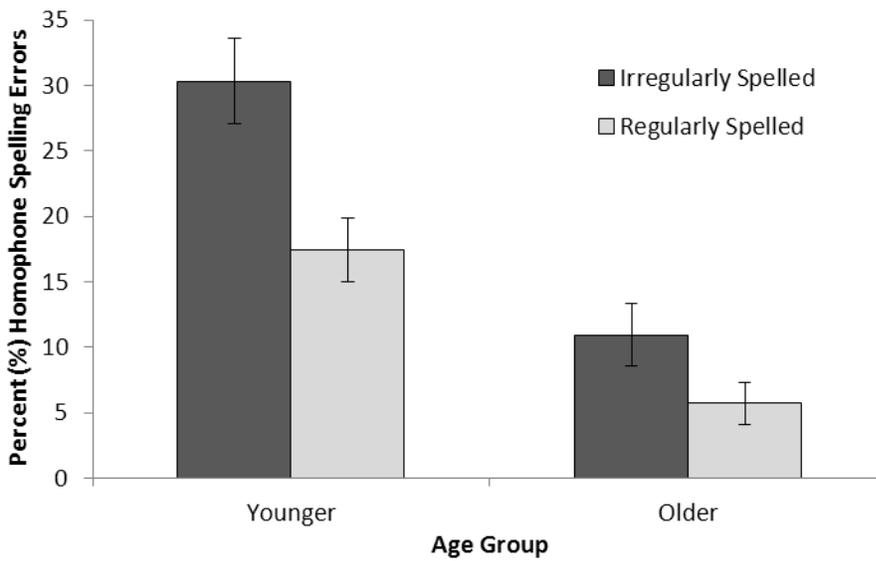


Figure 2. The percentage of homophone errors in Experiment 1, as a function of homophone regularity (irregularly spelled, regularly spelled) and age group (younger, older).

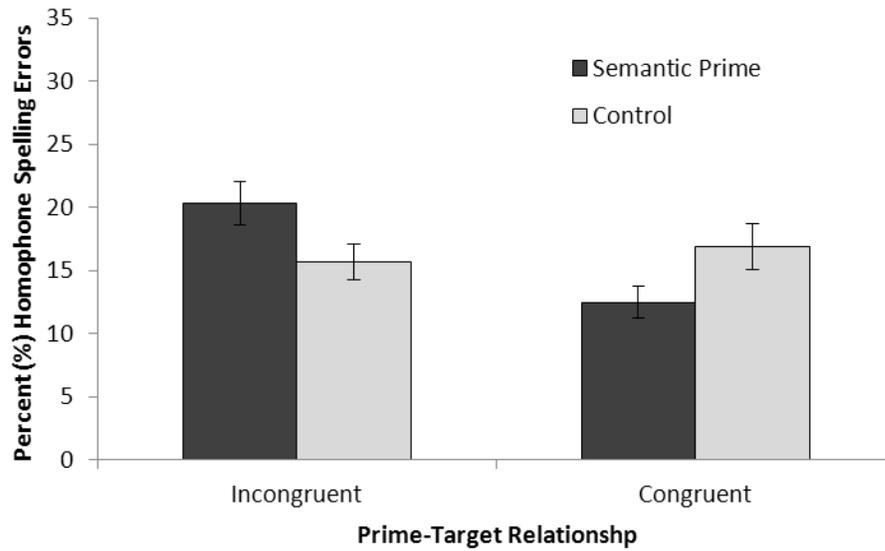
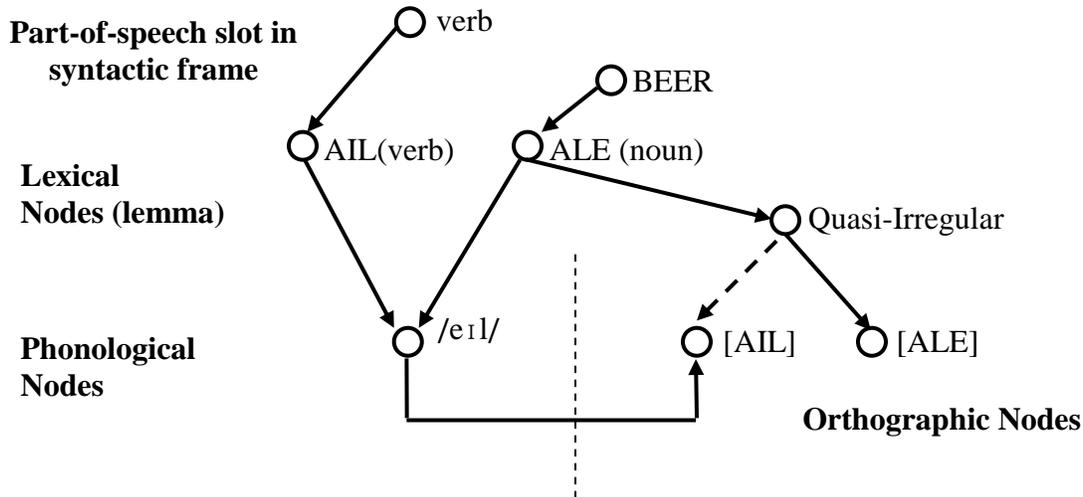


Figure 3. The percentage of homophone errors in Experiment 1, as a function of prime-target relationship (congruent, incongruent) and semantic prime condition (semantic prime, control).

Syntactically ambiguous homophones (different part of speech)

Tom gave up drinking beer after hearing that his injury would ail him forever.



Syntactically unambiguous homophones (shared part of speech)

Since Jane had lost her toes, it was quite a feat that she was able to climb the mountain.

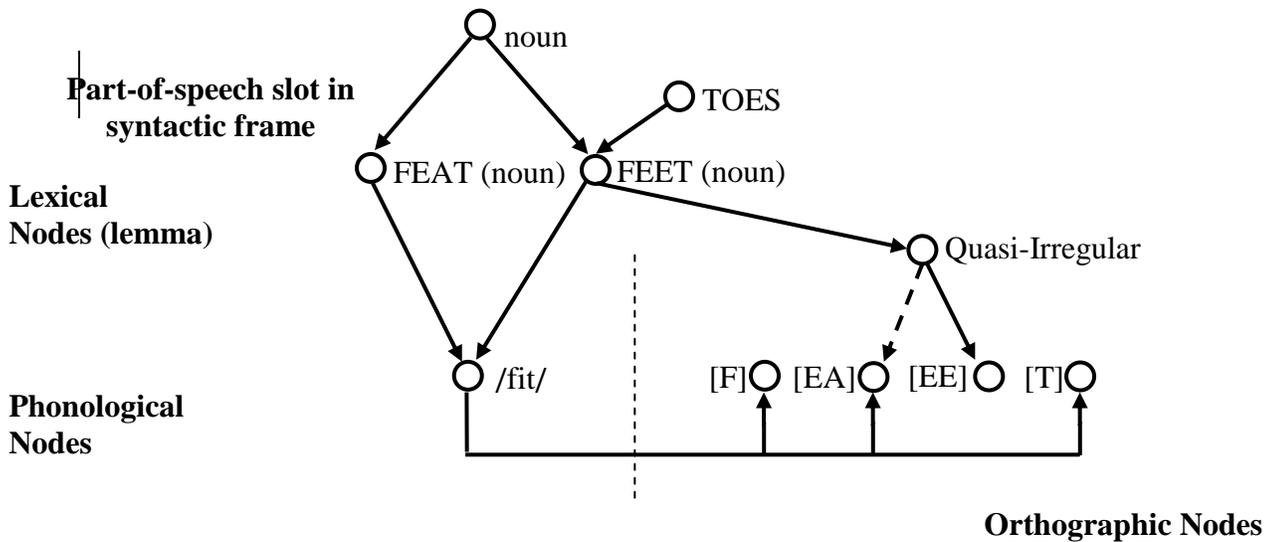


Figure 4. Example of spreading activation among nodes for syntactically ambiguous (top) and syntactically unambiguous (bottom) homophones preceded by incongruent semantic primes. The underlined word in the sentence is the target and corresponds to the part-of-speech slot in the syntactic frame.

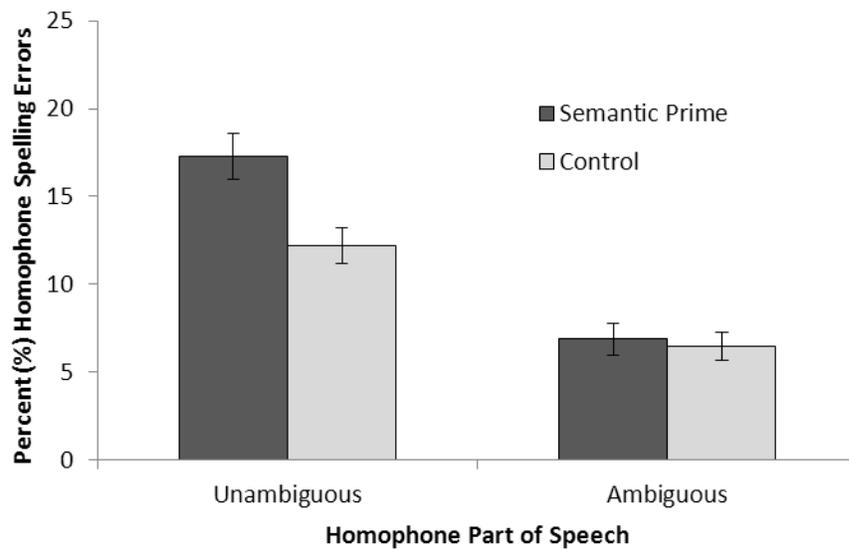


Figure 5. The percentage of homophone errors in Experiment 2, as a function of homophone part of speech (unambiguous, ambiguous) and semantic prime condition (semantic prime, control).