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Why a Superman Cannot Help a Tsunami: Activation of Grammatical Class Influences Resolution of Young and Older Adults' Tip-of-the-Tongue States

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Abstract

Young (aged 18-23), young-old (aged 61-73), and old-old (aged 75-89) adults saw general knowledge questions whose answers were designated target words. Participants responded that they knew, did not know, or were having a tip-of-the-tongue (TOT) state for the answer. After tip-of-the-tongue (TOT) states, participants saw a five-word list in which one was a "prime" containing the target's first syllable and that shared or differed in part of speech from the target. The question was then presented again, and target retrieval was attempted. Results revealed age differences in resolution of TOT states as a function of the prime's grammatical class. Following different part-of-speech primes, young and young-old adults showed increased resolution of TOT states relative to phonologically-unrelated words, whereas old-old adults did not. In contrast, old-old adults demonstrated decreased resolution of TOT states following same part-of-speech primes, whereas young and young-old adults' TOT resolution was unaffected. These findings are consistent with interactive activation theories of speech production where phonology can influence lexical selection and also suggest an increased susceptibility to phonological competitors in the later stages of the aging process.

Keywords: tip-of-the-tongue (TOT) states; phonological priming; grammatical class; young-old vs. old-old adults

Why a Superman Cannot Help a Tsunami: Activation of Grammatical Class Influences Resolution of Young and Older Adults' Tip-of-the-Tongue States

Tip-of-the-tongue (TOT) states, the frustrating experience of being unable to retrieve a known word (e.g., Brown & McNeill, 1966), have intrigued researchers for decades, spawning considerable research on issues such as the availability of partial information during TOT states (e.g., Brown & McNeill, 1966), factors that influence TOT resolution (e.g., James & Burke, 2000; Meyer & Bock, 1992), and age-related changes in TOT states (e.g., Burke, MacKay, Worthley, & Wade, 1991; Maylor, 1990). Although TOT states are intuitively appealing for their universality, their true significance lies in their contributions to our understanding of the cognitive processes underlying language production and how these processes change with the normal aging process. TOT states offer insight into the organization of the lexicon and the nature of syntactic and phonological processes involved in retrieving and speaking words (e.g., Vigliocco, Antonini, & Garrett, 1997), processes essential to normal language production. The present experiment examined how the activation of grammatical class during TOT states influences which words subsequently become available for retrieval and whether differences occur among young, young-old, and old-old adults.

The influence of phonologically-related words on speech production has been debated in the literature. Some studies suggest that phonologically-related words facilitate retrieval during speech production (e.g., Jescheniak & Schriefers, 2001; Schriefers, Meyer, & Levelt, 1990; Vitevitch, 1997, 2002), whereas other studies demonstrate competition from phonologically-related words (e.g., Maylor, 1990; Sevald & Dell, 1994). A similar pattern emerges for resolution of TOT states: Presenting phonologically-related words during TOT states often facilitates TOT resolution by increasing retrieval of the TOT (target) word (e.g., Heine, Ober, & Shenaut, 1999;

James & Burke, 2000; Meyer & Bock, 1992), specifically when the first syllable of the target is provided (Abrams, White, & Eitel, 2003; White & Abrams, 2002), but can sometimes delay or block word retrieval (see Jones, 1989; Jones & Langford, 1987).

Abrams and Rodriguez (2005) found that grammatical class plays a pivotal role in determining the impact that phonologically-related words have on resolution of TOT states. They presented young adults with general knowledge questions designed to induce TOT states for a specific target word (e.g., *rosary*, a noun). Participants then pronounced aloud a list of five words, in which one of the words was a phonological prime with the same first syllable as the target and matched in part of speech (e.g., *robot*, a noun), a phonological prime that differed in part of speech (e.g., *robust*, an adjective), or an unrelated control word (e.g., *fever*). The results showed that young adults' resolution of TOT states was increased only following phonologically-related words in a different grammatical class from the target word; phonologically-related words in the same grammatical class had no effect on TOT resolution. These results suggest that syntactic class functions to activate words that are candidates for production, so that phonologically-similar words in different grammatical classes facilitate word retrieval, whereas phonologically-similar words within the same grammatical class compete with each other and delay word retrieval.

Support for the latter conclusion can be seen in naturally-occurring speech production, where syntax has been shown to constrain possible word choices to words sharing that syntactic property. For example, alternate words that sometimes come to mind during TOT states frequently share grammatical class with the target word (e.g., Burke et al, 1991), a result that also occurs for speech production errors (e.g., Fay & Cutler, 1977). Burke et al. (1991)'s diary study of people's naturally-occurring TOT states also demonstrated that when TOT states were

accompanied by an alternate word (which shared grammatical class with the target 87% of the time, averaged across age groups), TOT states were *less* likely to be resolved in both young and older adults, and even when resolved, retrieving the intended word took longer relative to TOT states that occurred without alternate words in mind. These findings are consistent with the idea that alternates in the same grammatical class delay word retrieval once a TOT occurs. Other researchers have proposed that alternates may also cause TOT states by blocking access to the intended word (e.g., Jones, 1989; Reason & Lucas, 1984). However, studies with older adults do not support this hypothesis, showing that older adults have fewer alternates despite having more TOT states (e.g., Burke et al., 1991; Cohen & Faulkner, 1986; Heine et al., 1999).

If a phonologically-related alternate word competes with the target for retrieval during TOT states, then one might expect older adults to be more susceptible to the effects of alternates, based on the Inhibition Deficit Hypothesis (IDH; Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999; Zacks & Hasher, 1994). The IDH proposes that the ability to inhibit irrelevant information declines in old age. Thus, older adults will have more difficulty suppressing an alternate that comes to mind during a TOT state, enabling the alternate to "block" or prevent target retrieval. It is important to note that in Abrams and Rodriguez's (2005) experiment with college students, phonologically-related words that were the same part of speech as the target did not inhibit TOT resolution, which would have resulted in *fewer* TOT states resolved relative to unrelated words. Therefore, one possibility is that older adults' difficulties in suppressing competing alternates will result in inhibited TOT resolution, contrary to young adults. Despite predicting an age-related increase in competition from phonologically-related words, the IDH does not specify when a phonologically-related word will or will not become a competitor for older adults, i.e., it does not make differential predictions as a function of grammatical class.

Predictions about the role of grammatical class in causing competition for lexical retrieval can be made by interactive activation theories of language production (e.g., Dell, 1986, 1990; MacKay, 1987). Interactive activation theories propose that TOT states occur when connections to a word's phonological nodes are weakened, resulting in insufficient activation of the phonology to enable word retrieval. In these theories, lexical retrieval occurs by syntactic class, such that only lexical nodes in a syntactic class specified by context or conceptual representations are candidates for retrieval. In contrast, neither priming of TOT resolution nor differential effects of grammatical class are predicted by two-stage theories of speech production (e.g., Levelt, 1989; Levelt, Roelofs, & Meyer, 1999; Levelt et al., 1991), as phonology cannot "feed backward" activation to its corresponding lemma and influence lexical selection.

One interactive activation theory in particular, Node Structure Theory (MacKay, 1987), proposes the "most-primed-wins" principle (Burke et al., 1991; MacKay, 1987; MacKay & Burke, 1990), which designates that when nodes in the same domain (a set of nodes that all share the same syntactic function) receive simultaneous priming, only the node receiving the most priming will become activated. This principle is critical for determining how a phonologically-related prime's grammatical class can differentially influence TOT resolution, as shown in Figure 1. As can be seen in the figure, the TOT state initially occurs when the target's lexical node, *haiku*, becomes activated but transmits insufficient top-down priming to enable activation of all of the connected phonological nodes, which is necessary for target retrieval to occur. When a phonologically-related prime in any grammatical class is subsequently encountered, the prime's lexical node (e.g., *hired* or *highway*) gets activated and transmits priming to its phonological nodes, which in turn get activated. As a result, bottom-up priming is transmitted from these phonological nodes to all connected lexical nodes, including the target. It is at this

point that the prime's grammatical class is critical to TOT resolution. When the prime (e.g., *hired*) is in a different grammatical class from the target, both the prime and the target can be the most primed in their syntactic domains, allowing both lexical nodes to be activated. Consequently, the target's phonological nodes can now receive sufficient top-down priming from the lexical node because these lexical-to-phonological connections have been recently strengthened from the bottom-up priming, allowing activation of the phonological nodes and resolution of the TOT state (although in some cases, a different lexical node, e.g., *hiker*, can become the most primed and activated, which is why TOT resolution is not always facilitated). In contrast, when the prime (e.g., *highway*) is in the same grammatical class as the target, the most-primed-wins principle specifies that only one of these lexical nodes can be activated at a time. Since the prime is currently activated, its lexical node replaces the target's lexical node as most primed. Thus, the target's lexical node cannot be reactivated, and the target's phonological nodes will not get the necessary top-down priming to achieve activation (and retrieval).

In sum, Node Structure Theory predicts that if a word phonologically related to the target is activated and is the same part of speech as the unretrieved target word, then the phonologically-related word's activation level must subside before the target word can be retrieved, delaying resolution of the TOT state. A similar idea is used to explain primed competitor effects on picture naming (e.g., Vitkovitch, Humphreys, & Lloyd-Jones, 1993; Wheeldon & Monsell, 1994). In contrast, activating a phonologically-related word that is a different part of speech will facilitate retrieval of the TOT word by transmitting priming bottom-up from its phonological nodes to lexical nodes sharing the phonology in another syntactic domain, e.g., the TOT word, which may accumulate enough priming to become activated and retrieved. Both of the phonological primes are expected to influence TOT resolution differently

from a phonologically-unrelated word (e.g., *bitter;* see Figure 1). Upon activation of the unrelated word's lexical node, it then transmits priming to its phonological connections, which in turn transmit priming to all connected lexical nodes. Since the target is not one of these connected nodes, presentation of the phonologically unrelated word will have no effect on target retrieval. Thus, any TOT resolution that occurs following a phonologically-unrelated word represents the degree of spontaneous resolution unrelated to the prime.

Node Structure Theory (MacKay, 1987; MacKay & Burke, 1990) also accounts for age-related changes in lexical retrieval through a corollary called the Transmission Deficit Hypothesis (TDH; Burke, MacKay, & James, 2000; Burke et al., 1991; MacKay & Burke, 1990). The TDH maintains that the connections between nodes at all levels weaken with increasing age, resulting in a reduction in the rate and amount of priming transmitted among connections, making activation more difficult. This age-related transmission deficit is especially detrimental to older adults' performance when a node critical to a task receives priming from only a single connection within the network, e.g., such as the top-down priming between lexical and phonological nodes necessary for word retrieval. In older adults, this transmission of priming is reduced, resulting in increased TOT states.

Although older adult nodes will sometimes transmit insufficient priming to enable activation of their connected nodes, other factors such as frequency and recency of use can offset these age-related transmission deficits. For example, weakened connections can be strengthened via recent production of a word's phonology, a process that is expected to benefit young and older adults to the same degree (MacKay & Burke, 1990). As seen in Figure 1, reading or producing a phonologically-related prime in a different grammatical class from the target allows activation of its phonological nodes, strengthening these connections for both young and older

adults and allowing them to more effectively transmit bottom-up priming to connected lexical nodes. This increment in connection strength and transmission of priming following activation of the phonological nodes is thought to be unaffected by aging. Support for this claim can be seen in studies reporting equivalent phonological priming effects for young and older adults, both in TOT resolution and in TOT incidence (e.g., James & Burke, 2000; Rastle & Burke, 1996).

A similar equivalence would be expected for a phonologically-related word that could serve as a competitor, i.e., a word in the same grammatical class as the target. Production of the competitor allows its lexical node to be activated and increases transmission of priming to its phonological nodes, which offsets the age-related transmission deficits by strengthening these connections to the same extent in young and older adults. Thus, both age groups will have the competitor as the most primed lexical node in its domain. The TDH also proposes that priming decays at the same rate for young and old nodes (MacKay & Burke, 1990). Therefore, the duration that the competitor will remain the most primed lexical node will be similar in both age groups, delaying TOT resolution to the same degree.

These predictions about the time course of TOT resolution are more appropriate for testing within the context of diary studies, where participants do not have a time limit for retrieval. Diary studies are able to reveal age differences as a function of time course; for example, Burke at al. (1991, Experiment 1) found that older adults required significantly more time to resolve their TOT states than did young adults. In contrast, laboratory studies do not have the capability for assessing time-based predictions of TOT resolution, as the time permitted for TOT resolution is usually very short, e.g., less than a minute. However, predictions can be extended to accuracy, the likelihood of TOT resolution, when the time frame for retrieval is limited. Circumstances that speed resolution (i.e., different part-of-speech primes) will result in

increased accuracy, whereas circumstances that slow resolution (e.g., same part-of-speech primes) will result in decreased accuracy, relative to an unrelated control that offers a baseline of resolution accuracy within the brief retrieval interval. Furthermore, these effects are expected to be age-invariant, as phonologically-related primes increase the transmission of priming similarly for young and older adults.

Although the TDH postulates transmission deficits for older adults in general, there is converging evidence that these deficits progress throughout old age, resulting in greater declines for old-old adults in a variety of cognitive tasks (e.g., Bäckman, Small, Wahlin, & Larsson, 2000; Davis et al., 1990; MacKay & Abrams, 1998). In the few studies that have been conducted on TOT resolution in older adults, phonological priming of TOT resolution remains stable in the 60s and early 70s, with older adults in these ages showing facilitation from phonologically-related words equivalent to that of young adults (e.g., Heine et al., 1999; James & Burke, 2000; White & Abrams, 2002). However, people in their upper 70s and 80s exhibit deficits in their priming of TOT resolution, showing less or no TOT resolution following phonologically-related words (e.g., Heine et al, 1999; White & Abrams, 2002). Using the structure of the TDH to explain these findings, old-old adults may experience more severe transmission deficits than young-old adults, which will make it more difficult to accumulate the amount of priming needed for the target to gain the most-primed status in its domain. If so, old-old adults will have less priming of TOT resolution than young-old adults following phonologically-related primes in either grammatical class.

Method

Participants

Participants included 60 young adults aged 18 to 23 (M = 19.4, SD = 1.2), 60 young-old

adults aged 61 to 73 (M = 68.7, SD = 3.5), and 60 old-old adults aged 75 to 89 (M = 79.9, SD = 3.7). Young adults were recruited from Introductory Psychology courses at the University of Florida and received partial course credit for participation. Young-old and old-old adults were recruited from the University of Florida Cognition and Aging Laboratory participant pool, a database of older adult volunteers from the Gainesville community, and received $8 per hour for their participation. All older adults scored 25 or above on the Mini Mental State Exam (Folstein, Folstein, & McHugh, 1975). All participants spoke fluent English and had normal or corrected-to-normal vision.

Table 1 presents the means and standard deviations of various background characteristics for each age group, including a 25-item multiple-choice vocabulary test, years of education, health rating, and forward and backward digit span tests. One-way ANOVAs revealed that both young-old and old-old adults had higher vocabulary scores, F (2, 173) =53.47, MSE =10.22, p < .001, and more years of education, F (2, 174) = 28.45, MSE = 6.03, p < .001, than young adults. Young adults exhibited larger backward digit spans, F (2, 174) = 9.63, MSE = 1.48, p < .001, than young-old and old-old adults. No significant age differences were found for health rating, p > .216, or forward digit span, p > .172.

Materials

The experiment was conducted on a Pentium 4, 1.8 GHz PC-compatible computer via a program written in Visual Basic 5.0. The experimental stimuli consisted of 75 definition-like questions, each corresponding to a specific target word (e.g., *haiku*), that were modified versions of questions in Abrams and Rodriguez (2005). The target words (59 nouns, 14 verbs, and 2 adjectives) were between 1 and 6 syllables (M = 3.29, SD = .91), low in Francis and Kucera (1982) frequency (all were 0 to 8 per million, except one at 39 per million, M = 1.63, SD =

4.78), and none were proper names. Fifteen filler questions whose answers were easily retrievable proper nouns were also included.

For each target, two primes were created to share the first syllable of the target, with phonology being verified by the online version of the Carnegie-Mellon University Pronouncing Dictionary (http://www.speech.cs.cmu.edu/cgi-bin/cmudict). One prime was the same part of speech as the target (e.g., *highway*), whereas the other prime was a different part of speech from the target (e.g., *hired*). All same part-of-speech primes were relatively high in Francis and Kucera (1982) frequency (M = 68.61, SD = 65.97), as were different part-of-speech primes (M = 61.51, SD = 92.60). Because young adults typically have lower vocabularies than older adults, we wanted to ensure that the primes were words encountered by young adults. Seven young adults (who were not in the actual experiment) rated the primes' frequency in everyday use with a scale from 1 (very rare) to 7 (very common). These ratings showed that young adults were reasonably familiar with both same part-of-speech primes (M = 4.61, SD = .83) and different part-of-speech primes (M = 4.40, SD = .83). In terms of number of syllables, the two types of primes for a particular target were matched whenever possible. Although this was only achieved 43% of the time, the number of syllables in same part-of-speech primes (M = 2.67, SD = .89) was similar to those in different part-of-speech primes (M = 2.76, SD = .94) when averaged across all stimuli. Both primes were also similar in the amount of phonological and orthographic overlap that they shared with the target immediately after the first syllable; there were only four targets with differential overlap between the primes, e.g., the prime *downtown* shares the letter "w" with the target *dowry*, whereas the prime *doubtful* does not.

In addition to the primes, a control word for each target was chosen that was a different part of speech[1] and contained a different initial phoneme from the target (e.g., *bitter*). Moreover,

all control words were phonologically and semantically unrelated to any of the primes and targets. Half of the control words matched in number of syllables and Francis and Kucera (1982) frequency (± 10) with the same part-of-speech prime for its target, whereas the remaining half matched these characteristics in the different part-of-speech prime. Control words were generally high in Francis and Kucera (1982) frequency (M = 63.01, SD = 59.92). All of the targets, primes, and control words are provided in the Appendix.

Four filler words per target were also created. Filler words were a different part of speech from their targets, did not overlap in phonology or semantics with any of the primes or targets, and did not share the same first letter as their target, primes, or any other filler words for that target. A multiple-choice recognition test was used to ensure that participants were having a correct TOT, i.e., a TOT state for the intended target, assessed by their correct identification of the target. Of the four possible answers, one was the target word, one was phonologically related to the target, one was semantically related to the target, and one was unrelated to the target. All answer choices were the same part of speech as the target, and the phonologically-related choice was not positioned adjacent to the target. The target's position in the multiple-choice test was counterbalanced equally across choices "a", "b", "c", and "d" (with one less "d"). A post-experiment questionnaire was administered to determine if participants made an association between the primes' phonology and the targets, and if so, whether they intentionally used this relationship to deduce the target word.

Design and Procedure

The experimental design was a 3 (Age Group: young, young-old, old-old) x 3 (Prime Condition: same part-of-speech prime, different part-of-speech prime, unrelated control word) factorial design, with Age Group as a between-participants factor and Prime Condition as a

within-participants factor.

Prior to beginning the study, participants were instructed about what constituted a TOT state and how this experience differed from not knowing an answer. Participants then viewed one general knowledge question at a time, responding whether they knew, did not know, or were having a TOT for the answer. A filler question was presented after every five experimental questions. Following experimental questions, participants saw a list of five words, presented one at a time. The five-word list varied as a function of participants' response to the general knowledge question. A "Known" response was always followed by a five-word list containing the unrelated control, and then the next question appeared on the screen. In contrast, an "Unknown" or "TOT" response was followed by a set of four filler words intermixed with the same part-of-speech prime, the different part-of-speech prime, or the unrelated control, which appeared in the second position in the list. The computer program selected one of the three prime conditions equally often. Filler questions were not followed by word lists because responses to these questions were irrelevant and would receive no analysis.

Upon seeing each word, participants read the word silently and then judged aloud its difficulty in pronunciation using a five-point scale (1 = easy, 5 = hard). After rating all of the words, participants saw the five words again and rated each word's difficulty in spelling using the same 5-point scale. To disguise the association of the primes to the target questions, participants were informed that the ratings were for a separate study aimed at assessing people's knowledge of words on two dimensions, pronunciation and spelling. Following the ratings, participants saw the question to which they originally answered "Unknown" or "TOT" and were given another opportunity to answer the question. If participants now knew the answer, they verbally stated it and then saw the next question. Otherwise, participants stated that they did not

know the answer or were having a TOT and were then given the next question. After answering all 90 questions, participants took the multiple-choice recognition test for questions in which an answer was never retrieved. Following the recognition test, participants were administered the post-experiment questionnaire. All tasks were self-paced, participants gave their responses verbally, and the experimenter entered the responses into the computer during the experiment. All experimental sessions were recorded on cassette tapes for double-checking of responses when necessary.

Results

Prior to analysis, two old-old adults were excluded, one who reported having had a stroke and another who was presently suffering from macular degeneration. One young-old adult was excluded because of a computer error in recording the data. Examination of the post-experiment questionnaire showed virtually no awareness of the relationship between the primes and target words: Only one young adult, three young-old adults, and one old-old adult reported that they noticed a relationship. However, of these participants, only one young-old adult was able to give an example that correctly identified a phonological relationship between a prime and a target, and this participant reported not being able to use this relationship to facilitate word retrieval.

Resolution following Correct "TOT" Responses

TOT responses were classified as correct only if participants provided a correct answer following a "Known" response to the second presentation of the general knowledge question, or a correct response on the recognition test following a "TOT" response. Young adults, young-old adults, and old-old adults experienced correct TOT states on 8.9%, 9.8%, and 12.1% of trials, respectively. A 3 (Age Group: young, young-old, and old-old) x 3 (Prime Condition: same part-of-speech prime, different part-of-speech prime, and unrelated control) repeated-measures

ANOVA was conducted by participants[2] on the proportion of targets correctly retrieved following an initial correct "TOT" response. All effects were followed up with Bonferroni multiple comparison tests when appropriate. Means and standard deviations are shown in percents in the top half of Table 2. Ten participants (three young, three young-old, and four old-old adults) could not be included in the analysis because they did not have at least one correct TOT response in all three priming conditions.

The main effect of age group was significant, $F(2, 164) = 5.15$, $MSE = .15$, $p < .007$, and post-hoc tests showed that young adults had less TOT resolution than either young-old, $p < .013$, or old-old adults, $p < .029$, who did not differ, $p > .999$. The main effect of prime condition was also significant, $F(2, 328) = 5.40$, $MSE = .09$, $p < .005$, where TOT resolution following different part-of-speech primes was greater than resolution following same part-of-speech primes, $p < .008$, or following unrelated controls, $p < 004$, with no difference between the latter two conditions, $p > .868$. These main effects were moderated by a significant Age Group x Prime Condition interaction, $F (4, 328) = 3.23$, $MSE = .09$, $p < .013$. Further analysis of this interaction showed differences in TOT resolution as a function of prime condition for young adults, where young adults resolved more TOT states following different part-of-speech primes relative to unrelated controls, $p < .001$. In contrast, resolution of TOT states was equivalent following same part-of-speech primes and unrelated controls, $p > .246$. Young-old adults also exhibited priming following different part-of-speech primes relative to unrelated controls, but to a lesser degree than young adults, $p < .074$. Similar to young adults, young-old adults' TOT states were resolved equivalently following same part-of-speech primes and unrelated controls, $p > .252$. Unlike young and young-old adults, old-old adults exhibited equivalent TOT resolution following

different part-of-speech primes and unrelated controls, $p > .586$, and resolved more TOT states following unrelated controls relative to same part-of-speech primes, $p < .011$.

Analysis of the interaction within each level of prime condition revealed age differences in TOT resolution following same part-of-speech primes: Young-old adults had greater resolution than young adults, $p < .031$, but not old-old adults, $p > .271$, with no difference between young and old-old adults, $p > .999$. Age differences also occurred following unrelated controls: Young adults had less TOT resolution than young-old, $p < .046$, and old-old adults, $p < .001$, who did not differ from each other, $p > .253$. There were no age differences in resolution following different part-of-speech primes, $p > .752$. Because age differences occurred following unrelated controls, it is possible that these baseline differences contributed to the differential priming effects observed in the three age groups. To test this hypothesis, random samples from each age group were selected that did not significantly differ in resolution following unrelated controls (M_{young} = 25.2%, $M_{young\text{-}old}$ = 31.7%, and $M_{old\text{-}old}$ = 37%). Analyses conducted on these samples revealed identical patterns of results to the ones described above, suggesting that the age differences in resolution following unrelated controls were not responsible for the age differences in TOT resolution following same and different part-of-speech primes.

Resolution following "Unknown" Responses

To assess that the effects of prime condition were unique to TOT responses, a 3 (Age Group) x 3 (Prime Condition) repeated-measures ANOVA was conducted on the proportion of targets correctly retrieved following an initial "Unknown" response. Means and standard deviations are shown in the bottom half of Table 2. Young adults, young-old adults, and old-old adults initially responded "Unknown" on 26.5%, 19%, and 20.2% of trials, respectively. Five participants (one young, two young-old, and two old-old adults) could not be included because

an "Unknown" response was never given in one or more priming conditions. The only significant result was the main effect of age group, $F(2, 169) = 5.25$, $MSE = .01$, $p < .006$, where young adults retrieved targets less often than either young-old adults, $p < .03$, or old-old adults, $p < .011$, with no differences between the two older adult groups, $p > .999$. The main effect of prime condition was nonsignificant, $F(2, 338) = 2.13$, $MSE = .01$, $p > .12$, as was the Age Group x Prime Condition interaction, $F < 1$.

Discussion

The results showed that the activation of grammatical class differentially influenced young, young-old, and old-old adults' resolution of TOT states. These results are significant for theories of language production as well as theories of cognitive aging. With respect to language production theories, the finding that phonologically-related words influence TOT resolution is consistent with interactive activation theories that spread activation bidirectionally, but is difficult to explain within two-stage theories of language production (e.g., Levelt, 1989; Levelt, Roelofs, & Meyer, 1999; Levelt et al., 1991), where the phonological form cannot "feed back" activation to its corresponding lemma. Furthermore, the relationship between a prime and target's syntactic class would be irrelevant to phonological retrieval in two-stage theories because syntactic information (such as part of speech) is retrieved along with the lemma in the first stage of processing, but does not play a role in the second stage, retrieval of the phonological word forms (lexemes).

However, the differential effects of phonologically-related primes on TOT resolution as a function of their grammatical class were predicted by the most-primed-wins principle in Node Structure Theory (MacKay, 1987). Activating a phonologically-related word that is a different part of speech from the target facilitates TOT resolution by transmitting priming bottom-up to

connected phonological nodes in another syntactic domain, leading to activation of the target. In contrast, activating a phonologically-related word in the same grammatical class as the target does not help TOT resolution because only one node in a syntactic domain can be the most primed and get activated. The recency of presentation of the phonologically-related word gives it most primed status and forces the target to accumulate more priming than the phonologically-related word before retrieval of the target can occur (e.g., Vitkovitch, Humphreys, & Lloyd-Jones, 1993; Wheeldon & Monsell, 1994).

In terms of cognitive aging theories, there was some support for the IDH, evidenced by old-old adults showing inhibition from same part-of-speech primes: Their resolution of TOT states was lower after reading same part-of-speech primes relative to phonologically unrelated words. These data indicate an increased susceptibility in old-old adults for phonologically-related words in the same grammatical class to become fiercer competitors, reducing resolution of TOT states. Within the IDH, a likely mechanism underlying this increased susceptibility is one of the functions of inhibition: to delete irrelevant information from working memory (e.g., Hasher et al., 1999). Older adults' weakened inhibitory mechanisms make them less able to remove the phonologically-related prime once it is enters working memory, which prevents access to the target. However, the IDH has difficulty explaining the selectivity of the inhibition deficit. These inhibition effects on TOT resolution occurred only for phonologically-related words that were the same grammatical class as the target. The IDH does not explain why inhibition would only occur following these types of primes, not all phonologically-related words. Furthermore, the inhibitory result occurred only for old-old adults, not for both groups of older adults. In fact, the finding that young-old adults had greater TOT resolution following same part-of-speech primes than young adults suggests that these phonologically-related words were not competitors for

young-old adults more so than young adults. In fact, these primes were *less* competitive for retrieval in young-old adults. This latter finding is inconsistent with the IDH even if one assumes that inhibitory deficits get more pronounced with increasing age, causing differences between young-old and old-old adults; there are no circumstances where older adults would be expected to demonstrate less inhibition than young adults.

The inhibitory effect of same part-of-speech primes for old-old adults was predicted by the TDH (e.g., Burke et al., 2000; MacKay & Burke, 1990), where a phonologically-related prime in the same grammatical class delays the target from achieving most-primed status and subsequent activation. However, contrary to the predictions, this reduction in TOT resolution was not age-invariant; young and young-old adults' TOT resolution was not inhibited by same part-of-speech primes relative to unrelated controls. In fact, there was a (nonsignificant) trend for resolution following same-part-of-speech primes to be greater than resolution following unrelated controls, for both young adults and young-old adults. Despite using primes that were reasonably familiar to both groups, these primes may not have been competitive enough with the target for retrieval to demonstrate inhibition of TOT resolution. Identifying the conditions in which inhibition can be obtained in these age groups, consistent with the predictions of the TDH, is a question for future study.

The differential effects of age also extended to TOT resolution following different part-of-speech primes. Young adults' TOT resolution supported the predictions of the Node Structure Theory and replicated the findings of Abrams and Rodriguez (2005), where phonologically-related primes in a different grammatical class increased resolution of TOT states. Young-old adults also exhibited phonological priming following different part-of-speech primes but to a lesser degree than young adults, contrary to other studies showing equivalent priming effects

(e.g., Heine et al., 1999; James & Burke, 2000; White & Abrams, 2002). One methodological difference is that a single phonologically-related prime (that overlapped only in one syllable with the target) was used in the present experiment, relative to the other studies. For example, in White and Abrams (2002) and James and Burke (2000), young-old adults may have relied on the bottom-up priming being spread from multiple phonologically-related words, allowing sufficient priming to converge on the target and facilitate its retrieval. One phonologically-related prime may be insufficient to completely overcome age-related deficits in the transmission of priming in young-old adults, especially when only part of the target's phonology is provided. If so, the TDH's assumption that activation strengthens phonological connections similarly for young and older adults (e.g., Burke, 1999) may be limited to contexts where a considerable amount of phonological information is provided.

In contrast, old-old adults did not demonstrate priming following the presentation of different part-of-speech primes. The lack of priming for old-old adults replicates other studies finding diminished TOT resolution following phonologically-related words (e.g., Heine et al, 1999), even when three first-syllable primes were provided (White & Abrams, 2002). Within the TDH, old-old adults' inability to display phonological priming is consistent with the suggestion of more severe transmission deficits, which increase the difficulty in accumulating sufficient priming on the target to enable activation. These deficits cannot be overcome by phonological priming, at least not when the prime contains only the first syllable of the target. Given that TOT states increase with age (e.g., Burke et al., 1991), it is critical to determine the factors that will facilitate resolution, e.g., whether presenting the entire phonology of a word will lead to TOT resolution in this age group.

In sum, a *superman* (a noun) does not help resolve a TOT for *tsunami* (another noun), and in fact, becomes counterproductive for TOT resolution in very old age. Future research should continue to identify specific phonological and syntactic components that influence young and older adults' resolution of TOT states by testing other variables known to affect speech production. For example, neighborhood density influences other speech production tasks, such as picture naming and elicitation of speech errors. Words with high neighborhood density (having a large number of words with phonological resemblance) are produced more quickly and accurately than words with low neighborhood density (e.g., Gordon, 2002; Gordon & Dell, 2001; Vitevitch, 1997, 2002). Neighborhood density also influences the occurrence of TOT states, with words from dense neighborhoods having fewer TOT states than words with sparse neighborhoods (e.g., Harley & Bown, 1998; Vitevitch & Sommers, 2003). Therefore, primes with high neighborhood density may be more likely to resolve TOT states than primes with low neighborhood density because of the activation of more phonological neighbors; however, the syntactic class of these neighbors is important, such that activation of many neighbors in the same syntactic class as the target may not help TOT resolution. Furthermore, differences between young-old and old-old adults continue to emerge, indicating the need to assess TOT resolution among different groups of older adults and to understand why deficits in the transmission of node priming progress with increasing age, resulting in greater difficulty activating phonological information.

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Appendix

Targets, Phonologically-Related Primes, and Unrelated Control Words

Target	Same Part-of-Speech Prime	Different Part-of-Speech Prime	Unrelated Control Word
abacus	absence	absolutely	generalize
abdicate	abhor	abdomen	larval
acapella	occupation	occupy	regularly
actuary	accident	accurate	normally
agnostic	agriculture	aggravate	celestial
alchemy	allies	allocate	newer
ambergris	ambition	ambiguous	justify
ambrosia	ambulance	ambitious	testify
anagram	anticipation	answered	biological
anarchist	animal	analyze	delicate
aorta	agent	able	divide
atone	attend	atomic	worker
bandanna	banjo	banish	tender
cadaver	community	collect	somehow
capillary	captain	capsize	forward
carcinogen	carbon	carve	vague
contraband	concept	conscious	prevail
coroner	corporation	corresponding	apparently
covenant	coverage	covered	thoroughly
decanter	depression	destroy	proper
determinist	department	decide	already
detonate	demonstrate	definite	furthermore
dowry	downtown	doubtful	injure
ellipsis	election	elaborate	remember
embryo	employee	emphasize	popular
endorse	enable	energy	creative
ephemeral	effective	efficiency	discover
estrogen	essay	estimated	previously
euphemism	utility	useful	characterize
evangelist	event	eventually	administrative
fratricide	fraction	fragile	invade
haiku	highway	hired	bitter
hemophilia	heater	heated	awful
hemorrhage	hemmed	hemisphere	durable
hieroglyphics	hydrogen	hypothetical	dominate
hypochondriac	hyphen	hyper	disperse
incubate	include	income	ahead
insomnia	instruction	insist	ultimate
kaleidoscope	capacity	communicate	impossible
liaison	leadership	legal	moreover

ligament	liberty	limited	wonderful
lynch	listen	liberal	factory
marinade	manner	magnificent	accordingly
marsupials	martini	marginal	overlap
meticulous	mechanical	machine	assume
metronome	memory	medical	represent
misdemeanor	misfortune	missed	horrible
molt	motivated	moment	unconsciously
mutiny	music	municipal	apply
nepotism	network	never	very
omnivore	omelet	ominous	patiently
onomatopoeia	onset	onto	unique
origami	orientation	organized	technological
ornithology	orchestra	ordered	adequate
palindrome	passenger	passionate	supervise
parasite	paragraph	paralyze	historic
parsimony	participation	partially	interview
pasteurize	passed	passage	fully
pawn	paused	pauper	neat
pendulum	penalty	penetrate	movable
perjury	percentage	permanent	authorize
philatelist	fiction	figured	royal
plagiarize	placed	plate	odd
planetarium	plantation	planted	cautious
potpourri	poem	poetic	generate
pride	priority	primarily	systematic
procrastinate	proceed	profession	extreme
reiterate	realize	reasonable	observation
seismology	sidewalk	silent	imply
silhouette	silk	silly	cater
simile	symmetry	symbolic	explaining
soliloquy	solution	sophisticated	financial
torpedo	tornado	torn	bold
tranquilize	translate	transition	currently
utopia	union	usually	allow

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Footnotes

[1]Abrams and Rodriguez (2005) used unrelated control words that shared grammatical class with the target half the time. They found no difference in TOT resolution following lists containing same part-of-speech control words versus lists with different part-of-speech control words, suggesting that the control word's part of speech was irrelevant to TOT resolution because there was no phonological overlap with the target. Therefore, the present experiment used only control words with a different part of speech from the target for simplicity.

[2]Item analyses were not conducted because previous research has suggested that item analyses are inappropriate when the stimulus items are not selected randomly (e.g., Cohen, 1976; Raaijmakers, Schrijnemakers, & Gremmen, 1999; Vitevitch & Sommers, 2003). Furthermore, item analyses in TOT research often eliminate many items due to insufficient TOT states in all conditions, resulting in low statistical power.

Table 1

Background Characteristics for Young, Young-Old, and Old-Old Adults

	Young Adults		Young-Old Adults		Old-Old Adults	
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Vocabulary (max = 25)*	15.28	3.09	20.09	3.57	20.91	2.88
Years of Education*	13.39	1.24	16.31	3.17	16.36	2.57
Health (max = 10)	8.20	1.42	7.73	1.82	7.78	1.58
Forward Digit Span	7.28	1.23	7.10	1.11	6.86	1.32
Backward Digit Span*	6.03	1.01	5.34	1.41	5.09	1.20

Note. Asterisks indicate significant differences between young adults and the two older adult groups, $p < .05$.

Table 2

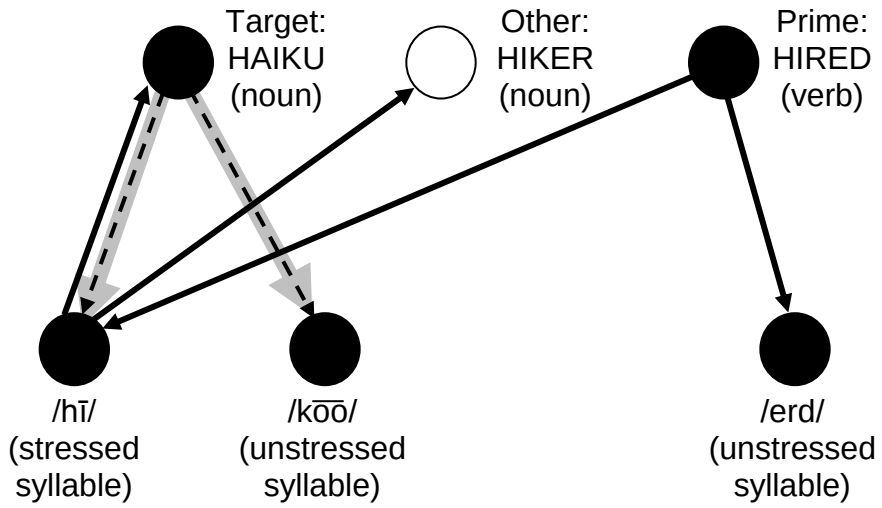
Target Word Retrieval (in %) Following Primes and Unrelated Controls after an Initial "TOT" or "Unknown" Response

	Age Group					
	Young Adults		Young-Old Adults		Old-Old Adults	
Initial Response	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Priming Condition						
TOT						
Same part-of-speech prime	22.5	33.6	38.2	34.2	27.3	30.6
Different part-of-speech prime	36.5	38.5	41.6	36.5	38.9	34.1
Unrelated control	15.9	25.0	31.7	32.4	42.0	33.1
Unknown						
Same part-of-speech prime	2.6	5.6	6.9	12.6	6.2	15.8
Different part-of-speech prime	3.1	6.5	5.0	12.5	5.2	10.6
Unrelated control	0.7	3.7	3.3	8.5	5.0	11.5

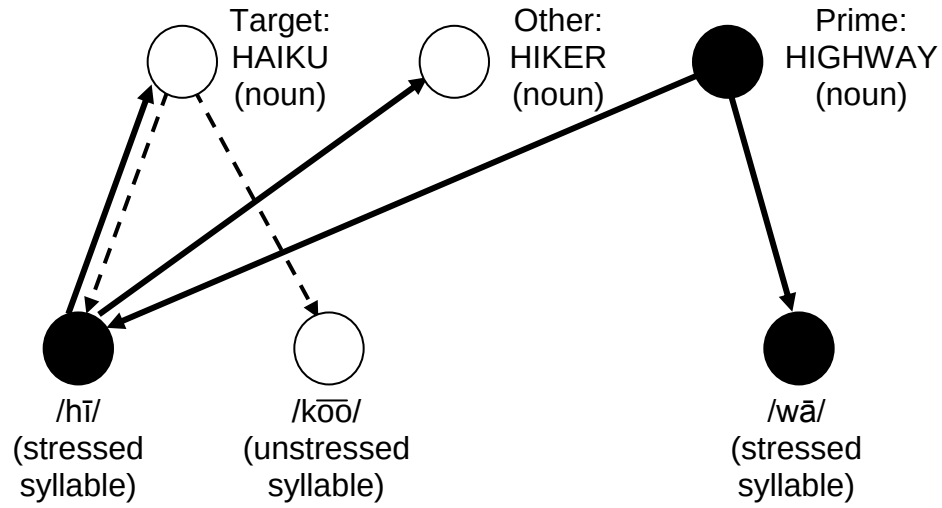
Figure Captions

Figure 1. Node Structure Theory's representation of a TOT target's lexical and phonological nodes, demonstrating how priming from a different part-of-speech word vs. a same part-of-speech word would influence TOT resolution, relative to a phonologically unrelated word. In each diagram, the dotted lines represent weakened connections between lexical and phonological nodes thought to cause TOT states. Filled-in nodes indicate nodes that have accumulated enough priming to become activated and thus transmit priming to connected nodes (via solid lines). The gray arrows demonstrate how once-weakened connections to the phonological nodes get strengthened.

TOT Resolution following a different part-of-speech prime:



TOT Resolution following a same part-of-speech prime:



TOT Resolution following a phonologically-unrelated word: