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Does Priming Specific Syllables During Tip-of-the-Tongue States Facilitate Word Retrieval in Older Adults?

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Abstract

This experiment investigated whether phonological priming of syllables helps resolve tip-of-the-tongue (TOT) states in young and elderly adults. Young (18-26 years), young-old (60-72 years), and old-old (73-83 years) adults read general knowledge questions and responded "know," "TOT," or "don't know" accordingly. Participants then read a list of ten words that included three phonological primes corresponding solely to the first, middle, or last syllable of the target word. Young and young-old adults resolved more TOTs after first-syllable primes, but old-old adults showed no increase in TOT resolution following any primes. These results support the Transmission Deficit hypothesis in that presentation of the first syllable of a missing word strengthens the weakened phonological connections that cause TOTs and increases word retrieval, but not for old-old adults who experience greater deficits in the transmission of priming across these connections.

Does Priming Specific Syllables During Tip-of-the-Tongue States Facilitate Word Retrieval in Older Adults?

The tip-of-the-tongue (TOT) phenomenon has been widely studied as a naturally occurring retrieval failure that is characterized by a temporary inability to recall a known word (R. Brown & McNeill, 1966). TOTs occur for people of all ages but are a particularly common complaint in older adults. Age differences in TOT incidence have been assessed both in the natural environment and in the laboratory. Compared to young adults, older adults generally report having more TOT states, fewer alternate words, and less phonological information about the target word, such as number of syllables or first and last letters (e.g., Burke, MacKay, Worthley, & Wade, 1991; Cohen & Faulkner, 1986; Heine, Ober, & Shenaut, 1999). One explanation for these findings is that older adults have greater difficulty activating the necessary phonology to facilitate word retrieval, resulting in more TOTs and less awareness of phonological information (e.g., Burke et al., 1991; James & Burke, 2000). The purpose of the present study was to isolate specific syllables of a word and measure the effect of repetition of these syllables on helping older adults to retrieve a missing word.

The idea of reduced activation in a TOT state is not new; TOTs in general are thought to result from insufficient activation of the target word (e.g., Burke, MacKay, & James, 2000; James & Burke, 2000; Kohn, Wingfield, Menn, Goodglass, Gleason, & Hyde, 1987; Meyer & Bock, 1992; Perfect & Hanley, 1992). Node Structure Theory (NST; Burke et al., 1991; MacKay, 1987; MacKay & Burke, 1990; for discussions of other recent theories, see Harley & Bown, 1998; Miozzo & Caramazza, 1997) specifies more precisely that word retrieval failures result from insufficient priming of the connections between lexical and phonological nodes. Connections between a lexical node (e.g., placebo) and phonological nodes (e.g., the syllables

/plə/, /cē/ and /bō/) are especially susceptible to weakening from infrequent and non-recent use because of the architecture of the phonological system, where nodes are linked by a single connection. For example, Figure 1 depicts the word “placebo” and its corresponding nodes in the semantic and phonological systems. The syllable nodes /plə/, /cē/, and /bō/ each have only a single connection to the lexical node *placebo*, indicated by dashed lines. In order for complete retrieval of a word to occur, each of these syllable nodes must be activated, in sequential order. According to NST, during a TOT state, the word is unable to be retrieved because sufficient priming (enough for activation) is not transmitted to *all* of the necessary phonological nodes, even though some of these nodes may get activated. This “incomplete” activation explains why a TOT experience might involve the feeling that the target word begins with “p”, but the word cannot be recalled in its entirety because the remaining phonology (i.e., /lə-cē-bō/) is not activated.

A corollary of NST, the Transmission Deficit hypothesis (TDH; Burke et al., 2000; Burke et al., 1991; MacKay & Burke, 1990), extends this account of TOTs to older adults by postulating that the normal aging process (in addition to infrequent and nonrecent word use) weakens the strength of the connections between nodes, resulting in more word retrieval failures for older adults. This weakening results in a reduction in the transmission of priming between elderly adults’ nodes (possibly due to neural slowing, produced by increased synaptic delays; MacKay & Burke, 1990), which makes word activation (and thus retrieval) more difficult. Therefore, older adults will have particular difficulty activating nodes via connections that are already susceptible to transmission deficits (e.g., between the phonological and lexical nodes). These reductions in the transmission of priming in old age predict an increase in the number of TOTs for elderly adults, which has been demonstrated in multiple studies (e.g., Burke et al.,

1991; Cohen & Faulkner, 1986; Heine et al., 1999).

Although TDH postulates transmission deficits for older adults in general, there has been little attempt to outline a trajectory for the increase in transmission deficits across old age. That is, research has yet to specify the rate at which these deficits progress in old age. Recent evidence has suggested that different age groups of elderly adults may differ in the nature and amount of transmission deficits. Old-old adults in their 70s and 80s sometimes show greater age-related declines than young-old adults in repetition priming (e.g., Davis, Cohen, Gandy, Columbo, VanDusseldorp, Simolke, & Romano, 1990; Hultsch, Masson, & Small, 1991; Jelicic, Craik, & Moscovitch, 1996; Maylor, 1998), in written spelling ability (MacKay & Abrams, 1998), and in word naming performance on the Boston Naming Test (e.g., Au, Joung, Nicholas, Obler, Kass, & Albert, 1995; Mitrushina & Satz, 1995). Given the broad nature of these age-related declines, one might predict an exacerbation of age-related difficulties pertaining to TOTs for the old-old adults, and recent evidence supports this claim. Heine et al. (1999) investigated TOT incidence, TOT resolution time, and resolution following an orthographic cue in young adults, young-old adults (ages 60-74), and old-old adults (ages 80-92). They found that the old-old adults had more TOTs, longer times to resolve TOTs, and less facilitation from orthographic cues than did the young-old adults.

In prior research on TOTs, TDH has not been used to explain differential patterns of age-related decline between young-old and old-old adults. However, because TDH predicts a decrease in connection strength with increasing age, it can be argued that this weakening progresses throughout old age, resulting in the weakest connections for the oldest adults. Fortunately, TDH provides a mechanism by which weakened connections can be strengthened: Repeated activation of the phonological and lexical nodes strengthens connections and should

offset age-related transmission deficits. Independent of age, activating a word frequently or recently will strengthen the connections between the phonological nodes. Correspondingly, words that are not activated frequently are more susceptible to TOTS (e.g., Harley & Bown, 1998). In addition, recent presentation of a word decreases the likelihood of later having a TOT for that word (Rastle & Burke, 1996).

TDH also makes predictions regarding the accessibility of an alternate word when in a TOT state. A persistent alternate (Burke et al., 1991; Jones, 1989; Reason & Lucas, 1984) is a word that involuntarily comes to mind during a TOT state and is not the one intended for retrieval. TDH predicts that older adults will be less likely to have a persistent alternate word when they are in a TOT state because their weaker connections make activation of any word difficult, even the wrong one. This prediction has been supported in the literature (e.g., Burke et al., 1991; Cohen & Faulkner, 1986; Heine et al., 1999).

The role of phonology in causing TOTs and in retrieving persistent alternates suggests that activation of phonological information is critical for word retrieval to occur; therefore, recent presentation of phonological information should influence the probability of resolving TOTs, i.e., retrieving the missing word. Studies on resolving TOTs have shown that cues that share phonology with the target word increase TOT resolution: Word retrieval is more likely to occur if words or letters that share phonology with the target word are presented during a TOT state (e.g., Kozlowski, 1977; Heine et al., 1999; Meyer & Bock, 1992; Perfect & Hanley, 1992). However, these studies used a cueing paradigm, where participants were aware that the cue might be related to the target word. Therefore, the increase in target word retrieval in these studies may reflect strategic, conscious retrieval processes used by participants to help recall the target word (see James & Burke, 2000, for further discussion of cueing). This issue is especially

relevant to old age because older adults generally are less able to utilize conscious recollection strategies (e.g., Light & LaVoie, 1993), which contribute to age-related declines on many explicit memory tests.

To minimize the role of conscious strategies, James and Burke (2000) examined the effects of phonological priming on TOT resolution by presenting young and older adult participants with words that cumulatively contained all of the syllables of the target word. For example, if participants had a TOT for the target word *abdicate*, they read aloud primes that included the following words: abstract, indigent, truncate, tradition, and locate. Use of a pronunciation difficulty rating task to present the words kept participants unaware of the relationship between the primes and the target word. Their results indicated that, when primed after experiencing a TOT, young and older adults equivalently resolved more TOTs after pronouncing a phonologically related list than after pronouncing a list of unrelated words. James and Burke concluded that phonological priming offsets weakened phonological connections that cause TOTs, increasing the likelihood of node activation and thus increasing word retrieval in both young and older adults.

Independent of age, Abrams and White (2001; Experiment 2) used a TOT priming paradigm with young adults to investigate if word retrieval could be facilitated by exposure to a single syllable of the target word, rather than the entire phonology as in James and Burke (2000). College students pronounced aloud or read silently primes that contained *only* the first, middle, or last syllable of the target word. The results showed that first-syllable primes increased TOT resolution relative to a list of unrelated words; in contrast, middle-syllable and last-syllable primes had no impact on word retrieval. Therefore, the first syllable seems to be a critical determinant in that its activation is essential for word retrieval to occur during a TOT state.

The present experiment expanded on the findings of Abrams and White (2001) by examining if there are age-related differences in phonological priming of specific syllables during TOT states. Age-invariant priming effects can only occur if a single syllable is sufficient phonological information to enable elderly adults to activate the phonological nodes for word retrieval. We predicted that young-old adults in the present study would show phonological priming from first-syllable primes: Priming the connections to the first syllable of the target word enabled word retrieval in young adults (Abrams & White, 2001), who have shown phonological priming effects during TOT states similar to older adults (James & Burke, 2000). In contrast, the old-old age group is expected to exhibit reduced phonological priming relative to the young-old age group, due to greater transmission deficits in priming across existing connections.

The finding that young adults in Abrams and White (2001) could not benefit from middle- and last-syllable primes to facilitate word retrieval was predicted by NST, which states that there is a sequential order of activation that must occur for successful word retrieval, i.e., the first syllable of the word must get activated first. Even if the middle or last syllable is primed, these syllables will not facilitate word retrieval unless the first syllable is already activated. Therefore, it is unlikely that either group of older adults will exhibit priming from middle- and last-syllable primes, especially with their age-related transmission deficits.

Method

Participants. Participants included 60 young (who were tested in Abrams & White, 2001, under identical conditions; 18-26 years, M=20.29, SD=1.58), and 80 older adults. The older adults were divided into two groups based on the overall mean age (M=72.0), yielding 40 young-old (60-72 years, M=66.73, SD=3.64), and 40 old-old (73-83 years, M=77.28, SD=3.34) adults. Young adults were recruited from introductory psychology and cognitive psychology classes at

the University of Florida and received course credit or extra credit for their participation in the experiment. Older adults were randomly selected from the Cognition and Aging Laboratory Participant Pool at the University of Florida and were paid $8 an hour for their participation. Participants in this pool were recruited from local organizations in the Gainesville area and from the University of Florida Alumni Association. All participants were asked to complete a questionnaire assessing their age, ethnicity, years of education, vision, hearing, and health. They also completed the Nelson-Denny Vocabulary Test (J. I. Brown, 1960), and a forward and backward digit span test. Older adults completed the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1989), a standard mental status exam used to measure a person's basic cognitive skills.

The means and standard deviations for the young, young-old, and old-old adults' background characteristics can be seen in Table 1. One-way ANOVAs revealed significant differences on education, $F(2, 134) = 27.48$, $MSE = 5.38$, $p < .001$ and Nelson-Denny vocabulary scores, $F(2, 132) = 69.29$, $MSE = 7.90$, $p < .001$. Bonferroni tests revealed that both groups of older adults had significantly more years of education ($ps < .001$) and higher scores on the Nelson-Denny vocabulary test ($ps < .001$) than young adults, with no differences between the two groups of older adults ($ps > .152$). The three age groups did not differ on self-reported ratings of health ($p > .25$), forward digit spans ($p > . 09$), or backward digit spans ($p > .62$). Young-old and old-old adults did not differ on MMSE scores ($p > .24$).

Materials. Five types of materials were used in the experiment: (1) general knowledge questions that corresponded to the target words, (2) three phonologically related word lists and one unrelated word list per target word, (3) three prime words per syllable of each target word, (4) a recognition test that was given after all general knowledge questions were presented, and (5) a

post-experiment questionnaire that was given at the completion of the experiment.

Ninety general knowledge questions were used to induce TOT states. Sixty of the target words and questions were taken from those generated by past researchers (Burke et al, 1991; Jones, 1989; Kohn et al., 1987; Meyer & Bock, 1992) but did not include proper names. The remaining thirty target words were taken from Nelson and Narens (1980) and Francis and Kucera (1982) word norms and were low-frequency words (less than 10 in one million). Definitions for the remaining words were found in Webster's New World College Dictionary (Neufeldt & Guralnik, 1997). Only words with three or four syllables were used as target words; at least three syllables were necessary in order to assess the effect of a middle syllable on TOT resolution. Fifty-two words contained three syllables and 38 words contained four syllables.

For each target word, a primed list containing three phonologically related words (primes) and seven unrelated words (fillers) was generated, as was an unprimed list containing ten unrelated words (see Appendix). In the related list, the three primes were phonologically related to only one syllable, either the first, middle, or last syllable of the target word. Phonological spellings for the target words and their corresponding primes were taken from Webster's New World College Dictionary (Neufeldt & Guralnik, 1997) in order to match the target and prime word phonologically. The distribution of consonant and vowel clusters (e.g., CVC, CV/CCV, V/VC) in each syllable position was similar across all target words. All unrelated words served as filler items and were phonologically and semantically dissimilar to the target. Words in both the related and unrelated lists varied in number of syllables such that each list contained words ranging between one and five syllables. The primes were positioned in the list so that no two primes appeared consecutively; primes were placed in positions one, four, and eight, positions two, five, and nine, or positions three, six, and ten.

The choice of which syllable to prime was determined randomly by the computer program so that each syllable (first, middle, last, unrelated) had equal probability of being primed. However, the computer program ensured that once one syllable had been primed (e.g., a list priming the first syllable was presented), that syllable would not be primed again until all other syllables (e.g., the lists priming middle and last syllables and the unrelated list) had appeared once. Hence, if participants reported having only four TOTs, they would be given one list priming the first syllable, one priming the middle, one priming the last, and one unrelated, in a random order. These precautions were taken to ensure equal probability that any syllable might be primed on any given occasion and to minimize the likelihood of intentionally using the primes as cues. For example, the repetition of the first syllable in first-syllable primes might have been noticeable to participants, but first-syllable primes would not occur on consecutive TOTs and therefore could not be used as a retrieval strategy on a regular basis.

To prime the middle syllables of four-syllable words, we combined the two middle syllables of the four-syllable words into one priming condition. That is, each four-syllable word received either one prime for the first middle syllable and two primes for the second middle syllable, or two primes for the first middle syllable and one prime for the second middle syllable. For example, the word *calibration* might be assigned one prime for the /i/ syllable, and two primes for the /bra/ syllable.

Of the 90 target words, 15 were considered fillers because they were always primed for only one of the three syllables across all participants. Due to the unique phonology in some of the syllables of these 15 words (e.g., /nome/ in *metronome*), it was impossible to find three primes for each syllable, and therefore we only primed one of their syllables. Five targets were always primed with first syllable words, five were always primed with middle syllable words,

and five were always primed with last syllable words. These stimuli were included in the target list because other studies have shown them to elicit high numbers of TOTs, which would help participants to better identify when they were in a TOT state; however, they were not included in any of the statistical analyses.

A recognition test was constructed in order to confirm the validity of TOT responses. Any question that was not resolved during the experiment was given in the recognition test. It was assumed that if participants were truly experiencing a TOT, they should have been able to recognize the answer as the word they were thinking of when given a choice. Each general knowledge question was assigned four possible answers in the test: the correct (target) answer (e.g., abdicate), a word that was semantically related to the target (e.g., relinquish), a word that was phonologically related to the target (e.g., abrogate), and a word that was semantically and phonologically unrelated to the target (e.g., presume). The answers were counterbalanced so that the target (correct) word appeared equally often as answer choice (a), (b), (c), and (d).

A post-experiment questionnaire was verbally given to the participants in order to assess any awareness of the priming manipulation as well as participants' intention to use the primes as cues to facilitate retrieval. The awareness questions asked participants if they noticed any relationship between the reading words task and the general knowledge questions, and if so, to describe that relationship. The intentionality questions asked participants if they intentionally used the reading words to try to generate answers to the general knowledge questions; if so, follow-up questions asked for a specific example, the point at which participants realized the relationship and the factors that caused this realization, and whether this strategy was used for later questions.

Apparatus. The experiment was performed on Pentium II, 350 MHz, IBM compatible computers.

The program was generated using the Visual Basic programming language.

Procedure. Participants were given the background characteristics questionnaire, the Nelson-Denny vocabulary test, the digit-span tests, and if they were older adults, the MMSE. They then read written instructions as to what to expect during the experiment. Participants were also given a verbal explanation of the TOT phenomenon: “You experience a TOT every time you are unable to retrieve a word that you are certain you know. When experiencing a TOT, you know the word’s definition, you know how you want to use it in a sentence, and sometimes you can say what letter it starts with or what it sounds like (i.e., the word is on the ‘tip of your tongue’). Sometimes you are able to produce the word’s synonym, but the EXACT word just won't come to mind at that moment.”

After presentation of each general knowledge question, participants were asked to make a choice as to whether they knew the answer, did not know, or were in a TOT state. If they did not know the answer or were in a TOT state, they were asked to either read silently or to pronounce aloud a list of ten words that contained either three primes and seven unrelated words, or all unrelated words. Each word appeared on the screen for 2.5 seconds. The participants either read aloud or silently for the first half of the experiment, then switched to the alternative task for the second half of the experiment. This manipulation was relevant to the role of production in TOT retrieval, which was outside the scope of this paper and was not analyzed here, namely because both aloud and silent production facilitated TOT resolution (Abrams & White, 2001). Participants were not told that these words could be related to the TOT task. After completion of the reading task, participants were given the question again and asked if they knew the answer. If they knew it, they responded and proceeded to the next question. If they still did not know or were in a TOT state, they were instructed to say whether or not any alternate word kept coming

to mind. That is, they were instructed to provide any word they thought of, which they knew was not the correct answer, but which they could not get out of their mind. If they had no persistent alternate, or after they provided one, they proceeded to the next question.

If the participants knew the answer after reading the question, they stated the word aloud. After responding "know," participants received a subset of the unrelated list, with either four or six words to pronounce or read silently. This manipulation was included in order to reduce the likelihood that participants would deduce that the words they read while in a TOT state were related to the target word, since they would read words on every trial, regardless of their response. After all 90 questions had been attempted, they were given the recognition test for those words to which they continually responded "don't know" or "TOT." The recognition test provided them with each question followed by four choices from which to choose the correct answer.

An experimenter assisted each participant through the experiment and typed all responses into the computer. This measure was taken in order to control for any difference in old and young adult performance that might be due to lack of experience with a computer and to control the time course of all responses. All responses made by the participants were tape-recorded, and all questionable responses were double-checked for accuracy. After the experiment was completed, participants were verbally given the post-experiment questionnaire. They were then debriefed and thanked for their participation.

Results

Awareness and Intent

Before measuring priming, responses on the post-experiment questionnaire were categorized to assess awareness of the priming manipulation and intent to use the primes as cues

to facilitate retrieval. This assessment was conducted first in order to eliminate potential participants who intentionally used the primes to help word retrieval. Participants were categorized as "aware" if they reported noticing a relationship between the primes and the targets and could accurately describe the relationship as one where the primes shared phonology (e.g., shared part of word or similar sound) with the target word. Intent was categorized as successful when participants accurately described a relationship between the primes and the TOT target word, and they reported an ability to use this relationship to facilitate word retrieval on at least one occasion (there was no way to discern the number of times that participants successfully used a strategy to resolve TOTs).

The responses were categorized into three types of awareness and four types of intent, and the percentages of participants that fell into each category are shown in Table 2. One young adult and one old-old adult were excluded for not having completed the post-experiment questionnaire. A chi-square test of independence with Age and Awareness as factors was significant, $\chi^2(4) = 18.96$, $p < .001$. Follow-up chi-square tests indicated differential patterns of awareness between young and young-old adults ($p < .032$) and between young and old-old adults ($p < .001$), where the two older adult groups were more often unaware of a relationship between the primes and target words. Furthermore, young adults demonstrated greater specificity in describing the relationship by stating that the "initial or first part of word" was present in the primes, whereas young-old or old-old adults most often described the relationship more vaguely as "sharing sound or some portion of word".

With respect to intentional attempts to use primes, a chi-square test of independence with Age and Intent as factors was significant, $\chi^2(6) = 18.21$, $p < .006$. Follow-up chi-square tests revealed differences in the pattern of intent between young and young-old adults ($p < .047$) and

between young and old-old adults ($p < .002$). Generally, most participants did not report making an attempt to intentionally use the primes; however, when an attempt was made, it was more often made by young adults, who were generally unsuccessful in their attempts (i.e., trying to use the primes to aid retrieval but were unable to do so). Nonetheless, in order to ensure the implicit nature of our priming task for all age groups, we excluded from all subsequent analyses those participants who *intentionally and successfully* used the primes to facilitate retrieval, i.e., 8 young adults and 3 young-old adults.[1]

Priming

Means and standard deviations for the percentage of correct resolution following each syllable priming condition were computed for "don't know" responses and "TOT" responses (see Table 3). A 3 (Age: Young, Young-old, Old-old) x 4 (Syllable: First, Middle, Last, Unrelated) x 2 (Initial Response: Don't Know, TOT) ANOVA was performed on percentage of correct word retrieval. This analysis was performed by participants only because an item analysis eliminated 100% of the stimuli due to missing responses in at least one of the syllable conditions. Seventeen young, 21 young-old, and 21 old-old adults (46% total) were excluded from participant analyses for not having at least one TOT or Don't Know in each of the four syllable conditions. The Age x Syllable x Initial Response interaction was significant, $F(6, 195) = 2.47$, $MSE = .07$, $p < .025$. Further investigation of this interaction revealed a significant Age x Syllable interaction for "TOT" responses, $F(6, 195) = 2.88$, $MSE = .10$, $p < .01$, but not for "don't know" responses, $F(6, 195) = 1.38$, $MSE = .04$, $p > .226$. The syllable main effect for "don't know" responses was also nonsignificant ($p > .888$), suggesting that there was no difference in word retrieval following the three syllable conditions compared to the unrelated condition.

To further explore the Age x Syllable interaction for "TOT" responses, a 3 (Age) x 4 (Syllable) ANOVA[2] was performed on the percentage of correct resolution following TOT responses; eliminating "don't know" responses from the design allowed 16 additional participants to be included in analysis. This analysis revealed no main effect of Age, $F < 1$, but yielded a significant main effect of Syllable, $F(3, 246) = 8.50$, $MSE = .11$, $p < .001$, and a significant Age x Syllable interaction, $F(6, 246) = 2.12$, $MSE = .11$, $p < .05$. A planned comparison of the three age groups on percentage of resolution in the unrelated condition showed that the three age groups did not differ in their baseline TOT resolution ($p > .344$). To examine priming effects, planned comparisons were made between each primed syllable (first, middle, last) and the unrelated condition for each age group. For young adults, these comparisons indicated a significant priming effect (i.e., difference between syllable and unrelated) for first-syllable primes ($p < .004$), with no priming for middle syllable ($p > .269$) or last syllable ($p > .744$). For young-old adults, these comparisons indicated a priming effect for first-syllable primes, ($p < .004$), but no priming effects for the middle ($p > .326$) or last syllable primes ($p > .354$). For old-old adults, there were no significant priming effects for first syllable ($p > .311$), middle syllable ($p > .097$), or last-syllable primes ($p > .170$).[3] A planned comparison on first-syllable priming showed that young and young-old adults exhibited similar amounts of first-syllable priming, $F < 1$.

Initial Responses to the Questions

Percentage of initial responses to general knowledge questions (for participants included in the priming analyses) are presented in Table 4. A response was considered correct only if participants provided either a correct answer to the question following a "know" response, or a correct response on the recognition test following a "TOT" response. Excluding incorrect

responses, a 3 (Age) x 3 (Response: correct "know," correct "TOT," and "don't know") ANOVA was performed on the proportion of initial responses using both participants (F1) and items (F2) as the units of analyses. Significant main effects of Age, F1(2, 82) = 8.24, MSE = .01, p < .001, F2(2, 148) = 17.72, MSE = .01, p < .001, and Response, F1(2, 164) = 43.85, MSE = .02, p < .001, F2(2, 148) = 21.86, MSE = .10, p < .001, were found, but were moderated by a significant Age x Response interaction, F1(4, 164) = 7.69, MSE = .02, p < .001, F2(4, 296) = 19.26, MSE = .02, p < .001. Further analysis of the interaction showed significant age differences for the correct "know" responses, F1(2, 82) = 4.24, MSE = .02, p < .018, F2(2, 148) = 9.30, MSE = .02, p < .001, and for the "don't know" responses, F1(2, 82) = 13.48, MSE = .02, p < .001, F2(2, 148) = 40.75, MSE = .01, p < .001. Specifically, young adults made fewer correct "know" responses than either young-old adults (ps < .026) or old-old adults (ps < .012), who did not differ (ps > .669). In contrast, young adults made significantly more "don't know" responses than both young-old adults (ps < .001) and old-old adults (ps < .001), who did not differ (ps > .307).

Age differences for correct "TOT" responses in terms of absolute number of TOTs were significant only in the item analysis, F1(2, 82) = 2.14, MSE = .01, p > .125, F2(2, 148) = 4.72, MSE = .01, p < .01, such that young adults had more TOTs than old-old adults (p < .01) and marginally more TOTs than young-old adults (p < .06). However, other studies (A. S. Brown & Nix, 1996; Burke et al., 1991; James & Burke, 2000) have used a proportional analysis to take into account elderly adults' greater number of "know" responses, which reduces their opportunities for TOTs. In these proportional analyses, TOTs are calculated as a proportion of unsuccessful retrievals, where participants are either unable to retrieve a word or recall an incorrect word. We modified this analysis slightly to define an unsuccessful retrieval as one where no word was retrieved; TOTs were therefore calculated as the proportion of correct TOT,

incorrect TOT, and Don't Know responses (all Know responses, correct and incorrect, were excluded, since older adults had a greater number of both types of Know responses). A one-way ANOVA with Age was performed on the percentage of correct TOTs as a function of unsuccessful retrievals and revealed a significant effect of Age, $F1(2, 82) = 5.59$, $MSE=.02$, $p < .005$, $F2(2, 148) = 3.57$, $MSE = .03$, $p < .031$. Young adults had proportionally fewer TOTs than either old-old adults ($p1 < .008$, $p2 < .063$) or young-old adults ($p1 < .061$, $p2 < .019$), with no difference between young-old and old-old adults ($p1 > .999$, $p2 > .588$).

Persistent Alternates

A one-way ANOVA on percentage of TOTs for which a persistent alternate word occurred revealed a marginally significant Age effect in the item analysis only, although the trend was the same in both analyses, $F1(2, 83) = 1.31$, $MSE = .097$, $p > .276$, $F2(2, 106) = 2.99$, $MSE = .13$, $p < .055$. Bonferroni tests on the item analysis showed that old-old adults ($M1 = 39.1\%$, $M2 = 32.1\%$) had fewer persistent alternate words during a TOT state than young adults ($M1 = 49.4\%$, $M2 = 46.8\%$, $p < .016$) and marginally fewer alternates than young-old adults ($M1 = 52.6\%$, $M2 = 47.4\%$, $p < .074$), with no difference in number of reported alternates between young and young-old adults ($p > .935$).

Discussion

This study tested the effect of phonological priming of specific syllables on TOT resolution in old age. Both young (aged 18 to 26) and young-old adults (aged 60 to 72) experienced an increase in TOT resolution when given first-syllable primes, whereas old-old adults (aged 73 to 83) did not exhibit any priming. The young-old adults' results are consistent with Abrams and White (2001), who showed that the first syllable was more critical for resolving TOTs in young adults than the other syllables. Similar to James and Burke's (2000) findings of

age-invariant phonological priming, young-old adults in our study showed the same amount of first-syllable priming as young adults, suggesting that there is no age-related decline (for young-old adults) in the ability to implicitly utilize first-syllable information when in a TOT state.

These results are consistent with TDH and demonstrate that young-old adults (as well as young adults) can overcome their transmission deficits and activate a word's phonological nodes when primed with only a single syllable. James and Burke (2000) found that older adults were able to overcome their transmission deficits when primed with complete word phonology. Their results suggested that priming all syllables of a target word was sufficient to activate all of the phonological nodes for a target word. However, the present study suggests that providing *all* of the phonology is not necessary; the initial syllable can be sufficient to overcome the transmission deficits in priming that accompany normal aging during a TOT state. The transmission deficits that precipitate TOTs are comparable in severity for young and young-old adults, except that young-old adults simply suffer more transmission deficits, yielding more frequent TOTs in everyday life.

In contrast to the young-old adults, old-old adults exhibited no significant priming in TOT resolution. With respect to TDH, these results suggest that the transmission deficits across old-old adults' connections were greater, making them less able to resolve TOTs even when presented with first-syllable primes. Because James and Burke (2000) did not include a separate age group of old-old adults (their older group mean age was 71.8 in Experiment 2), it is impossible to determine whether presenting the entire phonology of a word will lead to resolution in this age group. Our research, along with similar research on TOTs in two elderly groups by Heine et al. (1999), indicates the need to document the severity of transmission deficits among different age groups.[4]

Although Heine et al.'s (1999) old-old adults did not show as much orthographic facilitation as their young-old adults, they still showed increased resolution following orthographic cues compared to semantic cues. This finding suggests a qualitative difference in the priming versus cueing techniques. That is, it appears that adults of all ages are able to benefit from an explicit retrieval search induced by phonologically or orthographically related cues in the TOT paradigm, contrary to other findings of less efficacy in old age when using conscious recollection (e.g., Howard, 1988; Hultsch & Dixon, 1990; Titov & Knight, 1997). However, when these conscious strategies are eliminated in TOT retrieval, old-old adults do not benefit from presentation of phonological primes to the same extent as young-old adults.

Other issues that are important to this TOT research include (1) differences in the types of initial responses and in the number of persistent alternates made by the different age groups, and (2) evidence that our paradigm manipulated priming and not explicit cueing. Young adults reported significantly fewer correct "know" responses and significantly more "don't know" responses than young-old and old-old adults. The difference in the "know" and "don't know" responses is not surprising, as many of the target words were infrequently used words. Older adults have had a lifetime to accumulate a large vocabulary, as evidenced by their superior performance on the Nelson-Denny Vocabulary test, and naturally know more words than young adults.

There were also age differences in the proportion of TOTs such that young-old and old-old adults had a greater proportion of TOTs relative to other unsuccessful retrievals than did young adults. This result is consistent with research on both naturally occurring and laboratory-induced TOTs (A. S. Brown & Nix, 1996; Burke et al., 1991; Heine et al., 1999; James & Burke, 2000) and can be attributed to older adults' weaker connections between the lexical and

phonological nodes for a word (see Burke et al., 1991). The age difference in absolute number of TOTs is understandable, given that both groups of older adults had more “know” responses and fewer “don’t know” responses, suggesting that they had greater knowledge of the particular words used than young adults and therefore had less opportunity to have TOTs on these stimuli. Furthermore, our stimuli did not include proper names for target words, which are the most likely words to induce TOTs in older adults (e.g., Burke et al., 1991; Cohen & Faulkner, 1986).

Consistent with Heine et al. (1999), our results indicated that young and young-old adults were more likely to report an alternate word when in a TOT state than old-old adults, which supports TDH’s assumption that elderly adults' transmission deficits make it difficult to activate phonological information about the target word. Furthermore, young and young-old adults did not differ in number of persistent alternates, reinforcing the conclusion that the transmission deficits of old-old adults fundamentally differ from those of young-old adults.

With respect to the effectiveness of the priming measure as implicit, there were several indicators that the participants were not using the primes as cues. First, we excluded participants from analysis who acknowledged making attempts to use the primes explicitly to facilitate retrieval. Second, word retrieval was facilitated for both young and young-old adults only when participants reported being in a TOT state; no priming effect was found when participants responded “don’t know” to a question. This result, consistent with James and Burke (2000), suggests that participants did not use explicit, conscious attempts to link the primes to a known word, or there would have been an increase in resolution after responding “don't know”.

Third, the post-experiment questionnaire to determine each participant’s awareness of the primes and intent to use the primes revealed that young adults were more aware of a relationship between the prime words and the TOT questions than both young-old and old-old adults. The

finding that young adults were more aware of the relationship is not surprising; young adults are often more aware of relationships on implicit tasks, which frequently results in an intention to use the relationship, making an implicit task into an explicit one (Bowers & Schacter, 1990; Neill, Beck, Bottalico, & Mollory, 1990; Rybash & Osborn, 1991). However, even though the young adults exhibited greater awareness than young-old adults of the relationship between the primes and the targets and could more specifically describe the relationship in terms of the initial portion of the target word, they did not differ from young-old adults in the amount of resolution following first-syllable primes. If young adults had been able to use their greater awareness to facilitate word retrieval, we would expect them to demonstrate a higher proportion of resolution than young-old adults, who were less aware of the existing relationship.

In conclusion, phonological priming appears to have differential effects on young, young-old, and old-old adults' word retrieval. This finding has implications for the structure of our semantic and phonological systems. NST and TDH (MacKay, 1987; MacKay & Burke, 1990) assert that the connections between nodes in the semantic and phonological systems weaken with increasing age. Our results extend this hypothesis by illustrating breakdowns among specific connections within the phonological system when in a TOT state (i.e., middle and last syllables are less effective in facilitating retrieval) and by demonstrating greater transmission deficits in old-old adults who were unable to benefit from priming even to first-syllable nodes. These results emphasize the importance of determining at which point transmission deficits begin to occur, on which connections the transmission deficits have their largest effect, and if the deficits can be reversed or nullified through recent and frequent activation of nodes.

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Appendix

Example General Knowledge Question, Target Word, Primes, and Filler Words

		Related Syllable Primes			Fillers
Question	Target Word	First	Middle	Last	Unrelated Words
What word means to formally renounce the throne?	abdicate	tappet	tappet	tappet	tappet
		aberrant	indigent	educate	reread
		velvet	velvet	velvet	velvet
		menu	menu	menu	menu
		abacus	handicap	duplicate	vector
		dandelion	dandelion	dandelion	dandelion
		infant	infant	infant	infant
		survivor	survivor	survivor	survivor
		abdomen	tradition	fabricate	jump
		catchy	catchy	catchy	catchy

Note: Relevant portions of prime words are underlined, and filler words are printed normally.

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Footnotes

1. We specifically excluded participants from analysis on the basis of intent to use the primes, rather than awareness. In traditional repetition priming paradigms, awareness of the relationship between the primes and the to-be-retrieved words is critical because awareness often leads to successful intent, i.e., conscious attempts to recall the previously studied words. In our phonological priming paradigm, awareness did not lead to successful retrieval, and we have several sources of evidence to support this claim. First, post-hoc comments of participants who were aware of a relation between the primes and the TOT word suggest difficulty in using this relationship (e.g., “looking for relationships was not generally useful on most items”, or “the strategy did not help on remaining items”). Second, the majority of participants reported noticing the relationship after retrieving the word rather than before. Third, participants were primed for a specific position on only one out of four TOT trials, making it difficult to develop a strategy that consistently worked (e.g., searching for multiple words with the same first syllable). Furthermore, McKone and Slee's (1997) study on the priming of new associations also supports our decision to exclude participants on the basis of intent: They argue that “it is not mere awareness of the study list that leads to priming of new associations, but rather the subject's deliberate use of recall after becoming aware.” (p. 359).

2. The means and standard deviations in Table 3 for correct resolution following TOT responses come from this analysis.

3. Although the middle-syllable condition was somewhat different for three- versus four-syllable words (the latter had two middle syllables that were primed separately), an ANOVA excluding four-syllable words still revealed no middle-syllable priming, suggesting that the uniqueness of four-syllable words was not responsible for the lack of priming.

4. An anonymous reviewer noted that although differences in phonological priming were observed between young-old and old-old adults, there were no differences between these age groups in vocabulary scores, digit spans, or MMSE scores. NST and TDH explain these differential patterns of age deficits as a function of multiple- versus single-source connections: Tasks that utilize multiple connections converging on a single node can offset age-related declines in the transmission of priming. For example, age deficits in vocabulary are less likely because older adults are able to use their lifetime of semantic connections to a particular word, allowing priming from multiple semantic connections to converge on a lexical node and achieve activation. In contrast, phonological priming of TOT resolution requires strengthening of the connections between phonological and lexical nodes, which are single, one-to-one connections and are therefore most likely to be susceptible to age-related declines, particularly for old-old adults (see Burke & MacKay, 1997 for a detailed explanation of the effects of aging on multiple- and single-source connections).

Table 1

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

	Group								
	Young Adults[a]			Young-old Adults			Old-old Adults		
Variable	N	Mean	SD	N	Mean	SD	N	Mean	SD
Education (years)*	59	14.52	1.08	38	17.89	3.26	40	16.90	2.58
Vocabulary* (max = 25)	60	15.35	2.89	39	20.38	2.42	36	21.67	3.05
Forward Digit	60	7.67	1.07	40	7.10	1.43	39	7.33	1.38
Backward Digit	60	5.35	1.33	40	5.25	1.41	39	5.08	1.38
Health	59	7.83	1.42	40	8.25	1.33	40	7.76	1.59
MMSE (max = 30)				39	28.64	1.04	40	28.13	1.56

Note. Asterisks indicate significant differences between the three age groups, $p < .05$. Participants who were missing data from particular characteristics were excluded from that analysis.

[a] The young adult participants for these comparisons were taken from Abrams and White (2001), Experiment 2.

Table 2

Percentage of Participants Categorized into Awareness and Intent Categories Based on Responses to the Post-Experiment Questionnaire

Question	Age Group		
	Young Adults (N = 59)	Young-old Adults (N = 40)	Old-old Adults (N = 38)
Awareness			
Not aware of any relationship between primes and target word	39.0	65.0	81.6
Reported noticing a relationship but incorrectly described it	23.7	17.5	5.3
Reported noticing a relationship and correctly described it	37.3	17.5	13.1
Intent			
Never attempted to use primes	40.7	67.5	76.3
Attempted to use primes but incorrectly used a nonexistent relationship	13.6	12.5	2.6
Attempted to use primes but were unsuccessful in doing so	32.2	12.5	21.1
Attempted to use primes and were successful in doing so	13.5	7.5	0.0

Table 3

Word Retrieval (in %) Following Primes and Unrelated Words After an Initial "Don't Know" or "TOT" Response

	Age Group					
	Young Adults		Young-old Adults		Old-old Adults	
Initial Response	Mean	SD	Mean	SD	Mean	SD
Priming Condition						
Don't Know	(N = 34)		(N = 16)		(N = 18)	
First Syllable	7.1	14.0	10.6	20.9	20.5	31.6
Middle Syllable	7.7	19.6	19.8	35.1	8.8	17.7
Last Syllable	9.7	15.2	6.1	14.2	15.9	30.0
Unrelated	8.9	16.4	17.6	28.9	13.4	17.4
TOT	(N = 37)		(N = 22)		(N = 26)	
First Syllable	50.4	37.7	55.3	40.3	46.1	39.6
Middle Syllable	32.9	34.2	32.0	30.1	21.2	31.7
Last Syllable	22.6	25.2	31.2	32.7	47.2	36.2
Unrelated	24.9	30.6	22.8	33.2	35.6	38.6

Note: Mean represents the mean percent of trials with correct resolution.

Table 4

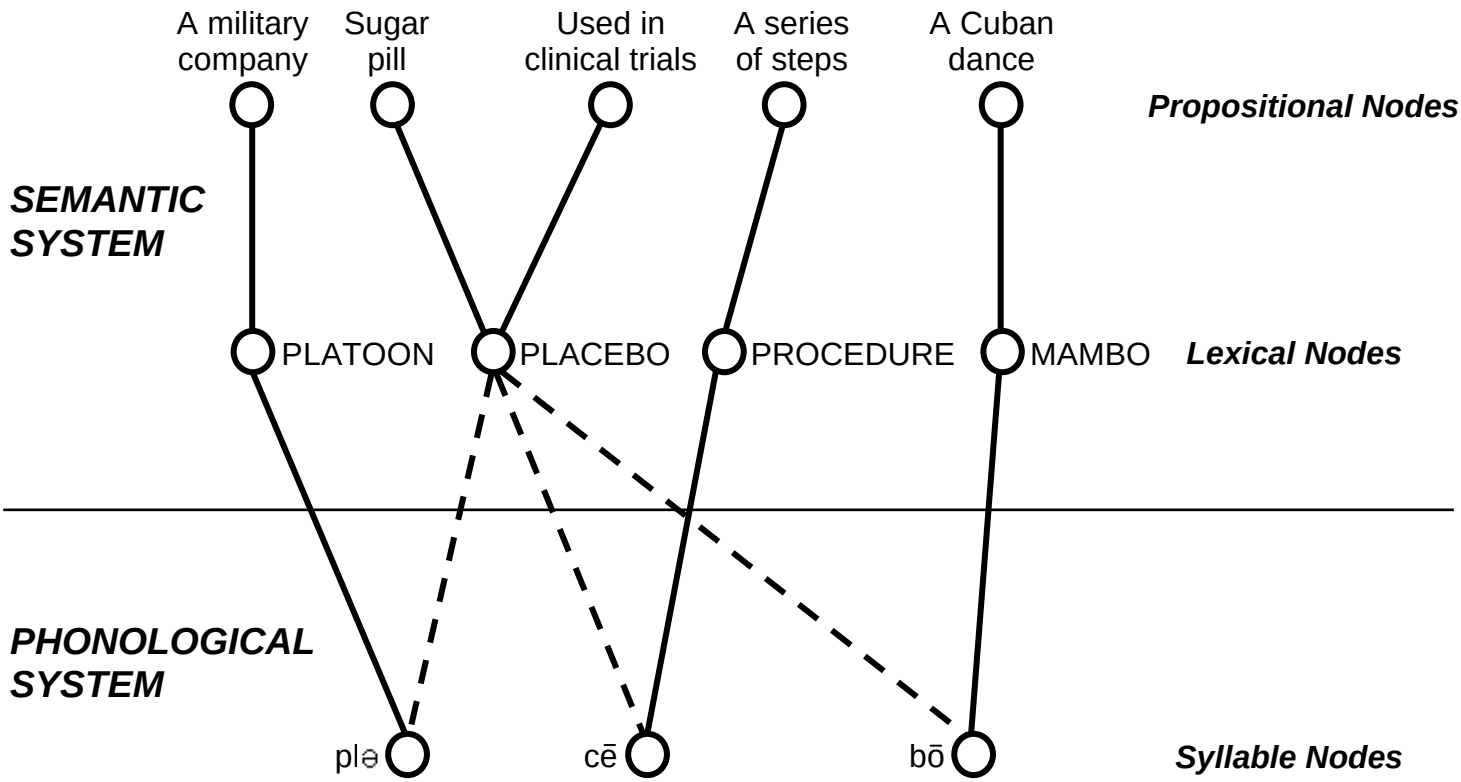
Percentage of Initial Responses to the General Knowledge Questions

Initial Response	Age Group		
	Young Adults (N = 37)	Young-old Adults (N = 22)	Old-old Adults (N = 26)
Know			
Correct	28.2	36.4	37.0
Incorrect	15.5	24.0	26.7
TOT			
Correct	16.6	14.3	13.2
Incorrect	7.3	6.3	5.1
Don't Know	32.4	19.0	18.0
TOT / Unsuccessful Retrievals [a]	29.6	37.9	40.0

[a] TOTs were calculated as a percentage of unsuccessful retrievals of *any* word, i.e., correct TOT, incorrect TOT, and don’t know responses.

Figure Captions

Figure 1. An example of Node Structure Theory's hierarchical network for the word "placebo." Many nodes have been omitted for simplicity.


A military company
Sugar pill
Used in clinical trials
A series of steps
A Cuban dance
Propositional Nodes
SEMANTIC SYSTEM
PLATOON
PLACEBO
PROCEDURE
MAMBO
Lexical Nodes
PHONOLOGICAL SYSTEM
plə
cē
bō
Syllable Nodes