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Asymmetric Aging Effects on Semantic and Phonological Processes: Naming in the Picture–Word Interference Task

Jennifer K. Taylor
Claremont Graduate University

Deborah M. Burke
Pomona College

In 2 experiments, participants named pictures while ignoring auditory word distractors. For pictures with homophone names (e.g., *ball*), distractors semantically related to the nondepicted meaning (e.g., *prom*) facilitated naming by top-down phonological connections for young but not for older adults. Slowing from unrelated distractors and facilitation from phonologically related distractors were age invariant except in distractors that were both semantically and phonologically related. Only distractors semantically related to the picture interfered more for older than younger adults. These results are inconsistent with age-linked deficits in inhibition of irrelevant information from either internal or external sources. Rather, aging affects priming transmission in a connectionist network with asymmetric effects on semantic and phonological connections involved in comprehension and production, respectively.

Research on language and aging has shown that some language functions are well maintained in old age, whereas others show pronounced age-related declines. Access to the meaning of words as reflected in vocabulary scores, for example, is relatively stable during adulthood (Schaie, 1994) as is semantic retrieval during processing of single words or sentences[1] (Burke, 1997; Kemper, 1992; Light, 1992; MacKay & Abrams, 1996; Mayr & Kliegl, 2000; Tun & Wingfield, 1993; Wingfield & Stine-Morrow, 2000). In contrast to these preserved semantic functions, older adults suffer deficits in language production related to phonological or orthographic retrieval, for example, word production failures in speaking (Burke, MacKay, Worthley, & Wade, 1991; Heine, Ober, & Shenaut, 1999) and spelling (MacKay & Abrams, 1998; MacKay, Abrams, & Pedroza, 1999). In this article, we examine aging effects on specific semantic and phonological retrieval processes to better understand this asymmetric aging effect on comprehension and production.

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Jennifer K. Taylor, Department of Psychology, Claremont Graduate University; Deborah M. Burke, Department of Psychology, Pomona College.

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Correspondence concerning this article should be addressed to Jennifer K. Taylor, who is now at the Department of Psychology, University of California, Los Angeles, Hilgard Avenue, Los Angeles, California 90095-1563, or to Deborah Burke, Department of Psychology, Pomona College, 550 Harvard Avenue, Claremont, California 91711. E-mail: jktaylor@psych.ucla.edu or dburke@pomona.edu

We use one of the most popular experimental paradigms for investigating language processes: the picture–word interference task (see, e.g., Cutting & Ferreira, 1999; Damian & Martin, 1999; Levelt, Roelofs, & Meyer, 1999; Peterson & Savoy, 1998; Schriefers, Meyer, & Levelt, 1990; Starreveld & LaHeij, 1996). The mental operations involved in this task are relatively well specified and have been formally modeled (e.g., Roelofs, 1992; Starreveld & La Heij, 1996). In this task, participants are instructed to ignore a distractor word and name an accompanying picture as quickly as possible. By manipulating the semantic and phonological relationship between distractor and picture name, we isolate specific comprehension and production processes and evaluate the impact of aging. We test predictions of the *transmission deficit hypothesis* (MacKay & Burke, 1990) for age-related changes in language; specifically, that aging effects on picture–word interference will be asymmetric, depending on the nature of the relation between the distractor word and picture. Our results are also relevant to an alternative account of aging and language, the *inhibitory deficit hypothesis* (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). This hypothesis states that older adults are less able to inhibit irrelevant information than young adults and, therefore, their language production will be more affected by distractor words.

Asymmetries in Language Processes in Old Age

Excluding sensory declines, there is little evidence for age-related deficits in perceptual processing of either a written or spoken word or in access to its meaning (for reviews, see Burke,

[1] Age-related deficits in comprehension are obtained in conditions in which language is presented in degraded form (e.g., Carlson et al., 1995; Schneider, Daneman, Murphy, & Kwong See, 2000), or language must be retained for correct responding (Light, 1992). These age differences may be attributable to older adults' general decline in sensory processes (e.g., Lindenberger & Baltes, 1994) and decline in memory for new information (MacKay & Burke, 1990), respectively, rather than to a decline in a language process.

MacKay, & James, 2000; Kemper, 1992; Light, 1992; MacKay & Abrams, 1996; Wingfield & Stine-Morrow, 2000). Semantic priming effects, the facilitation of word recognition in a semantically related compared with an unrelated context,[2] are often greater for older than for young adults (Madden, 1988; Pichora-Fuller, Schneider, & Daneman, 1995; Speranza, Daneman, & Schneider, 2000; Wingfield, Alexander, & Cavigelli, 1994), an age difference confirmed in meta-analyses (Laver & Burke, 1993; Myerson, Ferraro, Hale, & Lima, 1992). This age difference is not a consequence of older adults' generally slower word recognition latencies because when latency is constant across age in a response deadline procedure, older adults still produce larger semantic priming effects (Laver, 2000). There is considerable agreement that semantic priming effects reflect activation of semantic information during perceptual processing of a word or phrase, which benefits subsequent processing through a spread of priming along semantic connections to the lexical representations of related words (Neely, 1991). Thus, older adults' larger semantic priming effects suggest that more priming arrives at lexical representations in older than in young adults, perhaps because older adults' more extensive experience with word meaning increases the number of shared features among conceptually similar words (Laver & Burke, 1993).

Older adults do not, however, maintain top-down processes in phonological retrieval in word production. Perhaps the best example of phonological retrieval deficits is the tip-of-the-tongue (TOT) state, in which a person is unable to produce a word despite awareness of its meaning and despite absolute certainty that the word is known (e.g., R. Brown & McNeill, 1966). Older adults report more TOTs than young adults, but less partial phonological information about the target and fewer phonologically related alternate words, which is consistent with reduced access to phonological information (e.g., A. S. Brown & Nix, 1996; Burke et al., 1991; Heine et al., 1999; Maylor, 1990). The locus of the TOT deficit at the phonological level is supported by the finding that TOTs are reduced by prior phonological processing of the target word (Rastle & Burke, 1996) and by processing phonologically related compared with unrelated words (James & Burke, 2000; Meyer & Bock, 1992). Thus, the age-related increase in TOTs is strong evidence for a decline in phonological retrieval in old age.

Models of Language and Aging

The transmission deficit hypothesis explains aging effects on language processes within the framework of node structure theory (NST; MacKay, 1987). Like most connectionist models of language, NST postulates a representational architecture with two distinct levels: a semantic system representing conceptual and lexical information about words, and a phonological system representing the sounds and metrical structure of words (e.g., Burke et al., 1991; Caramazza, 1997; Dell, 1986; Levelt et al., 1999; MacKay, 1987). Under NST, language comprehension and production depend on how fast and how much priming can be transmitted across connections linking representational units called "nodes." Priming is a form of excitation that prepares a node for activation, the basis for retrieval of the information represented by the node. Language production begins with the activation of semantic representations that send priming throughout the network, preparing semantically appropriate lexical representations for activation. Frequent activation of nodes strengthens connections, increasing priming transmission, whereas aging weakens connections, reducing priming. Thus, weakened connection strength caused by disuse or aging produces transmission deficits that can impair activation, resulting in retrieval failure (Burke et al., 1991; James & Burke, 2000; MacKay, 1987; MacKay & Abrams, 1998; MacKay & Burke, 1990).

Why are age-related retrieval failures found for phonological but not for semantic information? The architecture of NST renders the phonological system more vulnerable to transmission deficits than the semantic system. Figure 1 shows some of the semantic, lexical, and phonological representations for the homophone *ball*. In comprehension, perceptual processing of a spoken word activates phonological nodes that transmit priming bottom-up, summating at a lexical node. When priming is bottom-up, transmission deficits at the lexical level are less likely because priming converges from many phonological nodes on to a lexical node. Activation of the lexical node transmits priming within the semantic system, which is aided by the many connections that link related concepts (Laver & Burke, 1993). The interconnected nature of semantic representations will offset a transmission deficit in any one connection within the semantic system. For example, if there is a weakened connection between the lexical node for *ball 1* in Figure 1 and the semantic proposition that balls can be held *at high schools*, this semantic information (*ball at high schools*) will still receive priming via connections from *ball 1* to the propositions that *teenagers attend balls* and *teenagers attend high schools*. In contrast, in production, priming proceeds top-down (i.e., driven by conceptual activation) from the semantic system to relevant lexical nodes; priming then diverges from lexical nodes along single connections to associated phonological nodes.[3] Because each phonological node must receive sufficient priming from its single top-down connection to be activated, a transmission deficit in only one connection will prevent retrieval of the phonology represented by that node. Unlike the semantic system, phonological nodes are not interconnected to each other, except via other lexical nodes whose phonology requires these identical nodes (Burke et al., 1991; MacKay & Burke, 1990).

The transmission deficit hypothesis predicts an age-related deficit in a specific pathway necessary for production, namely top-down priming of phonological information, and predicts no age-related deficit in bottom-up phonological priming or in semantic priming. The picture–word interference task allows us to isolate these pathways and loci of priming to test these predictions. First, priming in the semantic system underlies the semantic interference effect: A picture (e.g., *frog*) is named more slowly when accompanied by a semantically related distractor word that is a competitor (e.g., *turtle*) compared with an unrelated distractor (e.g.,

[2] In current psychological literature, *priming* has several different meanings. We use *priming effect* to refer to a behavioral change in which target information is more available as a result of processing related information. We use *priming* to refer to the theoretical mechanism of subthreshold excitation that prepares a representation in memory for activation or retrieval (MacKay, 1987). This type of priming is similar to the mechanism of spreading activation in some memory models.

[3] In the model, a special activating mechanism determines the order of retrieval of the phonemes (see MacKay, 1987).

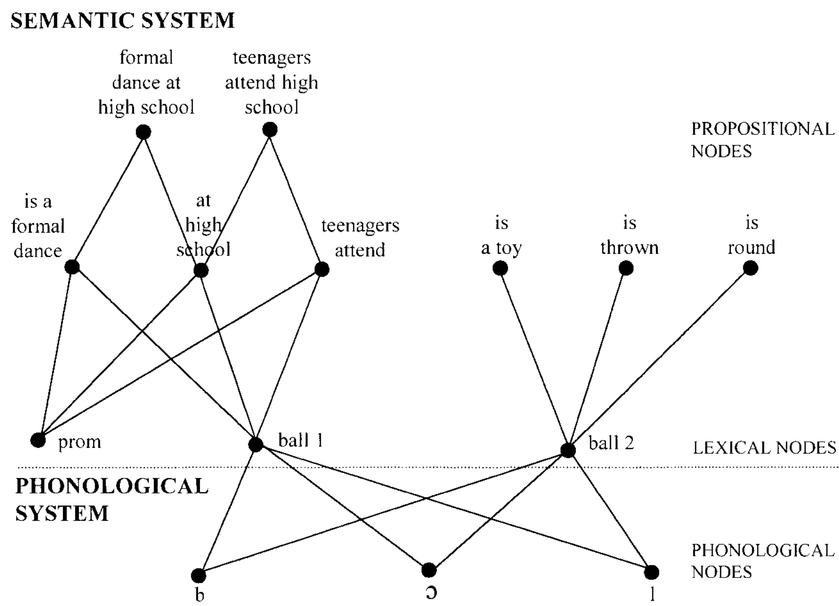

Figure 1. Semantic, lexical, and phonological nodes representing the homophone *ball.* Many nodes for comprehending and producing *ball* have been omitted for simplification.

lamp)[4] (e.g., Cutting & Ferreira, 1999; Levelt et al., 1991; Schriefers et al., 1990; Starreveld & La Heij, 1995, 1996). Semantic interference occurs because the processing of the picture activates semantic nodes, some of which are shared with the distractor, thereby transmitting priming to the lexical node for the distractor. Thus, the distractor lexical node receives priming from two sources: perceptual processing of the distractor and semantic priming from picture processing. This priming decreases the difference in priming levels between distractor and target lexical nodes, slowing lexical selection because selection requires that a target's priming level exceeds that of competitors' (e.g., the distractor) by a critical threshold. The lexical node for an unrelated distractor would not receive this extra semantic priming from the processing of the target picture, and, therefore, it would compete less with the picture name for selection (Glaser & Glaser, 1989; La Heij, 1988; Levelt et al., 1999; Roelofs, Meyer, & Levelt, 1996).

Semantic interference generally occurs when related distractors precede the picture (e.g., −150-ms stimulus onset asynchrony [SOA]), but not when they follow the picture (e.g., +150-ms SOA). This is consistent with the view that lexical selection occurs relatively early in picture naming and once selection occurs; priming of lexical competitors is irrelevant (Glaser & Glaser, 1989; La Heij, 1988; Starreveld & La Heij, 1995). The localization of the semantic interference effect to the lexical level is supported by findings that semantic interference disappears for responses that do not require lexical access, such as old–new recognition responses for pictures (Schrieffers et al., 1990). Thus, under the transmission deficit hypothesis, older adults will show larger semantic interference effects in the picture–word interference paradigm for the same reasons that they show larger semantic priming effects on lexical selection in word recognition.

The second pathway of interest in this study involves bottom-up phonological priming: A picture (e.g., *frog*) is named faster when accompanied by a phonologically related auditory distractor word (*frost*) compared with an unrelated distractor (*lamp*; e.g., Cutting & Ferreira, 1999; Damian & Martin, 1999; Schriefers et al., 1990). The phonology for *frog* is retrieved more quickly because some of its phonemes (e.g., /f/, /r/, and /a/) were primed by the bottom-up perceptual processing of *frost* (Damian & Martin, 1999; Schriefers et al., 1990; Starreveld & La Heij, 1996). Phonological facilitation generally occurs when related distractors follow the picture (e.g., +150-ms SOA), but not when they precede the picture (e.g., −150-ms SOA). This is consistent with the view that phonological retrieval occurs relatively late in picture processing and phonological priming effects are short-lived. Because this effect involves converging bottom-up priming, no age differences are predicted under the transmission deficit hypothesis.

The third pathway of interest is top-down phonological priming, isolated in an ingenious condition created by Cutting and Ferreira (1999). A picture with a homophone name (e.g., toy *ball*) is named faster when accompanied by a distractor word related to the nondepicted meaning of the picture (*prom*) compared with an unrelated distractor (*hammer*). The only relationship between the distractor and the picture is at the phonological level: The distractor (*prom*) is semantically related to a word (dance *ball*) that bears an exact phonological relationship to the picture (toy *ball*). The distractor effect can be explained as follows: The auditory distractor (*prom*) activates semantic nodes (*formal dance*, *high school*, and *teenagers*) that transmit priming to semantically related lexical

[4] It is important to note that not all semantically related words are competitors. For example, *cake* and *pie* are competitors in picture naming because they share a number of semantic features. *Bake* is associatively related to pie through cooccurrence, but it is not semantically similar and is not a competitor. Competitors, but not words that are only associatively related, produce interference in the picture–word paradigm (see Cutting & Ferriera, 1999).

nodes, including dance *ball* (see Figure 1). Priming proceeds top-down from the lexical node to the phonological system in which the appropriate phonemes (/b/, /ɔ/, and /l/) are primed. Meanwhile, the picture (toy *ball*) has been presented, activating semantic nodes that transmit priming to the appropriate lexical node (toy *ball*) and onto the corresponding phonemes (/b/, /ɔ/, and /l/) that have already been primed from the processing of the distractor. The residual phonological priming from the distractor speeds naming latency (Cutting & Ferreira, 1999). This effect depends on pathways implicated in word production failures under the transmission deficit hypothesis, namely top-down, diverging phonological connections, and, therefore, the effect is predicted to be weaker for older than for young adults.

Age differences in the picture–word interference task may also be consistent with the hypothesis that inhibitory processes are deficient in old age (Hasher & Zacks, 1988; Zacks & Hasher, 1994, 1997). Hasher et al. (1999) argued that inhibition is an essential attentional control process that allows activated goals to determine the content of consciousness by suppressing information that is irrelevant to these goals. Most important in the present context is the "access" control function of inhibition that prevents activated, but irrelevant information, from entering conscious awareness. The source of irrelevant information may be external or internal. Thus, "external distraction has a greater negative impact on older than younger adults because more activated information, cued by the environment, gains access to working memory for older adults" (Hasher et al., 1999, p. 660). Older adults' greater interference in the Stroop paradigm compared with young adults, for example, was attributed to age-linked deficits in inhibiting the distracting base word, thus slowing color-naming latency (e.g., Earles et al., 1997; Zacks & Hasher, 1994). In recent reformulations, Hasher et al. suggested that older adults' inhibition deficits are compensated for when there are salient perceptual cues—such as location or color—that distinguish targets and distractors.

Inhibition processes also apply to internally generated information. Older adults' priming spreads more broadly to extraneous, irrelevant information, and older adults are less able to control the access of this information to conscious awareness (Hasher et al., 1999). Reading text, for example, was slowed more for older than for young adults by distracting material that was semantically related to the target text. This finding was attributed to older adults' more diffuse spread of activation during reading, whereas young adults "activate meaning more narrowly in a given context [and] have fewer accidental matches with the distracting material" (Carlson et al., 1995, p. 434; Hasher et al., 1999).

In this article, we examine the adequacy of inhibition deficits in explaining semantic and phonological effects in the picture–word interference paradigm. If older adults suffer inhibitory deficits, their reduced ability to inhibit the distractor word would allow greater processing of the distractor and greater effects of the distractor on picture-naming latencies. If, however, the distractors are sufficiently perceptually distinct from the pictures, older adults may show no greater interference for picture naming than young adults (Hasher et al., 1999). Semantic relatedness, however, would be expected to produce stronger distractor effects for older than for young adults because older adults' inhibitory deficits on internal processes allow more diffuse activation.

Experiment 1

Following Cutting and Ferreira (1999), participants named pictures of objects with homophone or nonhomophone names; an auditory distractor word was presented 150 ms prior (e.g. –150-ms SOA) to the onset of the picture. For pictures with nonhomophone names, distractors were related either semantically or phonologically, or they were unrelated. For pictures with homophone names, (e.g., toy *ball*), distractor words were semantically related to the appropriate meaning of the pictured homophone (*frisbee*), to the inappropriate meaning of the homophone (*prom*), or were unrelated (see Figure 2). Thus, semantic interference effects were tested when semantically related distractors preceded nonhomophone pictures and when appropriate-meaning distractors preceded

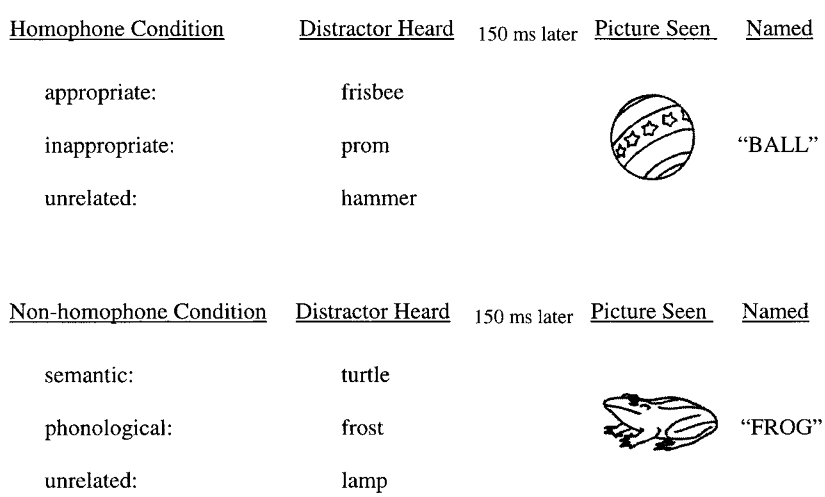

Figure 2. Schematic of the experimental paradigm used in Cutting and Ferreira (1999) and Experiment 1. From "Semantic and Phonological Information Flow in the Production Lexicon," by J. C. Cutting and V. S. Ferreira, 1999, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* p. 322. Copyright 1999 by the American Psychological Association. Adapted with permission of the authors.

homophone pictures. Bottom-up phonological effects were tested when phonologically related distractors preceded nonhomophone pictures. Top-down phonological effects were tested when the distractor was semantically related to the inappropriate meaning of the homophone picture.

The transmission deficit hypothesis predicts that young adults will benefit from inappropriate-meaning distractors, as reported by Cutting and Ferreira (1999), but older adults will not. This facilitation effect is dependent on top-down priming from the semantic to the phonological system. The single top-down connections within the phonological system are particularly vulnerable to age-related transmission deficits in priming. The effect of a phonologically related distractor on picture naming is generally small or nonexistent at a −150-ms SOA. Whatever the effect, though, it should be similar for young and old because it reflects bottom-up phonological priming, which is not impaired in old age. In the semantic and appropriate-meaning conditions, semantic interference effects should be greater for older than for young adults inasmuch as semantic priming effects increase with age.

The inhibitory deficit hypothesis predicts greater distractor effects for older adults than for young adults, if older adults' inhibition deficits cause greater processing of external distractors. When external distraction is successfully inhibited by older adults, however, greater interference may still occur for older than for young adults with semantically related distractors that stimulate broader and more diffuse activation that is less constrained by inhibition (Hasher et al., 1999). In this case, older adults would show greater semantic interference because they produce greater priming between toy *ball* and *frisbee*. The same mechanism should also cause an age-related increase in the effect of inappropriate-meaning distractors. That is, the distractor *prom* should produce greater priming of semantically related *ball* and then greater priming top-down to the phonology for *ball*, thus facilitating production of *ball*.

Method

Participants. Forty-eight young, age 18–29 years (M = 20.88 years, SD = 1.66), and 48 healthy older adults, age 62–85 years (M = 72.83 years, SD = 5.52), participated in the experiment. Young adults participated for credit in introductory psychology courses, and older adults were paid for their participation. Older adults were from the Claremont Project on Memory and Aging's participant pool and had been recruited from retirement communities and senior centers, or they were graduates or retired employees of the Claremont Colleges. Because all of the young adults were expected to obtain college degrees, we selected older adults with college degrees as often as possible from the participant pool. There was no difference in the mean score on the Shipley (1940) Vocabulary Test (maximum = 25) between young (M = 21.15, SD = 2.13) and older participants (M = 21.39, SD = 3.36). Mean years of education were 14.90 (SD = .99) and 15.48 (SD = 3.22) for young and older adults, respectively. All participants were native English speakers.

Materials. Figure 2 represents the experimental conditions used in Experiment 1. Twenty-seven black-and-white line drawings of objects with homophone names were taken from Cutting and Ferreira (1999). Each picture was paired with an appropriate-meaning and an inappropriate-meaning distractor word from Cutting and Ferreira's Experiments 3A and 3B, respectively. Appropriate-meaning distractors were competitors of the depicted meaning of a picture (e.g., *frisbee*, picture = toy *ball*), and inappropriate-meaning distractors were competitors of the nondepicted meaning of the name of the homophone picture (e.g., *prom*, picture = toy *ball*).

In addition to the homophone pictures, 27 pictures with nonhomophone names were taken from Cutting and Ferreira (1999); 5 of these were replaced with pictures created in our own laboratory that were easier to identify. The nonhomophone pictures were paired with phonologically and semantically related distractors from Cutting and Ferreira's Experiments 2 and 3A, respectively. The phonological distractors and picture names shared number of syllables, stress pattern, and their initial phoneme and vowel sound (e.g., *frost*, picture = *frog*). There were two exceptions that only partially satisfied these constraints: *apple–anchor* and *horse–house*. Semantic distractors were competitors with the picture names (e.g., *dresser*, picture = *bed*).

An unrelated condition was created within each type of picture by re-pairing the 54 distractor words for homophone pictures (27 appropriate meaning and 27 inappropriate meaning) and by re-pairing 54 distractor words for nonhomophone pictures (27 phonological and 27 semantic). This produced an unrelated homophone condition and an unrelated nonhomophone condition. Six counterbalanced lists were created such that for each picture type (homophone vs. nonhomophone name), every list contained nine items in each distractor condition. Across the six lists, each homophone picture was paired with each homophone distractor condition (appropriate-meaning, inappropriate-meaning, and homophone unrelated), and each nonhomophone picture was paired with each nonhomophone distractor condition (phonological, semantic, and nonhomophone unrelated) only once. For the practice phase, 15 pictures (5 with homophone names) were selected from Snodgrass and Vanderwart (1980) and were paired with 15 distractors unrelated to the picture names.

All distractor words were digitally recorded at a rate of 44 kHz on a Power Macintosh computer using SoundEdit software. To control the duration of the auditory distractor, the distractor words were compressed or expanded so that the duration of each word was between 510–599 ms.

Stimulus presentation was controlled with PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993) on a Power Macintosh computer with a 15-in. color monitor and two external speakers. Naming latency was measured with an Optimus unidirectional head-worn microphone (Optimus; Fort Worth, TX) with input to a PsyScope button box millisecond timer.

Procedure. Each participant was tested individually according to a procedure that generally followed Cutting and Ferreira (1999). Prior to testing, participants were shown a booklet containing 67 pictures (15 practice pictures and 54 test pictures), one per page, and were asked to generate the name for each picture. If a name other than the target name was given, the experimenter cued the participant to generate the target name. If the target name was still not produced, the experimenter presented the name. Participants were then seated approximately 18 in. away from the monitor, and the volume and microphone were adjusted for each participant.

The instructions presented on the computer informed participants that they would hear words and see previously presented pictures and that their task was to ignore the auditory words and name the picture as quickly as possible. Each trial began with a fixation point (i.e., an asterisk) at the center of the screen for 500 ms, followed by a 500-ms blank screen, which was then followed by an auditory distractor presented through the external speakers. One hundred and fifty milliseconds after the onset of the distractor word, a picture was presented on the screen. The picture remained on the screen until the voice key was triggered by the participant's naming response. The instruction "press any key when ready" appeared until a key response triggered the beginning of the next trial. The experimenter sat next to the participant, coding the accuracy of each response and the voice-key detection.

In a practice phase, 15 practice pictures and distractors were presented to participants, with each picture and distractor presented twice in the practice session. In the test phase, 54 pictures were arranged in a fixed random order, with each distractor and picture presented only once.

Results

All misnamed and mistriggered trials were discarded, and response latencies greater than three standard deviations above or below that participant's mean were then excluded. For young and older adults, 1.4% and 2.3% of all possible trials were misnamed, respectively. The voice key was mistriggered on 6.2% of all trials for young adults and on 8.1% of all trials for older adults. Outliers represented 1.6% and 2.5% of all included trials for young and older adults, respectively. Mean response times were calculated for each participant in each condition, which are shown in Table 1 by age and experimental condition. An analysis of variance (ANOVA) was performed on mean response times for homophone and nonhomophone pictures separately, with age as a between-participants variable and distractor type as a within-participant variable. Separate analyses were performed by using participants (F_1) and pictures (F_2) as units. To account for older adults' slower baseline latencies, t tests were also performed on proportion change for young and older adults in each experimental condition (Faust, Balota, Spieler, & Ferraro, 1999). We calculated proportion change scores by obtaining the difference between the mean latency for unrelated and related trials and dividing the difference by the mean latency for unrelated trials. All results reported as significant reached at least $p \leq .05$.

Homophone pictures. Older adults' naming latencies were longer than young adults' latencies, $F_1(1, 94) = 35.94$, $MSE = 41{,}720.24$; $F_2(1, 26) = 91.30$, $MSE = 11{,}297.29$, and the main effect of distractor type on naming latencies for homophone pictures was significant, $F_1(2, 188) = 23.88$, $MSE = 6{,}688.87$; $F_2(2, 52) = 11.80$, $MSE = 8{,}317.81$. As predicted, the distractor effect was modified by age, $F_1(2, 188) = 3.38$, $MSE = 6{,}688.87$; $F_2(2, 52) = 3.96$, $MSE = 3{,}368.09$.

Table 1
Experiment 1 Mean Naming Latencies (in Milliseconds) and Standard Deviations for Young and Older Adults

Group	*M*	*SD*
Young adults		
Homophone Pictures (round *ball*)		
Inappropriate (*prom*)	838	98
Appropriate (*frisbee*)	899	110
Unrelated (*hammer*)	859	104
Nonhomophone Pictures (*frog*)		
Phonological (*frost*)	811	112
Semantic (*turtle*)	863	103
Unrelated (*lamp*)	810	110
Older adults		
Homophone Pictures (toy *ball*)		
Inappropriate (*prom*)	989	144
Appropriate (*frisbee*)	1,070	199
Unrelated (*hammer*)	970	132
Nonhomophone Pictures (*frog*)		
Phonological (*frost*)	899	139
Semantic (*turtle*)	988	136
Unrelated (*lamp*)	896	110

The Distractor × Age interaction was explored by using the unrelated distractors as a baseline for the inappropriate-meaning and appropriate-meaning conditions. For the inappropriate-meaning condition, a 2 (young vs. old) × 2 (inappropriate meaning vs. unrelated distractor) ANOVA on latencies revealed a significant main effect of age, $F_1(1, 94) = 33.09$, $MSE = 24{,}836.77$; $F_2(1, 26) = 78.73$, $MSE = 6{,}329.50$, a significant Age × Distractor interaction in the participants' analysis, $F_1(1,94) = 4.33$, $MSE = 4{,}432.36$, and a marginally significant interaction in the item analysis, $F_2(1, 26) = 3.24$, $MSE = 2{,}804.65$, $p = .08$. Planned comparisons revealed that young adults were faster to name pictures when paired with inappropriate-meaning compared with unrelated distractors, $F_1(1, 47) = 4.03$, $MSE = 2{,}578.85$; $F_2(1, 26) = 4.35$, $MSE = 2{,}230.58$, replicating previous findings by Cutting and Ferreira (1999). As predicted by the transmission deficit hypothesis, however, there was no significant effect for older adults. The difference scores (unrelated minus related) for homophones pictures are represented in Figure 3A by age group and experimental condition.

For the appropriate-meaning condition, the 2 (young vs. old) × 2 (appropriate meaning vs. unrelated) ANOVA revealed that older adults were slower than young adults, $F_1(1, 94) = 28.70$, $MSE = 33{,}236.42$; $F_2(1, 26) = 70.48$, $MSE = 8{,}480.54$, and that pictures with appropriate-meaning distractors were slower than pictures with unrelated distractors, $F_1(1, 94) = 35.96$, $MSE = 6{,}584.61$; $F_2(1, 26) = 13.04$, $MSE = 9{,}928.98$. As can be seen in Figure 3, the Distractor × Age interaction was significant, $F_1(1, 94) = 6.64$, $MSE = 6{,}584.61$; $F_2(1, 26) = 6.26$, $MSE = 4{,}224.89$. Older adults were disproportionately slower than young adults in naming pictures paired with appropriate-meaning compared with unrelated distractors. This age difference was maintained in the analysis of proportion change, which was greater for older adults ($M = .10$) than for young adults ($M = .05$), $t(94) = -2.18$, $SE = 0.02$.

Nonhomophone pictures. Older adults produced longer naming latencies than did young adults, $F_1(1, 94) = 20.63$, $MSE = 342{,}963.74$; $F_2(1, 26) = 64.65$, $MSE = 6{,}201.86$, and naming latencies were dependent on the type of distractor presented, $F_1(2, 188) = 43.76$, $MSE = 3{,}722.78$; $F_2(2, 52) = 16.00$, $MSE = 6{,}194.89$. Distractor type interacted with age in the participant analysis, $F_1(2, 188) = 3.13$, $MSE = 3{,}722.78$, but not in the item analysis, $F_2(2, 52) = 2.16$, $MSE = 3{,}565.92$, $p = .13$.

The Distractor × Age interaction was explored by using the unrelated distractors as a baseline for the phonological and semantic conditions. Figure 3B represents the difference scores for nonhomophone pictures by age group and experimental condition. For the phonological condition, the 2 (young vs. old) × 2 (phonological vs. unrelated) ANOVA revealed that older adults were slower than young adults, $F_1(1, 94) = 14.68$, $MSE = 24{,}429.76$; $F_2(1, 26) = 68.01$, $MSE = 2{,}923.29$. No main effect of phonological distractors and no age interaction were found.

For the semantic condition, the 2 (young vs. old) × 2 (semantic vs. unrelated) ANOVA revealed that older adults were slower than young adults, $F_1(1, 94) = 23.88$, $MSE = 22{,}154.42$; $F_2(1, 26) = 42.68$, $MSE = 6{,}970.68$, and that pictures with semantic distractors were named more slowly than pictures with unrelated distractors, $F_1(1, 94) = 69.24$, $MSE = 3{,}620.17$; $F_2(1, 26) = 23.33$, $MSE = 6{,}289.84$. As can be seen in Figure 3, the Distractor × Age interaction was significant, $F_1(1, 94) = 6.64$,

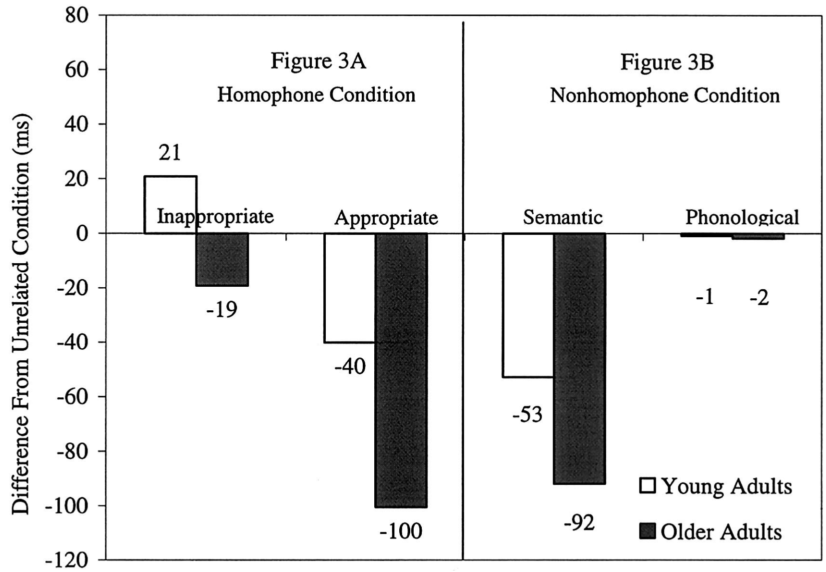

Figure 3. Distractor effects on naming latency for pictures with homophone and non-homophone names by condition and age (Experiment 1).

MSE = 6,584.61; $F_2(1, 26) = 6.26$, *MSE* = 4,224.89. Older adults were disproportionately slower than young adults in naming pictures paired with semantic compared with unrelated distractors. Proportion change tended to be greater for older adults ($M = .09$) than for young adults ($M = .06$), but these differences were only marginally significant, $t_1(94) = -1.77$, $SE = 0.02$, $p = .08$.

Discussion

Experiment 1 demonstrates two important age differences in language processes. First, the semantic interference effect was greater for older than for young adults. This difference was observed in both the semantic condition with nonhomophones (e.g., *turtle*; picture = *frog*) and the appropriate-meaning condition with homophones (e.g., *frisbee*; picture = toy *ball*), as well as with both absolute response time and proportion as the dependent measures, although the age difference was marginal with proportion change for nonhomophones. According to the transmission deficit hypothesis, greater semantic interference effects for older than for young adults were predicted on the basis of older adults' larger semantic priming effects. Acccording to the inhibitory deficit hypothesis, greater semantic interference for older adults could occur because older adults are less able to inhibit the external distractor, resulting in more activation of its competing lexical representation. Alternatively, older adults' greater semantic interference may be caused internally by broader, more diffuse, activation. Both explanations, however, are inconsistent with the absence of greater effects for older adults with inappropriate-meaning distractors.

The second important age difference is the significant Distractor Type × Age interaction such that young but not older participants were faster to name a picture of a homophone (e.g., toy *ball*), when preceded by an inappropriate-meaning distractor (*prom*), compared with an unrelated distractor condition. These results for young adults replicate the results of Cutting and Ferreira (1999), who attributed this effect to the transmission of priming from semantic representations for *prom* to those for dance *ball*, and then transmission of priming top-down to phonological representations for /b/, /ɔ/, and /l/. The transmission deficit hypothesis predicts the absence of this facilitation effect for older adults. Older adults suffer deficits in the transmission of priming along single connections such as those from lexical to phonological representations (see Figure 1), and these are the specific connections necessary for facilitation of homophone naming by inappropriate-meaning distractors. The age difference in this effect, however, is inconsistent with the inhibitory deficit hypothesis: Inasmuch as older adults are less able than young adults to inhibit the processing of the external distractor word, any distractor effect seen in young adults should be greater in older adults. Alternatively, if older adults are less able than young adults to inhibit the internal spread of priming stimulated by the distractor word, they should show greater semantic priming (Hasher et al., 1999) and thus greater benefit from the inappropriate-meaning distractor.

There was no effect of phonologically related distractors on picture-naming latency (e.g., distractor = *frost*; picture = *frog*) for young or older participants, as is generally the case at a –150-ms SOA (e.g., Damian & Martin, 1999; Schriefers et al., 1990). Why does phonological priming occur with inappropriate-meaning distractors (for young adults) but not with phonologically related distractors at the –150-ms SOA? Bottom-up priming of phonological nodes is believed to be a short-lived transitory effect (Cutting & Ferreira, 1999; Damian & Martin, 1999); at early SOAs, priming from partial overlap has already decayed by the time phonological retrieval of the picture name begins. Cutting and Ferreira suggested that the full phonological overlap between dance *ball* and toy *ball* yields stronger priming than the partial overlap among phonologically related words (e.g., *frost*, picture = *frog*), allowing the priming to be sustained until phonological encoding of the picture.

These results support the hypothesis that older adults suffer transmission deficits in specific top-down pathways involved in retrieval of phonology. Experiment 2 further tests aging effects on these same pathways by using distractors that are both semantically and phonologically related. Experiment 2 also features phonologically related distractor words at an SOA that produces stronger effects than in Experiment 1. Comparing the effects of phonological distractors and of unrelated word versus white noise distractors will further test the plausibility of age-related deficits in inhibition of irrelevant information from external sources.

Experiment 2

In Experiment 2, an auditory distractor word was presented either before the onset of the picture (–150-ms SOA) or after the onset of the picture (+150-ms SOA). The relationship between pictures (e.g., *squirrel*) and distractors was semantic (*mole*), phonological (*skate*), semantic and phonological (*skunk*), or unrelated (*lamp*). In addition, a nonlexical condition substituted white noise for the distractor word.

Distractors that are both semantically and phonologically related (S/P) to the picture name (e.g., *skunk*; picture = *squirrel*) reduced semantic interference compared with a condition when distractors are only semantically related (*mole*; Damian & Martin, 1999; for the same effect with visual distractors, see Rayner & Springer, 1986; Starreveld & La Heij, 1995, 1996). Moreover, the S/P effect is obtained at –150-ms SOA when distractors that are only phonologically related yield little or no reliable facilitation, as we saw in Experiment 1. In contrast, at the +150-ms SOA, when a distractor is presented after the picture, there is no semantic interference with semantically related distractors or S/P distractors, with the latter showing a facilitation effect comparable to distractors that are only phonologically related to the picture.

It seems unlikely that the attenuation of semantic interference with S/P distractors at –150-ms SOA is caused by bottom-up phonological priming because phonological distractors generally show weak effects on naming latency at –150-ms SOA (cf. Damian & Martin, 1999; Roelofs et al., 1996). Rather, picture processing triggers phonological priming with S/P distractors because it triggers semantic interference. That is, the picture (e.g., *squirrel*) activates relevant semantic nodes, some of which are shared with the distractor (*skunk*), thereby transmitting priming to the lexical node for the distractor. This semantic priming adds to priming at the lexical node from perceptual processing of *skunk* and is the source of the semantic interference because the lexical unit *skunk* is a competitor of the lexical unit *squirrel*. Priming also spreads top-down along connections from the lexical units (*skunk* and *squirrel*) to the corresponding phonological nodes, some of which are shared between these two lexical units (i.e., /s/ and /k/). Consequently, the availability of the overlapping phonemes is increased, and a reduction in the time required for phonological retrieval of *squirrel* is seen compared with a condition in which the distractor is semantically related only. Why is a phonological relatedness effect seen for S/P distractors when weak effects of distractors that are phonologically related only are seen at the same SOA? The S/P phonological priming occurs later than priming triggered by initial distractor processing and has not decayed when phonological encoding of the target occurs.

The inhibitory deficit hypothesis and the transmission deficit hypothesis make contrary predictions regarding the effect of an S/P distractor on older adults' naming latencies. Inasmuch as the attenuation effect is dependent on top-down priming from the semantic to the phonological system, transmission deficits in priming should be seen for older adults as they were in Experiment 1. Thus, the transmission deficit hypothesis predicts little, if any, attenuation of semantic interference for older adults when an S/P distractor is presented before the target. If, however, the S/P effect reflects bottom-up phonological priming of the picture lexical node from processing the distractor (e.g., Damian & Martin, 1999; Roelofs et al., 1996), then no age difference in attenuation should be seen according to the transmission deficit hypothesis. The inhibitory deficit hypothesis posits that older adults' inhibitory deficits cause them to process external distractors more than young adults, thereby increasing older adults' distractor effects relative to young adults' effects. In the S/P condition, greater processing of the distractor would strengthen both interference and facilitation effects, so there is no basis for predicting an age difference in the overall effect. Alternatively, age-related inhibition deficits of internally generated activation should result in broader semantic activation for older adults (Hasher et al., 1999). In the case of S/P distractors, this broader activation delivers more priming to semantically related words, thereby increasing top-down phonological priming and speeding target naming.

In the case of phonologically related distractors, naming is faster at late but not at early SOAs (Damian & Martin, 1999; Schreifers et al., 1990). When a phonological distractor is presented 150 ms before the picture (i.e., –150-ms SOA), priming of phonological nodes has decayed by the time phonological retrieval for the picture name ensues. However, when the distractor follows the presentation of the picture (i.e., +150-ms SOA), the distractor is priming its corresponding phonology closer to the time phonological encoding of the picture name occurs. The inhibitory deficit hypothesis predicts greater phonological facilitation for older adults than for young adults, inasmuch as older adults are less able to inhibit the processing of the external distractor. On the other hand, the transmission deficit hypothesis predicts comparable phonological facilitation for young and older adults because of differences in the architecture of bottom-up and top-down connections. Bottom-up connections converge on phonological nodes and are the basis for priming effects of phonologically related distractors at +150-ms SOA. For example, many feature nodes (e.g., place, voice) are connected to a phoneme node (MacKay, 1987). These converging connections compensate for any transmission deficits.

Finally, an unrelated distractor word slows picture-naming latency compared with a white noise condition because it competes with the picture name for selection (Schrieffers et al., 1990). If older adults are inefficient in inhibiting the external distractor word, the increased interference in unrelated word compared with white noise distractor conditions should be greater for older than for young adults. The transmission deficit hypothesis, however, predicts no age difference in this interference effect because it is caused by competition at the lexical level; this process is unaffected by age as long as no semantic priming is involved.

Method

Participants. Thirty-two young adults, age 18–22 years (M = 18.66 years, SD = 0.97), and 32 healthy older adults, age 60–89 years (M = 74.69 years, SD = 1.22), were recruited from the same sources as in

Experiment 1. Young adults participated for credit in introductory psychology courses, and older adults were paid for their participation. Older participants scored significantly higher (M = 21.75, SD = 3.23) than did young adults (M = 20.16, SD = 2.61) on the Shipley (1940) Vocabulary Test (maximum = 25), $t(62) = -2.17$, SE = 0.74. Mean years of education were significantly higher for older adults (M = 16.97, SD = 3.72) than for young adults (M = 12.47, SD = 0.72), $t(62) = -6.72$, SE = 0.67. All participants were native English speakers.

Materials. The picture and word stimuli were taken from Damian and Martin's (1999) Experiment 3. Each of eighteen line drawings was paired with a distractor in each of five distractor conditions: semantic, phonological, S/P, unrelated, and white noise. White noise was recorded to match the mean duration of the auditory distractor words. Each S/P distractor overlapped in the initial two phonemes with the picture name. In addition, Damian and Martin chose distractors for similar degrees of semantic and phonological overlap with each picture name. Phonological and S/P distractors deviated in phonological similarity no more than 10% with their corresponding picture names. Additionally, unrelated distractors were as phonologically unrelated to picture names as semantic distractors. All semantic and S/P distractors were competitors of the picture names and deviated no more than 10% in conceptual overlap from their corresponding picture names. Phonological and unrelated distractors were semantically unrelated to comparable degrees as well.

As in Experiment 1, all distractor words were digitally recorded at a rate of 44 kHz on a Power Macintosh computer using SoundEdit software. The distractor words and white noise were compressed or expanded so that each word/noise interval was between 510–599 ms during playback. Participants were presented pictures and distractors using PsyScope software (Cohen et al., 1993) on a Power Macintosh computer with a 15-in. color monitor and two external speakers. Naming responses were collected with an Optimus unidirectional head-worn microphone (Optimus; Fort Worth, TX) and a PsyScope button box millisecond timer.

Procedure. The general procedure was similar to Experiment 1, except that there were two SOA blocks (−150 ms and +150 ms). Again, prior to testing, participants were shown a booklet containing all 18 pictures and were asked to generate the name for each picture. Two practice blocks of 18 trials each, one block with white noise and one block with the unrelated distractor word, were conducted, which was followed by two experimental blocks of 90 trials each. The 18 target pictures were paired with a distractor from each condition so that each target picture appeared in random order in each of five blocks in the experiment (90 experimental trials). Each set of 90 picture word pairs was displayed two times at different SOAs for a total of 180 experimental trials. The order in which the participants received the SOA blocks was alternated across participants, and a stimulus never repeated on consecutive trials.

Table 2
Experiment 2 Mean Naming Latencies (in Milliseconds) and Standard Deviations for Young and Older Adults by Distractor and SOA

	SOA			
	−150		+150	
Distractor type	M	SD	M	SD
Young adults				
Noise	685	95	657	126
Unrelated	748	113	715	160
Semantic	813	98	715	152
Phonological	734	95	674	152
S/P	756	113	679	155
Older adults				
Noise	814	127	787	130
Unrelated	880	127	895	165
Semantic	963	130	890	182
Phonological	866	116	855	164
S/P	929	141	881	181

Note. SOA = stimulus onset asynchrony; S/P = distractor is semantically and phonologically related to the picture name.

Results

All misnamed and mistriggered trials were discarded, and response latencies greater than three standard deviations above or below a participant's mean were then excluded. For young and older adults, 2.7% and 2.6% of all possible trials were misnamed, respectively. The voice key was mistriggered on 9.1% of all trials for young adults and on 6.7% of all trials for older adults. Outliers represented 1.6% and 1.9% of all included trials for young and older adults, respectively. Mean response times were calculated for each participant and in each condition, which are shown in Table 2 by age and experimental condition. An ANOVA was performed on mean response times, with age as a between-participants variable and SOA and distractor type as within-participant variables.

Naming latencies were longer for older than for young adults, $F_1(1, 62) = 24.88$, MSE = 160,996.80; $F_2(1, 16) = 328.71$, MSE = 6,636.40, and for distractors presented before rather than after the picture, $F_1(1, 62) = 20.73$, MSE = 14,924.24; $F_2(1, 16) = 51.47$, MSE = 3,485.38. The interaction involving age and SOA was not significant by participants but was significant by items, $F_2(1, 17) = 33.72$, MSE = 667.65. In both analyses, the difference in naming latencies between –150-ms and +150-ms SOA was larger for young than for older adults. There was a main effect of distractor type, $F_1(4, 248) = 86.82$, MSE = 2,433.27; $F_2(4, 64) = 18.29$, MSE = 6,476.91, which was modified by age, $F_1(4, 248) = 5.63$, MSE = 2,433.27; $F_2(4, 64) = 7.27$, MSE = 894.32, and by SOA, $F_1(4, 248) = 18.22$, MSE = 1,616.77; $F_2(4, 64) = 4.72$, MSE = 3,956.04. The SOA × Distractor Type × Age interaction was not significant.

To explore specific age-related distractor effects, 2 (young vs. old) × 2 (unrelated vs. experimental condition) ANOVAs were conducted separately for semantic, phonological, S/P, and noise distractors by using the unrelated condition as a baseline for each distractor condition. These analyses were conducted for each SOA (–150 ms and +150 ms), and the results are reported according to each distractor condition in the following paragraphs. Figure 4 presents the semantic, phonological, and S/P distractor effects (unrelated minus related condition), with Figure 4A representing effects at –150-ms SOA and Figure 4B representing effects at +150 ms-SOA.

Phonological condition. At the –150-ms SOA, older adults were slower than young adults, $F_1(1, 62) = 22.56$, MSE = 24,614.79; $F_2(1, 16) = 175.71$, MSE = 1,668.60, and a main effect of distractor type was obtained in the participant analysis, $F_1(1, 62) = 5.25$, MSE = 1,142.29, but not in the item analysis. Age did not interact with distractor relatedness; both young and older adults showed small but similar facilitation effects when phonological distractors were presented before the picture. The t tests also revealed no age differences in proportion change. At the +150-ms SOA, older adults were slower than young adults, F_1(1,

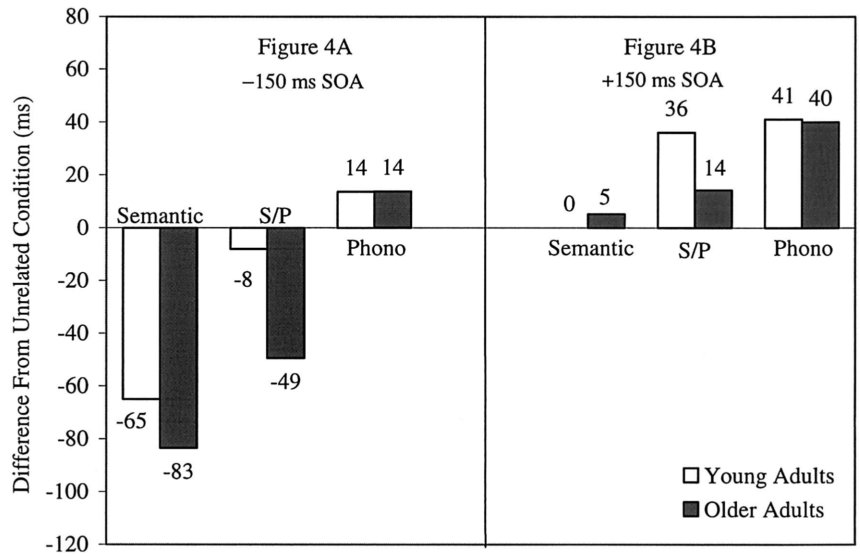

Figure 4. Distractor effects on naming latency by SOA, condition, and age (Experiment 2). SOA = stimulus onset asynchrony.

62) = 20.79, *MSE* = 50,030.46; $F_2(1, 16) = 271.31$, *MSE* = 2,138.61, and pictures with phonological distractors were named faster than pictures with unrelated distractors, $F_1(1, 62) = 43.87$, *MSE* = 1,173.84; $F_2(1, 16) = 9.40$, *MSE* = 4,928.96. As can be seen in Figure 4B, the Phonology × Age interaction was not significant. Moreover, *t* tests revealed no age differences in proportion change.

Semantic condition. At the –150-ms SOA, older adults were again slower than young adults, $F_1(1, 62) = 24.46$, *MSE* = 26,044.93; $F_2(1, 16) = 128.13$, *MSE* = 2,866.15, and pictures with semantic distractors were named slower than pictures paired with unrelated distractors, $F_1(1,62) = 98.83$, *MSE* = 1,778.57; $F_2(1, 16) = 13.68$, *MSE* = 5,486.45. There was no Age × Distractor Type interaction, and *t* tests on proportion change also revealed no age differences.

At the +150-ms SOA, older adults were slower than young adults, $F_1(1, 62) = 19.15$, *MSE* = 52,721.90; $F_2(1, 16) = 319.58$, *MSE* = 1,767.67, but there was no effect of distractor type or interaction.

S/P condition. At the –150-ms SOA, older adults were slower than young adults, $F_1(1, 62) = 25.15$, *MSE* = 29,463.38; $F_2(1, 16) = 113.83$, *MSE* = 3,695.89, and a main effect of distractor type was found in the participant analysis, $F_1(1, 62) = 20.20$, *MSE* = 1,336.04, but not in the item analysis. As can be seen in Figure 4A, the distractor effect was modified by age, $F_1(1, 62) = 9.89$, *MSE* = 1,336.04; $F_2(1, 16) = 8.96$, *MSE* = 506.12, because the difference in naming latencies between the S/P and unrelated distractors was smaller for young than for older adults. The *t* tests revealed no significant difference between naming latencies in the S/P and unrelated conditions for young adults, but for older adults latencies were significantly slower in the S/P than in the unrelated condition, $t(31) = -4.90$, *SE* = 10.08. The age difference in the S/P condition was maintained in the analysis of proportion change: older adults' proportion change (*M* = .05) was greater than younger adults' proportion change (*M* = .01), $t(62) = 2.77$, *SE* = 0.01.

At the +150-ms SOA, older adults were slower than young adults, $F_1(1, 62) = 21.92$, *MSE* = 53,293.00; $F_2(1, 16) = 222.30$, *MSE* = 2,795.97, and the S/P condition produced faster latencies than the unrelated condition in the participant analysis, $F_1(1, 62) = 14.65$, *MSE* = 1,377.34, but not in the item analysis, p = .19. The distractor effect was not modified by age in the mean latency analysis, but proportion change was greater for young adults (*M* = .05) than for older adults (*M* = .01), $t(62) = 2.02$, *SE* = 0.01.

White noise condition. To explore the prediction made by the inhibitory deficit hypothesis that older adults have greater difficulty ignoring irrelevant words, we performed a 2 (young vs. old) × 2 (white noise vs. unrelated distractor) ANOVA on naming latencies for the noise and unrelated distractors. At the –150-ms SOA, naming latencies were longer for older than for young adults, $F_1(1, 62) = 21.84$, *MSE* = 24,786.24; $F_2(1, 16) = 184.80$, *MSE* = 1,693.26, and for unrelated distractors than for noise distractors, $F_1(1, 62) = 58.46$, *MSE* = 2,253.40; $F_2(1, 16) = 20.33$, *MSE* = 4,978.73. Distractor type was not modified by age because the difference in naming latencies between unrelated and noise conditions was similar for young (63 ms) and for older adults (58 ms), as can be seen in Table 2. The *t* tests revealed that young and older adults did not significantly differ in proportion change.

At the +150-ms SOA, naming latencies were longer for older than for young adults, $F_1(1, 62) = 19.45$, *MSE* = 39,596.72; $F_2(1, 16) = 283.58$, *MSE* = 1,521.25, and for unrelated distractors than for noise distractors, $F_1(1, 62) = 70.07$, *MSE* = 3,106.39; $F_2(1, 16) = 18.01$, *MSE* = 7,135.93. Distractor type was modified by age such that the difference between unrelated and noise distractors was larger for older than for young adults, $F_1(1, 62) = 6.45$, *MSE* = 3,106.39; $F_2(1, 16) = 6.09$, *MSE* = 1,735.18. There was, however, no reliable difference in the proportion change between the unrelated and noise conditions for young (*M* = .08) and for older adults (*M* = .12), $t(62) = -1.53$, *SE* = 0.02, p = .13.

Discussion

As in Experiment 1, the pattern of distractor effects was not consistent with inhibitory deficits that cause older adults to process external distractors more than young adults. The increase in picture-naming latency in the unrelated word compared with the white noise distractor condition was comparable for young and older adults at –150-ms SOA. At +150-ms SOA, although the absolute difference was greater for older than for young adults, the age difference was not significant in the proportion change analysis, which takes into account age-related slowing. If older adults were less able to inhibit processing of the distractor, this should have increased distractor competition for lexical selection, thereby inflating the slowing of naming latency compared with a noise condition. In the phonologically related distractor condition, the decrease in picture-naming latency was also comparable for young and older adults at both the –150- and +150-ms SOA. If older adults were less able to inhibit processing of the distractor, this should have increased their phonological priming effects. In contrast to Experiment 1, the increase in picture-naming latency in the semantically related distractor condition at –150-ms SOA did not differ for young and older adults, although the difference was numerically larger for older adults. Within the inhibition deficit framework, these results suggest that older adults were able to inhibit external distractors because they were perceptually distinct from targets. There was also no evidence that older adults suffer inhibition deficits in internal processes because neither the semantically related nor the S/P distractors produced greater effects for older than for young adults.

As predicted by the transmission deficit hypothesis, young adults showed more attenuation of semantic interference than older adults with S/P distractors at –150-ms SOA. We have argued that at –150-ms SOA, this is an unlikely bottom-up effect. Phonologically related distractors without semantic relatedness produced small effects on naming latencies at this SOA for both young and older adults, which is in contrast to the large attenuation of interference seen with young adults for S/P distractors. Moreover, if the attenuation of interference for S/P distractors was caused by phonological priming during perceptual processing of the distractor, there is no basis for expecting smaller effects for older adults. Rather, the S/P effect seems best explained as a top-down priming effect from the processing of the picture, depending on the transmission of top-down priming to phonology, a process predicted by the transmission deficit hypothesis to be adversely affected by age. Note that the age difference in the S/P condition is unlikely to be the result of greater semantic interference for older adults because there were no age differences in semantic interference in the semantic condition in this experiment.

The age difference in the S/P effect at +150-ms SOA is difficult to explain. Both age groups showed phonological facilitation but not semantic interference with phonologically related distractors and semantically related distractors, respectively, as is usually observed at this late SOA (e.g., Damian & Martin, 1999; Schriefers et al., 1990). In the S/P condition, there was facilitation compared with unrelated distractors and no age interaction in the analysis of absolute RT. The proportion change in latency, however, was reliably larger for young than for older adults. The transmission deficit hypothesis predicts no age differences in the magnitude of the S/P effect at +150-ms SOA because the effect is dependent on bottom-up priming. The unexpected S/P age difference at +150-ms SOA raises the possibility that small age differences in semantic interference interact with phonological facilitation in unexpected ways. It remains for future research to determine if the small age difference in proportion change can be replicated.

General Discussion

Experiments 1 and 2 yielded four important results that support asymmetric aging effects on semantic and phonological language processes. First, when age differences in semantic interference were found, the interference effect was greater for older than for young adults. Second, larger distractor effects for older than for young adults were found only with semantically related distractors. Third, there was no evidence for age differences in bottom-up priming from phonologically related distractors. Finally, the results are consistent with age-related deficits in top-down phonological priming. Overall, these results challenge the view that older adults' language processing is impaired by their inability to inhibit irrelevant information from either external or internal sources. The results also cannot be explained by general slowing of processing in old age because distractor effects were comparable across age in some conditions and not others, holding SOA constant. The results are best understood in the context of a connectionist model in which aging enriches semantic representations but causes transmission deficits on specific connections involved in phonological retrieval driven by semantic but not perceptual processing.

Inhibition Deficits and Distraction

Greater distractor effects were predicted for older than for young adults in the picture–word interference task inasmuch as older adults are less able to inhibit irrelevant distracting information than young adults and thus process it more (e.g., Hasher & Zacks, 1988; Hasher et al., 1999). No distractors, however, produced greater effects for older than for young adults when general slowing was taken into account, except semantically related distractors. Hasher and colleagues suggested that older adults maintain their ability to inhibit irrelevant perceptual information when salient cues, such as location or color, distinguish targets and distractors, but not when distractors are semantically related (e.g., Carlson et al., 1995; Hasher et al., 1999). Under this hypothesis, the perceptual distinction between auditory distractors and visual pictures in the present study may have been sufficient for older adults to overcome inhibition deficits for external sources of interference.

However, this account seems implausible for several reasons. First, when distractors in the picture–word interference paradigm are visual and written through the middle of the picture, older adults still show interference effects equivalent to young adults in all but a semantically related condition (Christidis & Burke, 2002). Second, negative priming effects involve slower responses to targets that were distractors on the previous trials, a "key marker" of inhibition according to Zacks and Hasher (1994; but see McDowd, 1997). Meta-analyses, however, show significant negative priming effects for both age groups and little evidence for age differences (Verhaeghen & De Meersman, 1998) and, more recently, no evidence for age differences whatsoever (Gamboz, Russo, & Fox, in press). Most important in the present context, neither increasing spatial overlap nor decreasing color distinctiveness of targets and distractors affected the age equivalence of negative priming effects (Gamboz, Russo, & Fox, 2000; Verhaeghen & De Meersman, 1998).

Finally, no age differences in interference from auditory distractors emerged when sensory differences between young and older adults were eliminated in language perception tasks (Murphy, McDowd, & Wilcox, 1999; Schneider, Daneman, Murphy, & Kwong See, 2000). This suggests that previous findings in which perceptual distinctiveness of targets and distractors reduced inhibition deficits in a language perception task (Carlson et al., 1995; Connelly, Hasher, & Zacks, 1991) may reflect the poorer sensory acuity of older adults.

Semantic Processes and Aging

Processing a semantically related word may produce facilitation of or interference with production of a target word, depending on the SOA and the nature of the semantic relation (competitor vs. associate; Cutting & Ferreira, 1999; Wheeldon & Monsell, 1994). In Experiments 1 and 2, semantically related distractors were competitors with the target picture and slowed latency when presented slightly before the picture, as is typically observed (e.g., Schriefers et al., 1990). The basis for the interference is that picture processing triggers the spread of semantic priming to lexical representations of words that share components of meaning. This increases the level of priming at the lexical node for the distractor (compared with an unrelated distractor), prolonging lexical selection of the target. Inasmuch as older adults show larger faciliatory semantic priming effects (e.g., Laver & Burke, 1993), we expect them to show larger semantic interference because both effects involve the same mechanism: the transmission of priming along semantic connections linking conceptually related lexical nodes.

Why are semantic facilitation and interference effects larger for older than for young adults? Within NST, transmission of priming in the semantic system is aided by the many connections that link lexical nodes for semantically related concepts. Priming summates across multiple connections, reducing the effect of a transmission deficit in any single connection. Moreover, an increase in the number of connections transmitting priming between two nodes will increase the summation of priming arriving at a node. We suggest that a richer semantic network develops during adulthood through years of language use, a change reflected in increasing verbal ability during adulthood (Schaie, 1994). An increase in the number of semantic connections would produce greater summation of priming at a lexical node, yielding larger semantic priming effects and larger semantic interference effects. In the present study, we found significant age differences in the semantic interference effect in Experiment 1, but not in Experiment 2. These results are also consistent with age-related semantic priming effects in word recognition because some studies reported no age differences in the magnitude of the effect (e.g., Cerella & Fozard, 1984) and others reported larger effects for older than for young adults (e.g., Bowles & Poon, 1988). An issue for future research is to identify specific properties of semantic relatedness between two concepts that influence whether older adults show larger semantic effects.

Could older adults' greater semantic interference reflect activation of irrelevant information from internal sources? Under this reformulation by Hasher and colleagues, older adults' inhibition deficits allow broader and more diffuse spread of activation among semantic representations (Carlson et al., 1995; Connelly et al., 1991; Hasher et al., 1999). Indeed, it is argued that this broad activation is the source of older adults' greater semantic priming effects that "suggest that with very little context (a single word), more ideas come to mind for older than for young adults" (Hasher et al., 1999, p. 661). On the other hand, automatic activation has been specifically excluded from inhibition deficits (Zacks & Hasher, 1997). Given that age differences in semantic priming effects occur regardless of whether they are based on automatic or attentional processes (Laver & Burke, 1993), the relevance of inhibition deficits for semantic priming or interference is somewhat nebulous. Moreover, evidence for broader activation in older adults is notably absent in findings that response variability is age constant in a variety of semantic tasks, which require a single response (e.g., word association) or multiple responses (e.g., script generation and category instances; see Burke, 1997; Light, 1992; Wingfield & Stine-Morrow, 2000).

Predictions for the effects of inhibitory deficits on language have not been developed within a well-specified model of language processing. Moreover, the distinction between behavioral inhibition and theoretical inhibition is often unclear. As a consequence, predictions for behavior within the inhibition deficit framework may in fact be inconsistent with deficits in theoretical inhibition processes. For example, Cutting and Ferreira (1999) developed a detailed inhibitory model of semantic interference effects in the picture–word interference task. Within this model, inhibitory deficits would reduce semantic interference.[5]

Top-Down Phonological Priming and Aging

In Experiment 1, young adults were faster to name homophone pictures (e.g., *ball*) with an inappropriate-meaning distractor (*prom*) than an unrelated distractor (*lamp*) at –150-ms SOA. Older adults showed no such benefit on picture naming. This age difference in the homophone priming effect was predicted by the transmission deficit hypothesis because the effect is dependent on top-down phonological priming. Because there is no direct phonological relationship between distractor and target, young adults' facilitation must occur through top-down priming from the semantic to the phonological system. This finding of age differences is important because it is consistent with the mechanism proposed to explain older adults' decline in retrieving the phonology and orthography of words given semantic information. Aging increases transmission deficits in top-down pathways from the semantic to the phonological–orthographic system, which explains why older adults produce more spelling errors and TOTs (e.g., Burke et al.,

[5] Models of language production vary in the role assigned to the theoretical inhibition process. According to Cutting and Ferreira's (1999) inhibition model of production, interference from semantically related distractors occurs because the distractor lexical unit inhibits the target lexical unit. Thus, if older adults have an inhibitory deficit, less interference from semantically related distractors should be seen in older than in young adults.

1991; James & Burke, 2000; MacKay & Abrams, 1998; MacKay et al., 1999; MacKay & Burke, 1990).

Our attempt to test transmission deficits in top-down phonological processing in a different distractor picture condition in Experiment 2 met with only partial success. As predicted, older adults showed more interference with S/P compared with unrelated distractors than did young adults, at the −150 SOA. These results are consistent with transmission deficits in older adults, to the extent that the S/P effect is due to top-down priming from the presentation of the picture: Picture processing transmits priming to conceptually related lexical nodes including the distractor, increasing interference, and then on to appropriate phonological nodes, some of which are shared with the picture name, thus speeding production. However, this interpretation must be treated cautiously because the greater facilitation effects for young than older adults with S/P distractors at +150 suggest that phonological relatedness of S/P distractors may interact in unexpected ways with small age differences in semantic processing.

The effect of phonologically related distractors (with no semantic relatedness) was virtually identical for older and young adults (within 1 ms) in both experiments. There has been relatively little research on phonological priming effects in older adults, but the present results are consistent with James and Burke's (2000) finding that prior processing of phonologically related words decreased TOTs and improved correct production of the target word in response to a definition, with all phonological effects age invariant. These effects occurred with a much longer SOA between prime words and target production compared with the present research and were attributed to a different mechanism: a relatively long-term change in connection strength of pathways in the phonological system. Nonetheless, that result supports the conclusion that bottom-up perceptual processing has equivalent effects on the phonological system in both young and older adults.

MacKay et al. (1999) also tested bottom-up perceptual processes and top-down production processes by comparing young and older adults' performance in detecting spelling errors and producing correct spelling. There were no age differences in detecting correct spelling in briefly presented words, a task that involves bottom-up perceptual processes. Older adults, however, performed more poorly in immediately reproducing either the correct or the incorrect spelling of words that they detected correctly. MacKay et al. argued that this age asymmetry in orthographic perception and production reflects the age asymmetry in bottom-up perceptual processes versus top-down production processes.

Conclusion

There is growing evidence against inhibition deficits in old age. Recent research suggests there may be some task specific effects (e.g., McCrae & Abrams, 2001), although previous hypotheses about experimental conditions that reveal inhibition deficits have not weathered experimental tests (e.g., Schooler, Neumann, Caplan, & Roberts, 1997). The present results also provide little support for inhibition deficits in language production under specific experimental conditions, although predictions for the consequences of inhibition deficits are handicapped by the absence of a model of theoretical inhibition in language processing.

The present findings provide insight into why age-related declines are found in word production tasks such as picture naming and spelling, whereas no age declines are found in tasks involving on-line perception and comprehension. These production tasks require the retrieval of phonology or orthography through top-down priming because perceptual cues to phonology and orthography are absent. Comprehension tasks require the retrieval of semantic information through bottom-up processing of phonology or orthography. The behavioral asymmetry in age differences reflects the architecture of the phonological and semantic systems that make top-down phonological priming more vulnerable to age-related transmission deficits than bottom-up priming.

Within NST and other interactive activation models, frequent activation of nodes increases the strength of their connections. This explains why words that occur frequently in the language are less likely to suffer retrieval failures than less common words (e.g., Burke et al., 1991; Harley & Bown, 1998). Nonetheless, the present results suggest that detectable age-related transmission deficits occur even in the relatively high-frequency words used in the present study, although clearly not of the same magnitude as those that produce retrieval failures in TOTs.

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