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Language and Aging

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Language in old age has been an active research area since early experimental investigations in cognitive aging (e.g., Craik & Masani, 1967; Riegel & Riegel, 1964). This is undoubtedly because of the profound importance of language throughout the lifespan not only in cognition, but in social interactions as well. Declines in language processing, such as increased difficulty in understanding spoken language or in producing a word while speaking, undermine older adults' ability and desire to communicate, and can erode evaluation of their language competence by themselves and by others (e.g., Hummert, Garstka, Ryan, & Bonnesen, 2004; Ryan, See, Meneer, & Trovato, 1994). Negative self-appraisal promotes withdrawal from social interaction, and negative appraisal by others promotes their use of oversimplified speech to older adults (Hummert et al., 2004; Kemper, Finter-Urczyk, Ferrell, Harden, & Billington, 1998). This downward cycle highlights the practical significance of identifying patterns of change in language during adulthood and old age, especially since there is good news about aging in this research. The aging pattern is characterized by stability and improvement during adulthood in some language functions, unlike other cognitive abilities such as episodic or working memory which are characterized by quite uniform age-related decrements.

Research on language processing has also played an important role in the development of theory in cognitive aging (e.g., Baltes, Staudinger, & Lindenberger, 1999; Burke, Mackay, & James, 2000; DeDe, Caplan, Kemptes, & Waters, 2004; Hasher, Lustig, & Zacks, in press; Kemper, 2006;

Light, 1991; MacKay & Abrams, 1996; Madden, 2001; Murphy, Craik, Li, & Schneider, 2000; Tun, Wingfield, Stine, & Mecsas, 1992). We will briefly review six theories of cognitive aging that motivate much of the research reviewed in this chapter. These theories postulate age-related resource deficits, general slowing, inhibition deficits, transmission deficits, declining working memory, or sensory/perceptual deficits. Some of these theories are not independent inasmuch as resource deficits are sometimes specified as declines in processing speed, efficiency of inhibition and working memory capacity. We distinguish these models, however, because they are conceptually distinct and vary in their relevance to different research paradigms.

Testing these aging theories is aided by the fact that language research in general is a theoretically well-developed area of cognitive science. There are a number of well-specified models of the organization of the language system and although there are areas of controversy, (e.g., Caramazza, Costa, Miozzo, & Bi, 2001; Levelt, Roelofs, & Meyer, 1999), there is also agreement about aspects of the architecture and mechanisms. We outline basic principles of a modal model of comprehension and production that are relevant to aging research, and then turn to the six cognitive aging theories relevant to language comprehension and production in old age.

THE LANGUAGE SYSTEM

Figure 8.1 illustrates a tiny portion of the language system within a model with connectionist architecture and localist/symbolic representations. A vast network of pathways connects representational units organized into subsystems. The *semantic subsystem* represents proposition and word meanings and lexical information such as syntactic class. The *phonological/orthographic subsystem* represents word sounds and spellings (e.g., Burke, MacKay, Worthley, & Wade, 1991; Caramazza, 1997; Dell, 1986; Levelt et al., 1999; MacKay, 1987; Schwartz, Dell, Martin, Gahl, & Sobel, 2006). Although aging models have postulated distributed deficits in specific processes, for example, speed of propagation of excitation in the network (e.g., Salthouse, 1996), aging research has not used models with distributed representations wherein semantic, phonological and orthographic information is represented by patterns of activation over sets of units (e.g., Rogers & McClelland, 2004). Because we emphasize here language models that have been used as a framework in cognitive aging research, our modal model has localist rather than distributed representation.

Retrieval of information encoded in a representation occurs when

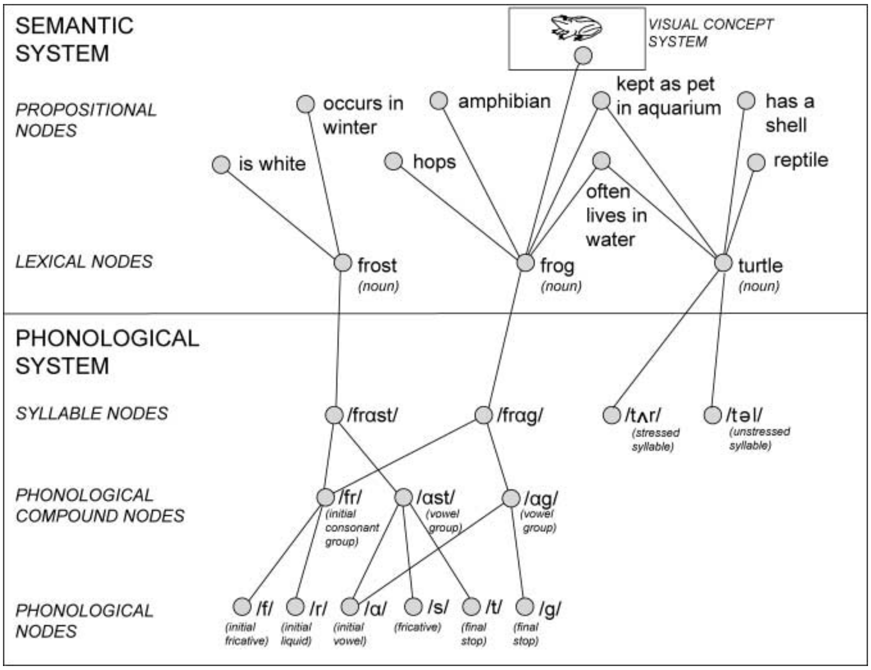

FIG. 8.1 Example of representation of some semantic, syntactic and phonological information in an interactive activation model. Many nodes necessary for perceiving or producing these words have been omitted to simplify the figure.

excitation reaches a threshold, either absolute or relative to the level of excitation of other representations in the domain (Levelt, 2001). We use the term *priming* to refer to pre-threshold excitation that prepares a representational unit for activation, the process that triggers retrieval (MacKay, 1987). Relative thresholds explain, for example, neighborhood effects wherein words that have many phonologically related neighbors are more difficult to hear than words with few neighbors. This occurs because it takes more perceptual processing for the presented word to achieve threshold relative to its phonologically related neighbors, which have also accumulated priming (e.g., Luce & Pisoni, 1998). Interactive activation models of language feature parallel bottom-up and top-down connections between representations that transmit priming between semantic, lexical and phonological/orthographic levels (see Figure 8.1) allowing feedback among representations at different levels (e.g., Cutting & Ferreira, 1999; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; MacKay, 1987; Rapp & Goldrick, 2000; Schwartz et al., 2006; but see Levelt et al., 1999). During lexical selection, priming spreads to connected units that share semantic or phonological characteristics with the target word (see Figure 8.1). Language comprehension and production depend on how fast and how much priming can be transmitted across the connections that link representations.

In comprehension of spoken language, the speech signal must be mapped onto abstract phonological representations such as phonemes and syllables. Priming is transmitted bottom-up from phonological representations to corresponding lexical and conceptual representations. This spread of excitation is interactive, cascading bottom-up from the phonological system to the semantic system and top-down from lexical and semantic representations to phonological representations. This interactive activation pattern provides the basis for top-down context effects on speech perception. For example, word recognition is more accurate when the target word is presented in a semantically relevant sentence that predicts the word than when it is in an unrelated sentence (e.g., Speranza, Daneman, & Schneider, 2000). Within these models, top-down excitation can compensate for reduced bottom-up excitation caused by degraded input as occurs with age-related loss of acuity (cf., Marslen-Wilson & Welsh, 1978).

Production of spoken language begins with the activation of a concept or message to be expressed. Excitation spreads top-down from conceptual representations to corresponding lexical and phonological representations. A word is produced when the lowest level representations, muscle movements, are activated (Dell, 1986; Levelt et al., 1999; MacKay, 1987). During production, top-down priming to the phonological level spreads back up to lexical representations for words phonologically related to the target word, and then back down to the target phonological representations, increasing their priming levels and moving them closer to threshold for retrieval. This interactive spread of priming explains, for example, why large phonological neighborhoods facilitate production: the larger the number of phonologically related neighbors of a word, the greater the cascade of priming to target phonological representations and the faster they will reach threshold (Vitevitch & Sommers, 2003).

Within current models, words and sentences are computed during comprehension and production, in contrast to having pre-existing unitary representations. The mechanism for encoding the correct serial order of sounds within a word and of words within a sentence is a highly significant problem (Lashley, 1951). Most interactive activation models postulate generative rules that define the sequencing possibilities of all representations at a given level. Rules are stated in terms of domains of representations, for example, syntactic rules govern lexical domains (noun, verb, etc.), and segmental rules govern phonological domains (initial consonant, vowel, end consonant, etc.). In production, generative rules determine which lexical domain may be activated at each point in construction of a sentence. The most primed word in a lexical domain is selected, and this explains why most word errors in production are from the same syntactic class as the intended word; only representations from a particular domain will be "eligible" for activation (Dell, 1986; MacKay, 1987). Thus transmission of priming and activation dynamics are critical for selection of the correct syntactic domain and the correct word within that domain. Indeed, errors in picture naming have been simulated by varying parameters of activation dynamics (Saffran, Dell, & Schwartz, 2000).

In comprehension, sentences must be syntactically parsed and a representation of the sentence meaning is created as well as a model of the discourse more globally. Selection of lexical meaning is influenced by both local and discourse level context. For example, the speed of word identification is affected by the compatibility of the word's meaning with the meaning of adjacent words as well as the meaning of the global discourse (see Ledoux, Camblin, Swaab, & Gordon, 2006 for a review). Comprehension models emphasize that the construction of sentence meaning occurs within a limited capacity system. In an influential model, Just and Carpenter (1992) argued that working memory stores perceptual input and the products of semantic and syntactic computations. Storage and computational processes require priming (spreading activation in their model) and the amount of priming available is limited, providing the basis for capacity limitations (for a different view see Caplan & Waters, 1999; Waters & Caplan, 2001, 2005; and cognitive aging models below). Thus, language deficits can be caused by limitations in working memory capacity. In contrast, capacity constraints are often absent from models of language production. This difference between comprehension and production models is reflected in explanations of age-related changes in language comprehension versus production. For example, capacity reductions figure prominently in accounts of age-related declines in language perception and comprehension, but not in production with the exception of production of complex syntax (e.g., Kemper & Kemptes, 1999).

COGNITIVE AGING MODELS OF LANGUAGE PROCESSING

We outline below the basic principles of several models of cognitive aging, emphasizing the characteristics of these models most relevant to research on language and aging. One important task for these models is to explain why some language functions decline with aging and others do not. For example, there is considerable evidence that semantic processing at a lexical and discourse level is maintained in old age whereas complex syntactic processing declines. Also, age-related decline is seen in retrieval of phonological and orthographic information about a word, but not in retrieval of lexical semantics (e.g., Burke & MacKay, 1997; Thornton & Light, 2006). As we will see, aging models tend to focus on decrements in language performance and there has been little attempt to evaluate the compatibility of models with both the positive and negative components of older adults' language functioning that we review below. Another challenge for cognitive aging models is to explain the impact of older adults' auditory and visual sensory deficits on higher level language functions. What is the mechanism whereby impairment at the sensory level affects processing at higher semantic or syntactic levels? Finally, cognitive aging models of language must be testable and this requires behavioral measures of critical mechanisms, for example, resources or inhibition. As we will see, there has been mixed success in locating these mechanisms within a language model and in identifying behavioral measures of each mechanism.

Resource theory is based on the idea that human capacity for processing information is limited (e.g., Miller, 1956) because a finite pool of attention or resources is shared by different mental processes that occur simultaneously or in close succession (Kahneman, 1973). Thus, under some conditions there may be insufficient resources to complete all the component processes necessary for accurate performance (e.g., Rabbitt, 1968). Resource theory explains age declines in performance by postulating that older adults have reduced resources compared to young adults and that certain operations are more resource demanding for older than young adults. Consequently, older adults reach the point where available resources are insufficient to complete a task before young adults do (Craik & Byrd, 1982; Hasher & Zacks, 1979; McCoy, Tun, Cox, Colangelo, Stewart, & Wingfield, 2005; Murphy et al., 2000).

What are resources? Definitions include processing speed, working memory, attention, and inhibition (Light, 1991; Salthouse & Craik, 2000; Wingfield & Stine-Morrow, 2000). There has been considerable criticism of the vacuity attached to definitions of resources and their underlying mechanisms (Light & Burke, 1988; MacKay, Hadley, & Abrams, 2006a; MacKay & James, 2001; McDowd & Shaw, 2000; Navon, 1984; Salthouse & Craik, 2000). Perhaps because of this criticism, recent studies of language and aging tend to focus on a specific resource, e.g., speed, inhibition or working memory, and there has been some attempt to follow Salthouse and Craik's recommendation to conceptualize resources in terms of specific behavioral measures (for problems with these attempts see Burke & Osborne, in press; MacKay et al., 2006a; Schneider, Daneman, & Murphy, 2005; Waters & Caplan, 2001).

The use of the broad term "resources" in Kahneman's (1973) sense of mental energy is used in language research primarily to explaining the relation between perception and memory. It is known that the difficulty of perceiving a word affects subsequent mental operations such as how well it is remembered (Aaronson, 1974; McCoy et al., 2005; Rabbitt, 1968). Within the resources framework, this is because difficult perceptual operations use more resources and this drains resources from subsequent cognitive operations, including language and memory processes. Age-related declines in sensory processing increase the difficulty of identifying words so that older adults, relative to young adults, have reduced resources remaining for subsequent cognitive operations involving those words (McCoy, Tun, Cox, Colangelo, Stewart, & Wingfield, 2005; Wingfield, Tun, & McCoy, 2005). Within the framework presented in Figure 8.1, resource limitations have been conceptualized as limitations in the amount of priming or activation that is shared among language processes and maintenance of items in memory (Haarmann, Just, & Carpenter, 1997; Just & Carpenter, 1992; Saffran et al., 2000). This level of specificity increases the predictive power of a resource model, but has not been developed in aging models which remain challenged by the need to specify resources in terms of a theoretical mechanism and a behavioral measure.

Theories focusing on a specific definition of resources, namely, speed, inhibition or working memory, have attempted to identify underlying mechanisms and behavioral measures that isolate the resource. *General slowing theories* postulate that age-related declines in cognitive performance are caused by slowing of component processes (Birren, 1965; Cerella, 1985; Madden, 2001; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1985, 1996, 2000) and are the most extensively researched of theories of cognitive aging. They are supported by findings showing that measures of perceptual-motor speed share much of the age-related variance in performance on a broad range of cognitive tasks, including some language tasks (e.g., Salthouse, 1985). There has been, however, disagreement about whether behavioral measures are successful in isolating speed from other processes, for example, memory processes (e.g., Parkin & Java, 2000).

There are different views on how general age-related slowing is. Some have argued that the amount of age–related slowing is the same for all cognitive operations (Cerella, 1985) and others have argued that slowing differs between verbal and spatial domains (Lima, Hale, & Myerson, 1991). Currently, it is acknowledged that the degree of age-related slowing varies considerably for different cognitive operations (Allen, Madden, & Slane, 1995; Fisher, Duffy, & Katsikopoulos, 2000). Slowing has been applied to older adults' language processing as an explanation, for example, of their greater difficulty in comprehending speeded speech

(Wingfield, 1996), their greater benefit from semantic context in word recognition (Madden, 1988) and their failure to use sentential context to disambiguate homophones (Dagerman, MacDonald, & Harm, 2006).

Salthouse (1996) postulated mechanisms through which general slowing causes errors. Some cognitive operations may be executed too slowly for their successful completion in the available time or their completion may spill over depleting the time available for successive operations. Both outcomes would cause an increase in speech comprehension errors. For example, speed of processing is critical with speech because the signal extends through time and no single moment is adequate for recognition. Rapid processing is essential for correct identification of fast changing components of the speech signal, such as voice onset time that distinguishes /pa/ from /ba/. If the processing is slowed, the stimulus may be gone before identification is possible. Within interactive activation models (see Figure 8.1) slowing would affect the dynamics of priming such as speed of transmission of priming. Slower transmission during a fixed interval would reduce the information that is prepared for activation and retrieval (Dell, 1986; Dell, Chang, & Griffin, 1999).

Slowing impairs functions requiring simultaneous availability of information because information from early processes may have decayed by the time information from later processes is produced. For example, sentence comprehension requires coactivation of successive words and their meaning in the sentence in order to build a representation of the sentence meaning. Comprehension will suffer if processing is so slow that the meaning of initial words has decayed before final words are represented (Saffran et al., 2000). Indeed, aging effects on language that have been attributed to older adults' smaller working memory capacity can be accounted for by slowing alone (MacDonald & Christiansen, 2002).

Inhibition deficit theory proposes that aging weakens inhibitory processes that regulate attention and the contents of working memory, thereby affecting a broad range of cognitive performance, including comprehension and production of language (Hasher et al., in press; Hasher & Zacks, 1988). Inhibition deficit theory has been applied to older adults' language processing to explain, for example, why older adults' performance suffers more from distracting stimuli during reading (Connelly, Hasher, & Zacks, 1991) or listening (Hasher et al., in press; Tun, O'Kane, & Wingfield, 2002), and why older adults' conversations are more likely to go off topic (e.g., Arbuckle, Nohara-LeClair, & Pushkar, 2000). Hasher and Zacks view inhibition as a controlled attentional process that occurs after automatic activation processes during the access function. Some language processing models postulate automatic inhibition of competitors during lexical selection (e.g., McClelland & Rumelhart, 1981), but such obligatory inhibition is not relevant to the Hasher and Zacks model (e.g., Zacks & Hasher, 1997). Nevertheless, inhibition deficits have been invoked to explain age differences in processes not under attentional control, such as competition between phonologically related neighbors and a target word during lexical selection in speech perception (e.g., Sommers & Danielson, 1999).

Working memory theories of cognitive aging build on models that postulate both storage and processing functions for working memory and subsume the principles of *resource theories* (e,g., Baddeley, 1986; Engle, Tuholski, Laughlin, & Conway, 1999; Just & Carpenter, 1992). It is proposed that older adults suffer reductions in working memory capacity and this constrains their ability to comprehend and produce complex semantic content and complex syntax (Kemper & Kemptes, 1999). For example, the computational demands of complex syntax such as left-branching sentences are hypothesized to require more working memory than simpler syntax such as right branching sentences. A listener must retain a longer initial clause in the left-branching sentence "The gal who runs a nursery school for our church is awfully young" than in the right-branching sentence "She's awfully young to be running a nursery school for our church" (from Kemper, Thompson, & Marquis, 2001b). Older adults' preference for producing right-branching sentences has been attributed to their reduced working memory (Kemper & Kemptes, 1999).

Some researchers have argued that language and other cognitive functions share the same working memory capacity that is measured with traditional span tasks (e.g., Just & Carpenter, 1992). Caplan and Waters (1999; Waters & Caplan, 2001, 2005), however, have argued for a dedicated working memory that is specialized for online interpretive processing of sentences, in particular for resolving the syntactic structure and the meaning of the sentence, and is not related to traditional span measures. Traditional measures of working memory span are related to postinterpretive processes which are controlled and conscious, and are involved in, for example, offline tasks such as plausibility judgments and sentence recall. The Caplan and Waters' approach emphasizes the distinction between online and offline language processes, with the former but not the latter unaffected by memory processes. This is an important distinction for aging research which aims to investigate language processes uncontaminated by age-related memory declines.

These working memory models of aging appear to differ conceptually from a general resources model in requiring a separate working memory component that is limited in terms of capacity rather than limited by the overall processing efficiency of the language system. MacDonald and Christiansen (2002) argue that this commits working memory theorists to explaining individual differences in language, including aging effects, in terms of changes in finite capacity (e.g., Just & Carpenter, 1992). An alternative approach is that the processing efficiency of the language system depends on properties such as the rate of transmission of excitation which in turn is influenced by experience or aging, with no working memory structure required. Less efficient processing would deplete finite resources sooner than efficient processing, but there is no difference among groups in finite capacity in this alternative to a working memory model (MacDonald & Christiansen, 2002; Saffran et al., 2000).

Transmission deficit theory is based on a model with connectionist architecture and localist/symbolic representations as in Figure 8.1 (MacKay, 1987). It postulates that connections among representational units in the network are strengthened by frequent and recent use (activation) and are weakened by aging. As connection strength weakens, it decreases the transmission of priming which may become so reduced that it is inadequate to activate connected representations. Aging weakens connection strength universally, causing general processing deficits, rather than deficits limited to a single process such as working memory or inhibition (Burke & MacKay, 1997; MacKay & Abrams, 1996; MacKay & Burke, 1990). Indeed, the theory does not include a resource mechanism and accounts for processing limitations through architecture and activation dynamics (cf. Dell et al., 1997; MacDonald & Christiansen, 2002). The transmission deficit theory is consistent with neurobiological characteristics of aging. For example, age-related atrophy of white matter has been linked to a reduction of the total length of the myelinated fibers of white matter, reducing neural connectivity (e.g., Marner, Nyengaard, Tang, & Pakkenberg, 2003; Tang, Nyengaard, Pakkenberg, & Gundersen, 1997; see Raz, 2000 for a review). At a functional level, consistent with weaker connections, somatosensory event-related potentials show that peripheral and central conduction time slows with aging in adulthood (Shaw, 1992; Tanosaki, Ozaki, Shimamura, Baba, & Matsunaga, 1999).

Although age-related transmission deficits are distributed across the representational system, the functional effects of transmission deficits depend on the architecture of the language system. For example, pathways diverge from the single lexical representation of a word (see Figure 8.1) to the phonological representations that are hierarchically organized in levels of syllables, phonological compounds down to the lowest level of phonological features (not shown in Figure 8.1). The single connections to phonological representations make them more vulnerable to transmission deficits during production, consistent with older adults' increased phonological retrieval failures in tip-of-the-tongue (TOT) experiences (e.g., Burke et al., 1991) and slips of the tongue (MacKay & James, 2004). In contrast to the phonological system, the semantic system is characterized by redundancy and converging of connections among representations that make them less vulnerable to transmission deficits, consistent with older adults' well-maintained semantic processing (e.g., Thornton &

Light, 2006). For example, the representation of the semantic knowledge that *frogs spend time in water* would be an unlikely candidate for transmission deficit and retrieval failure after activation of the lexical representation for *frog*. It would receive excitation not just from the lexical representation but also from associated semantic information, for example, that frogs are amphibians, that they swim, etc.

The sensory/perceptual deficit account or *degraded signal* account is the least developed theory but it makes a straightforward prediction: age-related declines in sensory and perceptual processes yield incomplete or erroneous input to the computation of lower level phonological and orthographic codes; this impairs lexical selection and other subsequent linguistic processes so that older adults select incorrect words or none at all (e.g., Brown & Pichora-Fuller, 2000; Murphy, McDowd, & Wilcox, 1999; Pichora-Fuller & Singh, 2006; Schneider et al., 2005; Schneider, Daneman, Murphy, & Kwong See, 2000; Schneider & Pichora-Fuller, 2000). Under the degraded signal account, impairment in word recognition should be eliminated when accuracy of language perception is equated across age.

As we will see, there is controversy about the extent to which errors in higher level language processes should be attributed to a degraded signal alone, or if resources available for cognitive processes are also required to account for the results (Humes, 1996; Schneider & Pichora-Fuller, 2000; Scialfa, 2002; Tun et al., 2002). There is, however, agreement that age-related perceptual declines directly influence language processing, especially under difficult perceptual conditions (e.g., Madden & Whiting, 2004; Schneider & Pichora-Fuller, 2000; Wingfield et al., 2005).

Organization of this Review

Because of the interactive nature of language processes, it is difficult to isolate processing of phonological/orthographic, semantic and syntactic information. These different types of knowledge, however, constitute different levels in linguistic theory, each with its own generative rules that guide production and understanding of familiar and novel constructions at each level. Within psycholinguistic models, the levels involve different architectures and mechanisms and thus may vary in their sensitivity to aging. We review relevant research for each of these three levels in separate sections. Within each section we organize our review by the units of analysis in the research, namely word, sentence and discourse, where relevant, and by the language function, namely comprehension/perception or production. We tend to focus on research published since Wingfield and Stine-Morrow's (2000) excellent review of language and aging in the last *Handbook of Aging and Cognition*.

PERCEPTION OF PHONOLOGY AND ORTHOGRAPHY

Visual and auditory acuity show steady decline with aging during adulthood with some studies showing an increased rate of decline after the age of 70 years (e.g., Baltes & Lindenberger, 1997; Committee on Hearing and Bioacoustics and Biomechanics [CHABA], 1988; Corso, 1971; Lindenberger & Baltes, 1994; Salthouse, Hancock, Meinz, & Hambrick, 1996). Baltes and Lindenberger (1997) pointed out that there had been little consideration of age differences in sensory functions in studies of aging effects on cognition. Indeed, Schneider and Pichora-Fuller (2000) reviewed 288 published articles measuring young and older adults' cognitive performance involving auditory or visual stimuli. Acuity was measured in only 18% of the studies using auditory stimuli and in only 21% of the studies using visual stimuli, and in only six studies was acuity covaried in the statistical analyses.

Thus, investigation of the sensory analysis of spoken or written language and investigation of higher level language processes have been carried out in remarkably separate domains of aging research. The relative lack of contact between these two separate subfields, namely sensory aging and cognitive aging, is surprising in the investigation of language because models of language processing emphasize the interaction between sensory, lexical and semantic processes (e.g., Dell, 1986; Marslen-Wilson & Welsh, 1978; McClelland & Rumelhart, 1981; Rapp & Goldrick, 2000). Moreover, it is well established that when perceptual processing becomes more difficult, higher level cognitive functions may suffer (Aaronson, 1974; Rabbitt, 1968).

Recently, however, interest in the interaction between sensory and cognitive processes in language has grown (e.g., Murphy et al., 2000; Pichora-Fuller & Singh, 2006; Wingfield et al., 2005), stimulated in part by compelling evidence that decline in sensory processes strongly affects higher level cognitive processing of language in old age (see Schneider & Pichora-Fuller, 2000 for an excellent review). Several different investigative approaches link sensory declines to language performance.

Correlations between Visual/Auditory Acuity and Language Performance

Large-scale cross-sectional and longitudinal studies have demonstrated that considerable age-related variance in cognitive performance is shared with measures of auditory and visual acuity. Many of these studies included a few measures of language functions in their cognitive batteries, for example, vocabulary tests, category fluency, confrontation naming of pictures, and the National Adult Reading Test (NART) requiring pronunciation of irregularly spelled words (e.g., Anstey, Hofer, & Luszcz, 2003; Anstey, Luszcz, & Sanchez, 2001; Anstey & Smith, 1999; Baltes & Lindenberger, 1997; Christensen, Mackinnon, Korten, & Jorm, 2001; Ghisletta & Lindenberger, 2005; Lindenberger & Baltes, 1994). The tests primarily measure semantic and phonological retrieval at the word level, and are relatively undemanding in terms of sensory processes because they tend to be untimed and stimuli are available for repeated inspection (e.g., NART). Nonetheless, language tests and visual and auditory acuity share considerable age-related variance. For example, Baltes and Lindenberger (1997) reported that controlling for auditory and visual acuity produced a 20-fold decrease in the age-related variance in language measures, eliminating the significant effect of age.

Several accounts have been proposed to explain the relation between sensory acuity and cognitive performance, including language tests, in these large-scale studies (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994; Salthouse et al., 1996). Although older adults' sensory declines may produce a degraded signal, this approach cannot explain why the link between language performance and sensory acuity occurs even when they involve different sensory modalities (Lindenberger & Baltes, 1994), or why language performance is correlated with physiological markers such as respiratory efficiency (Christensen et al., 2001). Moreover, degraded input would have little influence on tests such as fluency where the only sensory input is the instructions. In an experimental test of the degraded signal hypothesis, Lindenberger, Scherer, and Baltes (2001) reduced visual and auditory acuity of middle-aged adults to the level of adults aged 70 to 84 years but found no decline in their performance on the cognitive tests used in their earlier studies (e.g., Lindenberger & Baltes, 1994; but see Gilmore, Spinks, & Thomas, 2006 for a contrary result).

The dominant explanation of why sensory acuity shares age-related variance with cognitive performance in these large scale studies is that a *common cause* is responsible for age-related decline in sensory and cognitive functions, including language (but see Anstey et al., 2003). This account is supported by findings that sensory, language and other cognitive measures load on a common cause factor in samples with a large or narrow age range (Christensen et al., 2001). Candidates for the common cause are the structural and physiological integrity of the brain (Baltes & Lindenberger, 1997; Li & Lindenberger, 2002) or the integrity of conscious cognitive processes (Salthouse, Hambrick, & McGuthry, 1998). However, age does not have a homogeneous effect on the neurophysiological integrity of different regions of the brain. Structural MRI analyses have demonstrated that the rate of gray matter atrophy with age varies for different brain regions (Good, Johnsrude, Ashburner, Henson, Friston, &

Frackowiak, 2001; Ohnishi, Matsuda, Tabira, Asada, & Uno, 2001; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003; Sowell, Peterson, Thompson, Welcome, Henkenius, & Toga, 2003) and fMRI has demonstrated that age differences are found in neural activation of some brain regions and not others (see Raz, 2000 for an excellent review of differential vulnerability of neural regions). This differential age sensitivity of neural regions predicts that the amount of age-related variance accounted for by sensory acuity would depend on the neural substrate for the cognitive function, contrary to the common cause hypothesis. This is especially relevant to language functions where there is considerable regional specificity of semantic, phonological and orthographic processes (e.g., Indefrey & Levelt, 2004).

The cross-sectional and longitudinal studies investigating the relation between sensory and cognitive performance used only a few language measures that depended heavily on vocabulary size. A far more extensive relationship between sensory functioning and language processes has been demonstrated in experimental studies that examine language performance after manipulating sensory processing either directly or statistically so that young and older adults' recognition accuracy is equivalent. These studies provide evidence that the efficiency of sensory processing directly affects the integrity of higher level language processes. This is a specific factor that may, in addition to a common cause, contribute to the relation between sensory and language functions. We consider first research on the effect of perceptual factors on older adults' auditory language processing.

Speech Recognition: Effect of Auditory Sensory and Perceptual Changes

Presbycusis is age-related hearing loss, influenced by both physiological and environmental factors, and is characterized by bilateral loss of higher frequencies, the frequencies important for speech (e.g., Cheesman, 1997; CHABA, 1988). In a sample of adults older than age 65, about one third report significant hearing loss (Pichora-Fuller & Singh, 2006). The relation between acuity and speech recognition is well established. For example, in the Framingham Heart Study pure tone thresholds for 1662 participants aged 63–92 years predicted correct word recognition (Gates, Feeney, & Higdon, 2003; see also Humes, Watson, Christensen, Cokely, Halling, & Lee, 1994; van Rooij & Plomp, 1990). Consistent with this relation between acuity and speech intelligibility, older adults with hearing loss are poorer than normal hearing older adults at identifying speech stimuli ranging from syllables to sentences (Halling & Hume, 2000; Phillips, Gordon-Salant, Fitzgibbons, & Yeni-Kombshian, 2000).

There are, however, factors in addition to presbycusis that contribute to older adults' reduced ability to recognize speech (CHABA, 1988; Schneider, 1997; Schneider & Pichora-Fuller, 2000). Although much of the variance in speech intelligibility is accounted for by pure tone thresholds (Humes, 1996), age differences linger when young and older adults are matched on hearing loss, and for normal hearing adults when the speech is speeded or presented in noise (e.g., CHABA, 1988; Corso, 1971; Humes & Christopherson, 1991). These findings implicate age-related changes in auditory perceptual functions beyond acuity and higher level cognitive functions important for speech recognition. We turn to this issue next.

Auditory temporal processing is a critical perceptual function that declines with age and affects older adults' speech perception, especially for the fine structure of the speech signal (Fitzgibbons & Gordon-Salant, 1996; Humes & Christopherson, 1991; Schneider & Pichora-Fuller, 2001). Aging is associated with loss of auditory temporal synchrony in both the peripheral and central nervous system (e.g., Brown & Pichora-Fuller, 2000; Schneider, 1997). In an attempt to simulate age-related asynchrony in young adults, Brown and Pichora-Fuller (2000) presented sentences to young adults that had been "jittered" by changing slightly the timing of successive amplitudes in the speech signal. Young adults' performance in identifying and remembering the final word in the jittered sentences resembled older adults' performance with intact sentences, consistent with the hypothesis that older adults' speech processing is disrupted by internal jitter.

Detection of temporal gaps and the order of sounds are other aspects of auditory temporal processing that decline with aging (Fozard & Gordon-Salant, 2001; Schneider, Pichora-Fuller, Kowalchuk, & Lamb, 1994; Schneider, Speranza, & Pichora-Fuller, 1998; Trainor & Trehub, 1989). Older adults' gap detection threshold is about twice the size of young adults' (Schneider, Daneman, & Pichora-Fuller, 2002). Gap detection thresholds are negatively associated with recognition of syllables in noise (Phillips et al., 2000) and words in noise (Snell, Mapes, Hickman, & Frisina, 2002) but are uncorrelated with audiometric thresholds suggesting that temporal acuity is unrelated to hearing loss (Schneider et al., 1994). Perception of temporal acoustic cues is essential for distinguishing speech sounds that differ in voice onset time (VOT), as in /pa/ versus /ba/, because the initial phonemes differ primarily in the interval between the consonant stop release and the onset of voicing. Older adults performed more poorly than young adults in discriminating speech sounds that differ in VOT (Strouse, Ashmean, Ohde, & Grantham, 1998; Tremblay, Piskosz, & Souza, 2002), whereas age differences have not been found in discriminating vowels which are more steady state than consonants (Coughlin, Kewley-Port, & Humes, 1998). Despite the evidence for age-related declines in temporal processing of segmental and subsegmental speech cues, temporal processing at the supra-segmental level is well maintained in the use of prosody (Wingfield, Lindfield, & Goodglass, 2000).

Frequency discrimination also depends on temporal synchrony and is a critical component of speech perception; aging impairs frequency resolution ability (Schneider, 1997). Individual differences in the ability to resolve frequency may explain why some adults with hearing loss have good ability to recognize speech while others do not. Older adults with mild hearing loss and poor speech recognition were impaired in frequency resolution of complex stimuli compared to older adults also having mild hearing loss but with good speech recognition (Phillips et al., 2000).

These studies suggest a direct effect of age-related sensory and perceptual changes on language processing. The contribution of cognitive factors to speech recognition has been examined in experiments that degrade speech either with background distraction or by fast presentation rates. We turn to these studies next.

Speech Recognition: The Interaction of Perception and Cognition

Resources, Inhibition and Word Recognition with Distraction

Older adults complain about the difficulty of perceiving speech under conditions where there is a noisy background or multiple people speaking at once. Laboratory research supports this complaint because older adults' speech recognition declines more than young adults' as the signal to noise ratio (SNR) decreases (CHABA, 1988; Snell et al., 2002; Tun, 1998), even when there are no detectable age differences in performance in quiet (e.g., Dubno, Dirks, & Morgan, 1984; Pichora-Fuller, Schneider, & Daneman, 1995; Tun & Wingfield, 1999). These studies find age deficits at a noise level typical of common everyday environments such as restaurants, subways and parties, and thus we would expect older adults' speech recognition to be impaired in these environments.

Although it is generally acknowledged that older adults' sensory and perceptual deficits contribute to their vulnerability to noisy backgrounds (CHABA, 1988; Humes, 1996; Schneider & Pichora-Fuller, 2000; Tun & Wingfield, 1999; Wingfield et al., 2005), there is disagreement over the relative importance of sensory and cognitive factors. Some researchers argue that older adults' vulnerability to noise is primarily a consequence of auditory not cognitive deficits (Humes, 1996; Li, Daneman, Qi, & Schneider, 2004; Schneider et al., 2000, 2002). This position is consistent with the correlations found between the level of speech recognition in noise and perceptual functions, for example, gap detection (Snell et al., 2002). In contrast, other researchers have argued that cognitive deficits play a major role in noise effects (Hasher et al., in press; Sommers & Danielson, 1999; Tun et al., 2002). Under the resources account, aging reduces resource capacity and increases resources required during word recognition because of sensory deficits, leaving older adults insufficient resources for comprehension and memory (Pichora-Fuller et al., 1995; Wingfield et al., 2005). Under the inhibition deficit account, perception of speech in noise is a selective attention task in which older adults' inhibition deficits impair their ability to selectively attend to the target speech and ignore the irrelevant background noise (Hasher et al., in press; Tun et al., 2002; Tun & Wingfield, 1999). Under general slowing, older adults are impaired more in noise because fast processing is necessary to analyze bits of target speech that are available during pauses in the noise but that must be analyzed before being masked by subsequent input (Tun & Wingfield, 1999).

Some of the most powerful evidence supporting a primary role for age-related sensory deficits comes from experiments that eliminate older adults' sensory deficit by equating perceptibility of stimuli across age. If perceptual problems are responsible for older adults' impaired language processing in noise, then age differences observed when young and old are tested with no acuity adjustment should disappear when SNR is adjusted on the basis of each participant's threshold for word recognition in noise. On the other hand, if diminished inhibition or resources contribute to older adults' impaired language processing in noise, then this adjustment for acuity will not eliminate age differences in the negative effect of increased background noise levels. When Schneider et al. (2000) presented prose passages at an adjusted SNR, age differences in correct answers to detail questions about the passage were eliminated at all SNRs except the lowest. Schneider et al. argued for the degraded signal account: age-related declines in perceptual processes produce errors in the perceptual representation of speech and these errors impair subsequent comprehension and memory, especially for details in the prose that may be easy to miss when audition is poor. Even when Schneider et al. added a secondary task, its effect on correct responses was the same for young and older adults.

Using the same SNR adjustment technique to compensate for age differences in hearing, Murphy, Daneman, and Schneider (2006) eliminated age differences in recall of dialogues presented in quiet and noise except when the two speakers were spatially separated. This suggests that older adults' difficulty in following conversations may be a consequence of perceptual deficits in word recognition and in using auditory cues to spatially differentiate the speakers. Murphy et al. (1999) equated speech intelligibility across age and in three experiments, each using a different distraction paradigm, found that when stimuli were equivalent in perceptibility across age, there was no age-related deficit in the effect of distracting information. These results are consistent with a degraded signal account, but not with either an inhibition deficit or a resource account which predict that older adults will show a greater effect of factors that tax inhibition or resources, namely noise, distraction or a secondary task.

Tun et al. (2002) reached different conclusions about the role of inhibition deficits. They argued that if distracting irrelevant speech has a greater effect on older adults' speech processing because of their sensory declines, then the semantic content of the distracting background speech should be irrelevant to the age difference (Lustig & Hasher, 2001). They found that recall of sentences was impaired more for older than young adults when the distraction was meaningful text compared to random words or quiet. Recall in the distraction conditions was related to performance on the Trail Making Test which the authors interpreted as evidence that processing speech with distraction involves executive control processes (but see Salthouse et al., 2000 for alternative interpretations of the Trail Making Test). Li et al. (2004) reported comparable decline across age in sentence recall with syntactically correct but meaningless sentences as distraction compared to white noise. Moreover, spatial separation of target and distraction virtually eliminated the difference in interfering effect of speech and noise for both young and older adults, providing no evidence that older adults were less able to ignore distraction. Future research is needed to identify the critical characteristics of distracting speech that are required for age differences in the distraction effect. Moreover, online measures in addition to memory measures would indicate whether age differences in distraction effects occur during language processing, or after.

Finally, McCoy et al. (2005) manipulated the difficulty of word recognition not with noise, but by comparing normal and hearing impaired older adults and by manipulating the amount of predictive context. With words correctly identified, recall declined more for impaired than normal adults and more for the low versus high predictive contexts. Under the resources account, the greater perceptual difficulty imposed by hearing impairment and low context drains resources from memory processes. The results are not compatible with the degraded signal account alone because the words were perceived correctly.

In summary, the investigation of sensory and cognitive factors influencing age differences in language processing in noise has yielded results that are not consistent in their entirety with a single theoretical account. Much of the evidence suggests that equating word recognition across age removes age differences in the effects of noise, contrary to the inhibition deficit account. The strongest case, however, for the primary role of perceptual rather than inhibition deficits can be made when an interaction between age and noise level occurs without adjustment for acuity and then disappears with the acuity adjustment. This has not been demonstrated. The resources account of perceptual effects is supported by evidence that older adults' recall is impaired under conditions where they have correctly identified the signal, but word recognition is difficult because of hearing impairment or poor semantic context.

Phonological Neighborhood

Word recognition is also influenced by a "background" that is activated internally during word recognition, namely, words that share phonemes with the target word, known as the phonological neighborhood. Words with dense neighborhoods have many phonological neighbors and are more difficult to perceive than words with sparse neighborhoods, an effect attributed to lexical competition for recognition among phonologically similar words in the lexicon (Luce & Pisoni, 1998). Sommers (1996; Sommers & Danielson, 1999) adjusted SNRs for young and older adults so that identification of sparse neighborhood (easy) words was the same across age. Using these adjusted SNRs, identification was poorer for dense neighborhood (hard) words, with greater decline in identification for older than young adults. Sommers attributed older adults' greater neighborhood density effect to inefficient inhibition of alternative words that competed during lexical selection. Consistent with this, young and older adults' ability to identify dense neighborhood words was negatively related to an interference score derived from tasks believed to measure inhibition such as Stroop (Sommers & Danielson, 1999). These findings suggests that inhibition occurring automatically during lexical selection, (involved in the neighborhood effect) is related to inhibition that is under conscious control (involved in ignoring a Stroop baseword) and that both are negatively affected by aging (cf. Zacks & Hasher, 1997).

Studies testing young normal hearing adults and older adults with hearing loss, however, found comparable effects of high neighborhood density (plus low word frequency) on word recognition across age (Carter & Wilson, 2001; Takayanagi, Dirks, & Moshfegh, 2002). Clearly, the relation of aging and acuity to phonological neighborhood effects is an important area for future research. It is interesting to note in this context that strong *semantic* competitors that are primed internally during lexical selection because of shared semantic features, not sensory features, show equivalent effects on word production and recognition for young and older adults (Persson, Sylvester, Nelson, Welsh, Jonides, & Reuter-Lorenz, 2004; Prull, Godard-Gross, & Karas, 2004; Stine & Wingfield, 1994).

Effect of Speech Rates on Perception

When speech rates are accelerated, older adults decline more than young adults in speech perception (Gordon-Salant & Fitzgibbons, 1999), comprehension (Wingfield, Peelle, & Grossman, 2003), and recall (Stine, Wingfield, & Poon, 1986; Tun et al., 1992; Wingfield, Poon, Lombardi, & Lowe, 1985; Wingfield, Tun, Koh, & Rosen, 1999). Recall of accelerated speech improves with practice and the improvement is comparable for young and older adults, although older adults show less transfer of improvement to different accelerated speech rates (Peelle & Wingfield, 2005). Increasing meaningfulness and syntactic structure also improved speech processing at fast rates and the improvement is often greater for older adults (Gordon-Salant & Fitzgibbons, 2001; Wingfield et al., 1985). Indeed, age differences in comprehension of meaningful sentences often do not occur until speech rates become very fast, for example, at least 595 wpm for short sentences, a rate that would not be encountered in normal everyday conversation (Wingfield et al., 2003). As we saw in studies of background noise, older adults are adept at using linguistic context to aid processing. It is clear, however, that in general older adults perform better at slower speech rates and that they prefer them (Wingfield & Ducharme, 1999).

Both degraded signal accounts and cognitive accounts have been used to explain why fast speech rates affect older adults more than young adults and there is disagreement about which account is primary (e.g., Schneider et al., 2005; Wingfield et al., 2005). The usual method for speeding speech rates is to eliminate tiny segments of speech at regular intervals. The degraded signal account postulates that speeded speech primarily affects the difficulty of perceptual processing by making transient acoustic cues even briefer, compounding older adults' problems in processing temporal aspects of the speech signal that are critical for word recognition (Gordon-Salant & Fitzgibbons, 2001). Thus older adults may not correctly perceive compressed words. Adding a resource account, the increased difficulty of perception drains resources from higher level cognitive processes. On the other hand, faster speech rates reduce the time available for processing and this may directly disrupt older adults' syntactic, semantic and memory processes, as well as perceptual processes, under general slowing.

Although hearing impairment increases speech compression effects for both young and older adults (Gordon-Salant & Fitzgibbons, 2001; Wingfield, McCoy, Peelle, Tun, & Cox, in press), older adults perform more poorly than young adults with compression even when tone or speech thresholds are matched across age (Wingfield et al., 2003). These results do not eliminate the degraded signal account because older adults' deficit in processing transient cues may only be visible under speeded conditions; matching thresholds in unspeeded conditions would not control this deficit in temporal processing.

Wingfield and his colleagues reported that syntactically difficult sentences impaired comprehension compared to syntactically simpler sentences, and the impairment increased with compression and more so for older adults and hearing impaired adults (Wingfield et al., in press; Wingfield et al., 2003). They argued that compression affects both the quality of the speech signal and higher level syntactic processes. Under the resource account, compression exacerbates older adults' sensory deficits and the greater difficulty of sensory analysis reduces time or resources available for subsequent syntactic processes. Under general slowing, compression may limit the time available for syntactic processing, independent of sensory analysis, which will impair older adults more because they are slower to complete syntactic analysis. The degraded signal account is inadequate because the quality of the stimulus should not be affected by syntactic complexity.

One approach to differentiating the degraded signal and slowing accounts is to increase speech rate by compressing different parts of the speech signal. Consonants are characterized by transient acoustic cues requiring rapid processing compared to vowels or pauses which are more steady state. Gordon-Salant and Fitzgibbons (2001) reported that selective compression of consonants produced greater age deficits in recall than selective compression of vowels or pauses; consonant compression was the best predictor of performance with uniform compression. Similarly, Schneider et al. (2005) reported comparable compression effects on word recognition across age when they compressed only steady state portions of the sentence (e.g., pauses, steady state portions of vowels), but greater compression effects for older adults when they compressed sentences in the usual way by deleting 10 msec segments at regular intervals. The former technique leaves intact cues for identifying phonemes, but eliminates time for higher level cognitive processes such as semantic and syntactic analysis. These results suggest that compression reduces older adults' performance not by reducing time for processing, but rather by reducing critical temporal features of speech. Wingfield et al. (1999) selectively *restored* deleted time to compressed speech by inserting silent intervals at random locations in a passage or at clause and sentence boundaries. Only the restored time at clause or sentence boundaries improved recall, and recall was lifted to the level for unaltered speech only for young adults, not older adults. The results are consistent with age-related decrements in processing at all levels but also with an age-specific perceptual decrement that cannot be corrected by adding time at linguistic boundaries.

In sum, the pattern of findings overall provides evidence that accelerated speech rates impair older adults' perceptual processing more than young adults', especially of transient acoustic cues. Acceleration of speech also impairs older adults' higher level processing, either directly by removing time needed for syntactic analysis (general slowing) or indirectly by increasing the difficulty of perceptual analysis (resources account).

Visual Word Recognition: Effects of Sensory and Perceptual Processes

In addition to declines in visual acuity, older adults exhibit other visual processing deficits that are relevant to reading, for example, retinal blurring (Artal, Ferro, Miranda, & Navarro, 1993), reduced accuracy of voluntary saccadic eye movements (Scialfa, Hamaluk, Pratt, & Skaloud, 1999), and reduced retinal illumination and loss of contrast sensitivity (Haegerstrom-Portnoy, Schneck, & Brabyn, 1999). Aging reduces the amount of light transmitted to the retina so that under comparable viewing conditions retinal illumination is considerably lower for older than young adults, a factor likely to increase word recognition threshold (Scialfa, 2002; for excellent reviews of visual sensory and perceptual deficits in older adults, see Fozard & Gordon-Salant, 2001; Madden & Whiting, 2004; Schneider & Pichora-Fuller, 2000; Scialfa, 2002). Even corrected vision is negatively related to age (Salthouse et al., 1996).

Recent research suggests that such sensory and perceptual changes affect the ability to read text under certain conditions. Steenbekkers (1998) determined the font size required for adults aged 20 to 80+ years, wearing corrective lenses when appropriate, to read text that was presented with 4 levels of contrast and under 3 levels of room illumination. Font size varied from 3.2 to 12.6 points. There were age deficits under all conditions, with the greatest differences for lower illumination and lower contrast. Participants in their seventies required a font that was almost twice as large as that of 20–30-year-olds to read without excessive delays.

Studies of visual language processing often rely on participants' reports of corrected to normal vision to rule out effects of age-related sensory deficits. The results of MacKay, Taylor, and Marian (2006b) suggest that this procedure is inadequate. They administered a close vision acuity test to young and older participants who self-reported 20/20 corrected vision; 20% of the older adults and 79% of the young adults actually scored 20/20. Older adults who reported 20/20 vision were faster to read large words (30 point lower case and 24 point upper case) than small words (24 point lower case and 18 point upper case), whereas young adults showed no effect of word size and were faster overall. Akutsu, Legge, Ross, and Schuebel (1991) also reported that older adults with self-reported normal vision were slower than young adults to read text in the range used by MacKay et al. (2006b), and also to read very small and very large text. Clearly, studies of visual language processing should report levels of contrast and illumination, administer vision tests and compensate for observed age differences in visual acuity.

There is also evidence that age-related sensory deficits are linked to age-related declines in activation of visual cortex during word recognition. Increasing word length slowed older adults' lexical decision latency more than young adults' and was associated with decreased visual cortex (BA 17) activation (Madden et al., 2002; Whiting, et al., 2003). Whiting et al. reported that the advantage in lexical decisions for high frequency words over low frequency words increased with activation of both anterior (BA 17 and 18) and posterior (BA 37) regions of the occipito-temporal pathway for older adults only. They suggest that the frequency effects indicate that older adults access lexical level features of words to aid in word recognition and compensate for age-related declines in sensory analysis of the visual stimulus (Madden, Whiting, & Huettel, 2005).

Evaluation of aging, visual acuity and word recognition has been carried out within a larger framework to test whether aging affects perceptual, lexical and semantic processes during word recognition to the same extent. General slowing models predict a general rather than a process specific effect of aging on word recognition processes (e.g., Lima et al., 1991). A number of studies, however, have shown that variables differ in their effect on young and older adults depending on the processes involved. Degradation of visual words, for example, by presenting words in visual noise or with asterisks between letters, produces a greater effect on older than young adults, as was also true for auditory processing in noise (Allen, Madden, Weber, & Groth, 1993; Madden, 1992; Speranza et al., 2000). Madden (1992) reported this greater cost of degradation on lexical decision latency even when visual acuity was covaried. Statistical control of performance on a test of speed reduced age-related variance in lexical decision latency and in the degradation effect, although age effects remained for both measures. Madden found that the benefit for semantically related compared to unrelated words, and for words compared to nonwords, was equivalent across age, suggesting that these lexical and semantic components of word recognition are unaffected by general slowing (for similar conclusions see Allen, Lien, Murphy, Sanders, & McCann, 2002; Madden, Pierce, & Allen, 1993; see Semantics section below for further discussion).

Spieler and Balota (2000) reported that, relative to young adults, older adults' word reading latency showed a smaller effect of word length and neighborhood density, variables affecting perception, and a greater effect of word frequency, a lexical level variable. They argued that older adults rely less on perceptual analysis during recognition because of their sensory deficits and rely more on lexical level characteristics. However, other studies have not reported the same effects of these variables in word naming (Morrison, Hirsh, & Duggan, 2003) or lexical decision (Tainturier, Tremblay, & Lecours, 1989; Whiting et al., 2003). Although age of acquisition and frequency of occurrence are correlated, Morrison et al. (2003) argued that age of acquisition rather than frequency predicts word naming latency and that it has equivalent effects on young and older adults.

Visual Word Recognition: Cognitive Operations and Studies of Distraction

As was true for auditory language processing, background visual noise (known as distraction in reading research) has a greater effect on older than young adults' visual language processing. Targets are typically written in one font and the distracters in another so that to read correctly the participant must discriminate between italicized and normal font (Carlson, Hasher, Zacks, & Connelly, 1995; Connelly et al., 1991; Duchek, Balota, & Thessing, 1998; Dywan & Murphy, 1996; Earles et al., 1997; Li, Hasher, Jonas, May, & Rahhal, 1998). The dominant framework for explaining why visual noise slows reading time more for older than young adults has been the inhibition deficit account: older adults' inhibition deficits impair their ability to ignore the distracting material so that it enters working memory and undermines the reading of the target text (Hasher et al., in press). Alternatively, under the degraded signal account, age-related declines in perceptual processing make differentiation of targets and distracters more difficult for older than young adults (Burke & Osborne, in press). When targets were distinguished from distracters spatially so discrimination between italics and standard font was no longer required, no age differences in distracter interference were observed (Carlson et al., 1995). Distracters that are semantically related to the target text increase interference more for older than young adults, a finding consistent with inhibition deficits (Carlson et al. 1995; Connelly et al., 1991; Li et al., 1998). On the other hand, older adults compensate for sensory losses under conditions of difficult reading conditions by engaging in more top-down processing than young adults (e.g., Speranza et al., 2000) so this effect is also consistent with sensory deficits. Visual acuity for participants is not typically reported in reading with distraction studies so the impact of a degraded signal is an important question for future research.

Kemper and McDowd (2006) introduced a new approach for investigating age differences in the effect of distraction on reading, namely, measurement of online eye movements during reading. They hypothesized that inhibition deficits would produce greater eye fixation on distracters. Sentences with a distracter word were read more slowly and comprehended more poorly than sentences without a distracter, but these effects were the same across age. Participants looked back more at distracters related to the sentences than unrelated distracters and more at distracters distinguished by font than by color, but again the effect was age invariant. These results provide no support for age-related inhibition deficits.

In sum, older adults' visual word recognition is affected by their declining perceptual processing, but it remains to future research to determine whether perceptual declines also contribute to age differences in distraction.

Summary of Perception of Phonology and Orthography

There is consistent evidence that age-related declines in acuity and perceptual processes, especially temporal processes in audition, impair older adults' language performance. In studies of auditory processing, equating intelligibility of stimuli across age eliminates much of the age differences in identifying and remembering language when background noise is increased. The direct effect of a degraded signal in older adults is in addition to the common cause hypothesized as the basis for correlations between sensory acuity and a range of cognitive functions including language (e.g., Baltes & Lindenberger, 1997). There is also evidence for indirect effects of perceptual declines in older adults wherein the greater difficulty of perceptual processing affects subsequent processes by constraining available resources. Overall, findings emphasize the necessity of equating across age the intelligibility of auditory or visual language before making inferences about age declines in nonperceptual processes important for language.

PRODUCTION OF PHONOLOGY AND ORTHOGRAPHY

Language production is an extraordinary skill that allows a speaker to retrieve words from a lexicon of 50–100,000 words and speak them at a quite normal rate of 2 to 4 words per second. Moreover, errors in word production occur rarely, once or twice in 1000 words (Levelt, 2001). Older adults know more words than young adults (Kemper & Sumner, 2001; see Vocabulary section below), but they are more likely than young adults to experience difficulty producing a specific word (see Burke et al., 2000; Kemper, 2006; Thornton & Light, 2006). What level of the language system is responsible for this age-related change in production? There has been consensus for a number of years that semantic representations and the processes that act on them are well maintained and some actually improve during adulthood until very old age (Botwinick, 1977; Burke & MacKay, 1997; Kemper, 1992; Light, 1991; Wingfield & Stine-Morrow, 2000). In contrast, retrieval of phonological and orthographic information appears to decline with aging (see Burke & Shafto, 2004; Mortensen, Meyer, & Humphreys, 2006 for reviews). A variety of evidence suggests that the locus of the deficit causing age-related increases in word finding failures is in the phonological and orthographic system. We now consider this evidence.

Phonological Production

Picture Naming

Dozens of studies over the last 30 years have examined aging effects on picture naming and there has been controversy about the conclusions (e.g., Connor, Spiro, Obler, & Albert, 2004; Feyereisen, 1997; Goulet, Ska, & Kahn, 1994; Schmitter-Edgecombe, Vesneski, & Jones, 2000). The evidence suggests that older adults make more errors in naming pictures of objects or actions than young adults, but this difference does not become significant until older adults are in their seventies (e.g., Barresi, Nicholas, Connor, Obler, & Albert, 2000; Connor et al., 2004; MacKay, Connor, Albert, & Obler, 2002; Morrison et al., 2003; Nicholas, Obler, Albert, & Goodglass, 1985; for a meta-analysis, see Feyereisen, 1997). Age deficits in picture naming, however, are not consistently found in individual studies (Goulet et al., 1994). One explanation of this inconsistency is that older adults' larger vocabulary (see Semantics section) allows them to identify pictures of rare objects better than young adults, e.g., *trellis, abacus* in the Boston Naming Test, compensating for errors caused by word retrieval deficits (Schmitter-Edgecombe et al., 2000). In the context of this account, it is interesting that vocabulary (Lindenberger & Baltes, 1997) as well as picture naming decline after age 70.

Although perceptual, semantic, lexical and phonological deficits can cause naming errors, analyses of types of errors (Albert, Heller, & Milberg, 1988), patterns of errors over repeated presentations (Barresi et al., 2000), and the greater effectiveness of phonological cues over semantic cues (MacKay et al., 2002) suggest that older adults' naming errors reflect deficits in lexical or phonological access rather than semantic access (see Mortensen et al., 2006). It is difficult, however, to use picture naming to unambiguously locate the level of the deficit in the language system that causes a naming error (Hodgson & Ellis, 1998).

Older adults are also slower than young adults to name pictures and several studies have varied characteristics of the picture or its name in an attempt to identify the processes responsible for the age-related slowing. Morrison et al. (2003) reported that visual complexity of pictured actions affected latency to produce the appropriate verb for old but not young adults, suggesting age differences in perceptual recognition time. However, the age difference in latency was equivalent for word reading and picture naming when general slowing was taken into account, a finding inconsistent with a greater effect of visual complexity of pictures for older adults. Age of acquisition and name agreement also affected naming latency but with comparable effects for young and older adults (Mitchell, 1989; Morrison et al., 2003). In sum, although there is some evidence that older adults' picture naming errors reflect lexical or phonological retrieval problems, we lack comparable evidence for naming latency.

Tip-of-the-tongue experiences

Perhaps the strongest evidence that older adults suffer deficits in phonological retrieval comes from studies of tip-of-the-tongue states (TOT) in which a person is temporarily unable to produce a well-known word. In the throes of a TOT, a person can produce semantic and grammatical information about the TOT target, but only partial information about the phonology of the word, such as number of syllables or first phoneme (e.g., Brown & McNeill, 1966; Burke et al., 1991; Miozzo & Caramazza, 1997). Older adults rate word finding failures as a cognitive problem that is most frequent, most affected by aging, and the most annoying (Lovelace & Twohig, 1990; Rabbitt, Maylor, McInnes, Bent, & Moore, 1995; Ryan et al., 1994; Schweich, Van der Linden, Brédart, Bruyer, Nelles, & Schils, 1992; Sunderland, Watts, Baddeley, & Harris, 1986).

Consistent with retrospective self-reports, in diary studies older adults record more spontaneous TOTs during their everyday life than young adults (Burke et al., 1991; Heine, Ober, & Shenaut, 1999). Older adults also report more TOTs than young adults when they are induced in the laboratory with pictures or definitions for relatively low frequency words (Burke et al., 2005; Gollan & Brown, 2006; Heine et al., 1999; Rastle & Burke, 1996; see also Brown & Nix, 1996). TOTs for low frequency words in the laboratory, however, are relatively rare and the age difference in number of TOTs is not always obtained (Burke et al., 1991; Vitevitch & Sommers, 2003; White & Abrams, 2002). However, the majority of naturally occurring TOTs are for proper names for both young and older adults (Burke et al., 1991) and there are consistent age-related increases in TOTs for proper names in the laboratory (Burke, Locantore, Austin, & Chae, 2004; Cross & Burke, 2004; Maylor, 1990) with a greater age-related increase for proper names than for other types of words (Burke et al., 1991; Evrard, 2002; James, 2006; Rastle & Burke, 1996).

A leading account of TOTs is the transmission deficit theory that TOTs occur when connections between lexical and phonological representations in the language system are too weak to transmit adequate priming for phonological representations to reach threshold. Activation of a lexical representation produces a feeling of knowing the word and makes available syntactic information about the word, but awareness of the phonological code for the word requires activation of representations in the phonological system down to the lowest level. Infrequent or nonrecent use of a word and aging of the participant weaken connections to and within the phonological system (Burke et al., 1991; Burke & Shafto, 2004). Consistent with this account, Vitevitch and Sommers (2003) demonstrated that both young and older adults produced more TOTs for low than high frequency words. They also reported that in young adults words with few phonological neighbors were more susceptible to TOTs than words with dense neighborhoods. A paucity of phonologically related neighbors reduces the spread of priming to phonological representations for the target. In older adults, however, the density effect only occurred for low frequency neighborhoods, perhaps because transmission of priming in dense neighborhoods was already reduced by aging.

If aging reduces transmission of excitation to phonological representations, then older adults should recall less phonological information while in a TOT state, as observed (Brown & Nix, 1996; Burke et al., 1991; Heine et al., 1999). Moreover, TOTs should be decreased by production of words that share phonology but not meaning with the target word because activation of phonological representations, required for production, strengthens connections. This prediction was confirmed: when young and older adults pronounced words sharing a few phonemes with a target word, it decreased the probability of inducing a TOT for the target word, for example, saying *decreed* and *pellet* decreased the probability of a TOT for v*elcro* (James & Burke, 2000). Prior production of a homophone (e.g., [cherry] *pit*) increased correct naming and reduced TOTs for the name of a famous person (e.g., *Brad Pitt*) for older but not young adults when there was no awareness of the homophone manipulation (Burke et al., 2004).

Pronunciation of phonologically related words not only reduces the likelihood of a TOT, but in the midst of a TOT state it actually increases resolution of a TOT for both young and older adults (James & Burke, 2000). Words sharing the initial syllable with the target are more effective than words sharing the middle or final syllable (White & Abrams, 2002). In the only phonological priming study to divide older adults into young-old and old-old groups, White and Abrams found that old-old adults, aged 73–80 years, showed no priming effect. In very old age connections to phonological representations may become so weak that multiple activations are required to overcome transmission deficits. This is consistent with reports that phonological cuing in picture naming is less effective for adults older than 70 years compared to younger adults (Au, Joung, Nicholas, Ober, Kass, & Albert, 1995).

There has been some controversy about whether older adults suffer a disproportionate impairment in producing known proper names compared to other types of words (James, 2006; Maylor, 1997; Rendell, Castel, & Craik, 2005). The transmission deficit model predicts that proper names are more susceptible to retrieval failures than common names because proper names carry reference but not meaning. Thus, proper name representations at the lexical level lack converging top-down semantic connections from representations of meaning and this makes them vulnerable to transmission deficits in the single connections from conceptual representations of their referents (see Burke et al., 1991, 2004). The strongest relevant evidence comes from studies that control familiarity of the names across age. Rendell et al. (2005) found older adults in their seventies named fewer famous people who were known than did younger adults, although there were no age differences in naming known objects. James (2006) asked young and older adults to name and give occupations for familiar famous people. Participants produced more TOTs for names than occupations, and the increase was greater for older than young adults. Thus, the evidence suggests that lexical retrieval is more difficult for proper names than other types of words, especially for older adults.

An alternative explanation for TOTs is that they are caused by a more accessible but incorrect alternate word that comes spontaneously to mind and interferes with retrieval of the target word (e.g., Jones, 1989; Logan & Balota, 2003; Zacks & Hasher, 1997). Under the inhibition deficit model, older adults are impaired in the ability to inhibit the alternate irrelevant word and this increases interference and the likelihood of a TOT. Contrary to this prediction, older adults are less likely than young adults to experience an alternate word during a TOT (Burke et al., 1991; Heine et al., 1999; White & Abrams, 2002). Moreover, when young and older adults were cued to produce an alternate name (e.g., *Eliza Doolittle*) prior to producing the name of an actor/actress pictured depicting this character (e.g., *Audrey Hepburn*), the alternate name did not increase the probability of a TOT, even though older adults produced more TOTs than young adults (Cross & Burke, 2004).

In sum, there is considerable evidence for age-related increases in phonological retrieval failures in research on picture naming and TOTs. Phonological priming techniques have been used to show that strengthening phonological connections decreases the likelihood of a TOT and increases resolution of a TOT, without the participant's awareness of the phonological relation. There is some evidence that retrieval failures in adults in their late seventies and older may involve connections so weak that they respond poorly to phonological cues or priming. The evidence is consistent with the transmission deficit model which postulates that aging weakens connections between semantic and phonological representations of verbal knowledge. This is counter to the view that existing knowledge representations, the basis for crystallized intelligence/cognitive pragmatics, are insensitive to aging (e.g., Baltes et al., 1999; see Burke, 2006).

Competitor Priming in Phonological and Orthographic Production

If older adults are less efficient than young adults in inhibiting competitors during word production, then priming competitors should have a more deleterious effect on production for older than young adults. Wheeldon and Monsell (1994) defined competitors in picture naming as sharing both physical and conceptual similarity with a target word. When they elicited a competitor with a verbal cue, for example, *largest creature that swims in the sea*—response: *whale*, latency was slower to name a picture of a shark compared to when the verbal cue elicited an unrelated word. Results using a similar paradigm provide no evidence that the delay in picture naming caused by a primed competitor was greater for older then young adults (Burke, 1999; Tree & Hirsh, 2003). Examining the role of competitors in lexical retrieval more broadly, Logan and Balota (2003) reported that presentation of an orthographically related (but incorrect) competitor (e.g., *ANALOGY*) slowed the completion of a fragment (e.g., *A-L- -GY*) with a previously studied correct word (e.g., *ALLERGY*) and increased errors. These effects were again comparable for young and older adults, but older adults made more intrusions errors by producing the competitor than young adults. Logan and Balota concluded that older adults have more difficulty differentiating the source of activation for competitors and targets.

Competitors do not have to be explicit but rather can be internally and implicitly generated. In a verb generation task, a *low competition* noun cue elicited a single dominant verb response (e.g., *broom* → *sweep*), and a *high competition* noun cue elicited no dominant verb response (e.g., *pill* → *swallow, take*, etc.). Under the inhibition deficit theory, age differences in retrieval time should be greater for high than low competition nouns because they require suppression of competing alternatives to select a response. Responses were slower for high than low competition nouns, but there was no age difference in the magnitude of this effect, contrary to the prediction (Persson et al., 2004; Prull et al., 2004). An alternative explanation of competitor effects is that they slow production because it takes longer for the lexical representation of target word to reach a critical threshold relative to the level of excitation of competitors (e.g., Burke, 1999; Wheeldon & Monsell, 1994). It is interesting that in auditory word perception the effect of internally generated competitors is greater for older than young adults (Sommers & Danielson, 1999; see above). Thus, there are age differences in effects of internal perceptual competitors but not of internal semantic competitors.

In sum, studies of the effect of implicit and explicit competitors on lexical production provide little evidence that older adults are less able to inhibit competitors for selection. We return to competitor effects in the Semantic section where we consider interference from semantically related words.

Slips of the Tongue and Dysfluencies

There are relatively few aging studies of a phenomenon that has been central to the study of language production: speech errors known as slips of the tongue In a slip of the tongue, the speaker misproduces one or more sounds in an intended word, for example, saying "coffee cot" instead of *coffee pot*, or one or more words in a sequence, for example, saying "take the hands out of the guns of people" instead of "take the guns out of the hands of people". Slips have been critical in the development of language production models which must account for the systematic patterns in these errors, for example, sequential class regularity as when nouns replace other nouns and initial syllables replace other initial syllables.

Although slips are infrequent in spontaneous speech, techniques for inducing slips in the laboratory provide insight into the locus of age changes in language production. MacKay and James (2004) induced slips by asking young and older adults to change /p/ to /b/, or /b/ to /p/, when there was a /p/ or /b/ in a visually presented word. Age differences in speech errors in their responses occurred for some error types but not others. Older adults were more likely than young adults to omit sounds (e.g., "beach" instead of breach) whereas young adults were relatively more likely to substitute a different sound ("puck" instead of pug). Studies using tongue twisters (e.g., "The Swiss wristwatch strap snapped") also reported more omissions for older than young adults (Taylor & Burke, 2000) or that older adults added pauses to produce responses (Vousden & Maylor, 2006). This pattern is predicted by the transmission deficit theory because omission errors are caused by insufficient transmission of priming to phonological representations so that they fail to reach threshold for production. Older adults' weaker connections increase the probability of such transmission deficits. Some transformations required phonological accommodation for a suffix under English morphology, as when the stimulus "ribs" /ribz/ is correctly transformed to rips /rips/. Older adults made more errors when this accommodation was required than when it was not, e.g., "bugs" correctly transformed to "pugs". Phonological accommodations errors are predicted by the changes in activation dynamics caused by transmission deficits (see MacKay & James, 2004).

Dysfluencies are another type of speech error that interrupt the flow of speech and appear to indicate a word retrieval problem. In describing a picture or other stimulus, older adults produced more lexical fillers (e.g., *you know*), non-lexical fillers (e.g., *um*), word repetitions (e.g., just on the left left side), lengthy pauses and empty words than young adults, although studies are not always consistent in the specific type of dysfluency showing an age difference (e.g., Bortfeld, Leon, Bloom, Schober, & Brennan, 2001; Heller & Dobbs, 1993; Kemper, Rash, Kynette, & Norman, 1990; Schmitter-Edgecombe et al., 2000). These dysfluencies have been interpreted as devices to secure time for word finding. Consistent with this, Bortfeld et al. reported that older adults produced more fillers than young adults within syntactic phrases where word finding failures might occur, but not between syntactic phrases where fillers can signal the intention to continue speaking.

In sum, speech error data provides evidence for an increase in lexical and phonological retrieval deficits in old age and are consistent with age-related transmission deficits affecting language production.

Orthographic Production

Older adults reported that they can no longer spell words they once knew how to spell, and despite their higher vocabulary and education in these studies, they were more likely than young adults to misspell words they read or heard (Abrams & Stanley, 2004; MacKay & Abrams, 1998). Older adults regularized irregularly spelled letter combinations more than young adults, e.g., *calendar* → *calender*, but only the old-old group (M age = 77 years) misspelled regularly spelled combinations, e.g., *calendar* → *kalendar* (MacKay & Abrams, 1998; MacKay, Abrams, & Pedroza, 1999). Margolin and Abrams (in press) reported that the age difference was found for poor spellers but not good spellers. The transmission deficit model predicted an age-related decline in orthographic production (i.e., spelling), parallel to the predicted decline in phonological production. Aging weakens connections, and orthographic representations like phonological representations are especially vulnerable to transmission deficits because of their architecture: orthography is accessed via single connections from lexical nodes (Burke & MacKay, 1997; MacKay et al., 1999).

Cortese, Balota, Sergent-Marshall, and Buckner (2003) reported that older adults made more errors than young adults in spelling spoken homophones with heterogeneous spellings, e.g., *vein, capitol*, and were more likely to produce a spelling that corresponded to the dominant meaning but was a non-dominant spelling for that sound (e.g., *vein*). Young adults' production favored a spelling that corresponded to a non-dominant meaning but was a dominant spelling for that sound (e.g., *vane*). This suggests that semantics has a stronger effect than orthography on lexical selection for older but not young adults.

In sum, older adults are more vulnerable to lexical retrieval failures while speaking single words and during discourse. Lexical competitor effects in production seem to be comparable for young and older adults. Rather, findings are consistent with phonological retrieval failures caused by transmission deficits. Parallel age-related deficits on orthographic retrieval increase spelling errors in old age.

SEMANTICS

Reviews of language function have consistently concluded that conceptual representations underlying the meaning of language at the word, sentence or discourse level are well preserved during adulthood (e.g., Botwinick, 1984; Burke et al., 2000; Kemper, 1992; Kliegl & Kemper, 1999; Thornton & Light, 2006; Wingfield & Stine-Morrow, 2000; Zacks & Hasher, 2006). Performance on tests of general knowledge improves during adulthood, suggesting that older adults have richer semantic representations than young adults (Ackerman & Rolfhus, 1999; Beier & Ackerman, 2001). In contrast to age-related declines in retrieval processes at the phonological/orthographic level, there is little evidence for age-related changes in semantic retrieval processes, except in their speed. Where there are age deficits, they tend to appear under specific circumstances, such as in very old age (e.g., Lindenberger & Baltes, 1997) or as measured by online electrophysiological techniques such as event-related potential (ERP; e.g., Cameli & Phillips, 2000). Moreover, some age-related changes may not reflect age-related deficits, but rather experience-based changes, for example, in communication goals (e.g., Radvansky, Zwaan, Curiel, & Copeland, 2001). This is especially relevant to semantic performance because experience with language continues to affect the representation and structure of the semantic network across the lifespan. Thus, it is a particular challenge for researchers in this area not only to identify age-related deficits which may affect semantic processing, but also to distinguish between the effects of age per se and the effects of a lifetime of language experience.

Lexical Semantics: Vocabulary

Cognitive aging studies often report vocabulary scores in descriptions of their participants' background characteristics and these scores are usually higher for older than young adults; this was confirmed in a meta-analysis of 210 studies published in *Psychology and Aging* between 1986 to 2001 (Verhaeghen, 2003). However, education is strongly related to vocabulary and older adults in the surveyed studies were more highly educated than young adults. When Verhaeghen took education into account, the superior performance of older adults was eliminated for multiple choice vocabulary tests, but not for those requiring production of a definition for a target word. In addition to standard vocabulary measures, the National Adult Reading Test (NART; Nelson, 1985), which requires pronunciation of irregularly spelled words (e.g., *leviathan*), yields superior performance for older than young adults, even after removing education effects (Uttl, 2002). In discourse, older adults demonstrate their larger vocabularies with a greater type-token ratio wherein they produce a greater number of different words relative to the total words produced compared to young adults (Kemper & Sumner, 2001).

There is some recent evidence that older adults' greater vocabulary and verbal experience may affect lexical processing by increasing the relative frequency of low frequency words. In a homophone priming paradigm, young adults had greater priming effects with high frequency than low frequency words, but older adults did not show this frequency effect. In addition, older adults produced the low frequency version of a homophone in an unprimed spelling task more often than young adults, consistent with an age-related increase in relative frequency of use for low frequency words (Gomez, 2002). Moreover, highly educated older participants (who would be likely to have larger vocabularies) show smaller differences in lexical decision response times to low and high frequency words than young adults (Caza & Moscovitch, 2005).

Although there is a great deal of support for age-related superiority in vocabulary, cohort effects complicate the interpretation of vocabulary differences in cross-sectional studies. Vocabulary scores have increased steadily through the twentieth century (e.g., Schaie, 2005), and in studies published between 1965 and 1995 the increase over time was greater for older than young adults (Uttl & Van Alstine, 2003). Some but not all of this age difference is because educational level at the time of testing rose for older but not young adults, who are typically college students, again highlighting the importance of controlling education in evaluating the effect of aging on vocabulary. Longitudinal studies, however, confirmed that independent of education and cohort, aging is associated with improved vocabulary during adulthood until very old age (e.g., Schaie, 1994, 2005).

Vocabulary does decline in very old age. Lindenberger and Baltes (1997) reported that vocabulary scores in the Berlin Aging Study declined from age 70 to 103 years in cross-sectional comparisons. However, 6-year longitudinal data showed that vocabulary scores were maintained and did not begin to decline until age 90 years (Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003). Alwin and McCammon (2001) found that after adjusting for cohort effects older adults' scores did not decline to the level of 20-year-olds until participants were in their eighties (see Schaie, 1994, 2005 for similar findings).

Why do vocabulary scores level off in late adulthood and start to decline sometime after the age of 70 years? Insight into this issue is provided by research on HM, the famous anterograde amnesic whose hippocampus was bilaterally removed in 1953. HM was tested at the age of 71 on a lexical decision task of circling words but not nonwords. HM's correct identification of high frequency words was similar to age and education matched controls, but controls outperformed him in identifying low frequency words by almost 5 standard deviations. Comparing HM's lexical decision performance at age 53 to his performance at age 71 showed that his accuracy in identifying words had declined over 6 standard deviations at age 71 relative to same-age controls. The decline was attributed to errors on low frequency words and constituted an exaggerated age-linked decline (James & MacKay, 2001).

Using the transmission deficit model, James and MacKay argue that frequent and recent use of high frequency words maintains the strong connections in their representations, aiding their retrieval. Connections for low frequency words, however, weaken from disuse and from aging which both cause transmission deficits that impair retrieval. In the case of extreme disuse, all connections to a lexical representation can weaken to the point of being nonfunctional for the transmission of priming so that the word is no longer in the lexicon. When this happens for controls with no hippocampal damage, new representations can be readily made when the word is encountered again. However, HM, because of his hippocampal damage, cannot readily form new connections. Thus, low frequency but not high frequency words disappear from his lexicon (James & MacKay, 2001; MacKay, 2006; MacKay & James, 2001). In normal old age, formation of new semantic representations declines (e.g., McIntyre & Craik, 1987; Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994), although obviously on a much lower scale than for HM. Nonetheless, this impedes reconstruction of representations of low frequency words that have been lost from extreme transmission deficits. Within this framework, the changes in vocabulary in very old age reflect the weakening and eventual loss without reinstatement of low frequency words, an interesting prediction for future research.

Within this framework, proper names would be expected to be especially vulnerable to loss. In addition to their susceptibility to transmission deficits (see TOT section above), older adults learn the proper name of an unknown person more poorly than young adults when there are no age differences in learning the occupation (James, 2004). Moreover, other processes necessary for learning new vocabulary decline in very old age. Adults 75 years or older were less able than younger adults to derive the correct meaning of unknown words from context because of declines in inferential processes that are essential for abstraction (McGinnis & Zelinski, 2000, 2003).

In addition to changes in cognitive processes, Carstensen's socioemotional selectivity theory postulates that there is a shift in old age to emotional goals that bring immediate satisfaction, and away from the goal of accumulating knowledge because the uncertainty of the future calls into question when this knowledge would be put to use (e.g., Carstensen, Isaacowitz, & Charles, 1999; Isaacowitz, Charles, & Carstensen, 2000).

In sum, education, cohort and age range all contribute to age differences in vocabulary measures, but the evidence suggests that semantic and lexical knowledge accumulates during adulthood and remains stable until very old age. Further research is needed to understand why vocabulary does not continue to increase in very old age and begins to decline.

Semantic organization

There is consensus that aging has little effect on the organization of semantic knowledge as revealed, for example, by word associations and the structure of taxonomic categories and scripts (Burke et al., 2000; Light, 1991; Thornton & Light, 2006; Wingfield & Stine-Morrow, 2000). Nonetheless, recent findings show that there is age variance in the strength of specific responses. Contrary to the inhibition deficit prediction that older adults would have more difficulty inhibiting esoteric responses in word production, Hirsh and Tree (2001) found that young adults produced more diverse word association responses than older adults and young and older adults agreed on the dominant response for only 36 out of 90 words. Previous studies have reported no age difference in variability (e.g., Burke & Peters, 1986). In a homophone association task, White and Abrams (2004a) found that young and older adults differed in their dominant response on one-third of items, and on their dominance ratings for homophones for one half of items. These findings highlight the importance of using association norms based on both young and older adults in semantic research. Associative relationships are similar across age groups with higher levels of contextual support, as when participants generate (Lahar, Tun, & Wingfield, 2004) or rate the predictability of sentence-final words (Little, Prentice, & Wingfield, 2004).

Lexical Level Comprehension: Semantic Priming

Facilitory Effects of Semantic Relatedness

In addition to word associations, the integrity of semantic organization and processes is often evaluated with semantic priming tasks which show faster response times to a target when preceded by a semantically related prime word or picture compared to an unrelated prime word or picture. This facilitation is attributed to excitation that spreads via semantic connections between the representations of the prime and target, moving the representation for the target closer to threshold. Previous research has provided evidence for preserved priming effects in older adults (e.g., Burke, White, & Diaz, 1987; Howard, McAndrews, & Lasaga, 1981), and more recent findings support this conclusion (e.g., Balota, Watson, Duchek, & Ferraro, 1999; Faust, Balota, & Multhaup, 2004; Lazzara, Yonelinas, & Ober, 2002; Tree & Hirsh, 2003). Preserved semantic processing at the lexical level is also supported by studies of the effects of semantic relatedness on the N400 in ERP studies. The N400 is a negatively going potential which is larger in response to semantic anomaly. The N400 to pairs of semantically related words is reduced in magnitude compared to unrelated words and this reduction is the same in magnitude and timing for young and older adults (Federmeier, Van Petten, Schwartz, & Kutas, 2003).

As with the frequency effects discussed earlier, older adults' greater linguistic experience may explain some age-related changes to semantic processing, for example, the *greater* semantic priming effects for older than young adults in meta-analyses (Laver & Burke, 1993; Myerson, Ferraro, Hale, & Lima, 1992). One account of this age difference is that during adulthood the semantic network not only gains lexical representations, but additional connections are generated between existing lexical representations so they become more richly connected (Laver & Burke, 1993). Thus, a prime word would have more and stronger connections to a related target, increasing priming effects. An alternative explanation is that greater priming effects are simply a byproduct of age-related general slowing (Giffard, Desgranges, & Kerrouche, 2003; Myerson et al., 1992).

Recent studies have attempted to address the general slowing explanation by controlling age differences in response time. If priming effects are greater for older adults when baseline latency is the same across age, this cannot be explained by the general slowing argument that priming effects are proportional to latency. Laver (2000) used four response deadlines (from 100 to 600 ms) to control young and older adults' lexical decision latencies. He reported an age-related increase in the size of priming effects but no age difference in absolute latency. Giffard et al. (2003) controlled age-related slowing statistically rather than behaviorally by entering unrelated latency and age in a regression on absolute priming effect. Although older adults' absolute semantic priming effects were larger than young adults', unrelated latency but not age was a significant predictor of priming effects in the regression, consistent with the general slowing explanation of age differences. Another approach was taken in a recent word stem completion task (White & Abrams, 2004b), where the priming effect was the probability of stem completion with a target word (e.g., *sand*) following a semantically related word (*beach*) compared to an unrelated word (*batch*). Older adults had a larger priming effect, responding more often with the target word following a semantic prime. This was despite no age difference in the size of a mediated *phonological* priming effect, where the target word (*sand*) was produced more often following a word phonologically identical to the semantically related word (*beech*) compared to an unrelated word. It is not clear how this age increase in priming could be explained by general slowing. Thus, the evidence is inconclusive as to whether larger priming effects for older adults are caused by cognitive declines such as general slowing, or by an increase in the interconnected nature of the semantic network due to experience.

Interfering Effects of Semantic Relatedness

Older adults' reading or listening is disrupted more than younger adults' by visual or auditory distracting information when it is semantically related to the target language (Carlson et al., 1995; Connelly et al., 1991; Li et al., 1998; Tun et al., 2002). Under the inhibition deficit theory, this is because older adults are less efficient in inhibiting the distracting information which competes with the target for attention.

Recent studies provide mixed support for the inhibition deficit explanation. As we saw above in discussing phonological production, production of a semantic competitor before picture naming (e.g., production of *rope* before naming a picture of a *chain*) produces comparable slowing across age (Burke, 1999; Tree & Hirsh, 2003), except at a very short prime-target lag time where young but not older adults showed interference (Tree & Hirsh, 2003). When semantic competitors are implicit (i.e., internally generated without awareness) rather than explicit, production is also slower for both young and older adults with no age differences in the effect (see above: Competitor priming in phonological and orthographic production). In the picture-word interference paradigm, participants ignore a word presented with a picture they are to name. Slowing from unrelated word distracters (compared to a white noise condition) and facilitation from distracters phonologically related to the picture name (compared to unrelated distracters) was equivalent across age; only semantically related distracters showed greater slowing for older than young adults (Taylor & Burke, 2002). Under an inhibition deficit account, age-related inhibition deficits should apply to all irrelevant information regardless of its phonological or semantic relatedness to the target. Taylor and Burke argue that older adults' greater semantic interference reflects their more elaborated semantic network which increases the transmission of priming to related concepts, an explanation related to the "enriched semantics" account discussed earlier to explain age-related increases in semantic priming.

In sum, there is evidence for age-related increases in interference from semantically related distracters when they are presented, but not when they are implicit or produced by the participant. It is unclear how this overall pattern can be explained by age-related inhibition deficits. It has been suggested that age-related increases in perceptual interference, as in reading with distracters, are related to perceptual deficits (Burke & Osborne, in press), but further investigation of the pattern of age differences with implicit and explicit distracters or competitors is needed.

Sentence Comprehension

Although the priming effect between semantically related words is a common measure of semantic network integrity, words are rarely comprehended in isolation, and efficient semantic processing at sentential and discourse levels is critical. Additionally, lexical-level tasks may not provide a fair test of some models of cognitive aging which predict interactions of age and increasing processing complexity. For example, under the working memory model, older adults' capacity may be taxed during sentence comprehension by the requirement to integrate incoming information into a developing sentence-level representation, but these coordinative efforts may not be required in single word processing. Moreover, under a general slowing account, impairment to semantic processes may only become apparent when multiple successive processes are required in time-sensitive online tasks, as with auditory sentence comprehension.

Conclusions about the integrity of semantic processes during comprehension differ for online and offline measures. Online measures minimize nonlinguistic memory requirements and meta-linguistic judgements about meaning; they occur during language processing and reflect semantic processes involved in computing a representation of a sentence. Offline measures of comprehension occur after computation of the representation and are vulnerable to age-related declines in episodic memory. Not surprisingly, retention of a sentence or text after it is read or heard declines with age (e.g., Johnson, 2003; Van der Linden et al., 1999), as does performance on comprehension measures that depend on memory for the text (Kemper & Sumner, 2001). Mackenzie (2000b), however, reported that accuracy in responding to questions about details, inferences or metaphors in texts was comparable in middle-aged and young-old adults, but declined in adults 75 to 88 years of age. Although this may reflect a memory decline, aging effects on semantic processing of text may differ before and after the age of 75 years as is the case for aging effects in semantic processing at the lexical level (e.g., vocabulary).

Online measures usually show age equivalence in constructing semantic representations of sentences and using these representations top-down to prime relevant concepts (e.g., Light, Valencia-Laver, & Zavis, 1991; Roe et al., 2000; Stine & Wingfield, 1994; for review see Kemper, 1992; Light, 1991). Indeed, meaningful sentential contexts often facilitate word identification during language processing more for older than young adults, especially under difficult perceptual conditions (Manenti et al., 2004; Schneider et al., 2005; Sommers & Danielson, 1999; Speranza et al., 2000). When errors in an offline recognition task reflected the correct generation of inferences during sentence processing, older adults showed at least as much evidence of inference generation as young adults (Zipin, Tompkins, & Kasper, 2000).

Online studies that show priming of relevant meanings and suppression of irrelevant meanings are important because under the inhibition deficit model, older adults should be less able to inhibit contextually inappropriate meanings. Newsome and Glucksberg (2002) demonstrated that both young and older adults were faster to respond to a metaphor-relevant probe (e.g., *Sharks are tenacious*) after reading a metaphor prime (e.g., *The lawyer for the defense is a shark*) than after reading a literal prime (e.g., *The large hammerhead is a shark*). Responses to a metaphor-irrelevant probe (e.g., *Sharks are good swimmers*) were slower after metaphor primes than literal primes, suggesting suppression of attributes irrelevant to the metaphor, with no age effect. Similarly, when a homophone was presented in a sentence biasing one meaning, both young and older adults' word recognition was faster for a word related to the contextually appropriate meaning than the inappropriate meaning suggesting that only the appropriate meaning was available (Hopkins, Kellas, & Paul, 1995; Paul, 1996). Dagerman et al. (2006), however, reported that young but not older adults used context online to disambiguate noun-verb homophones. They presented an auditory fragment biasing the verb interpretation of the ambiguous word (e.g., *The union told the reporters that the corporation fires*) or the noun interpretation (e.g., *The union told the reporters that the warehouse fires*) followed immediately by visual target word that was compatible with the verb interpretation (e.g., *us*). Young adults' naming latency for the target word was faster with the verb bias context than the noun bias context, whereas older adults showed no context effect. Both young and older adults showed context effects in an offline judgment about the compatibility of the fragment and the visual target. The authors argued that older adults' processing was too slow to use the context to resolve the ambiguity by the time the target was presented. This explanation was supported in a simulation of the age difference in use of sentential context that implemented a model which manipulated a speed parameter controlling activation of all nodes in the model.

Age differences in semantic processing are also suggested by recent research that makes inferences about semantic processing of sentences based on the N400 response in ERPs. N400s are negatively going potentials which are larger following a semantically anomalous word in a sentence than a semantically congruent word. Kutas and Federmeier (2001) argued that words which are congruent with the sentence are primed by the sentence context and this readies them for activation and lowers the N400. Because this priming is feature based, a sentence-incongruent word sharing semantic features with the congruent word will also receive some priming, reducing the N400 amplitudes compared to an incongruent and unrelated word. While young adults demonstrate this graded progression of N400 amplitudes, this pattern was reduced or absent in older adults. This age difference has been interpreted as older adults using the sentence context less effectively (Cameli & Phillips, 2000; Federmeier, McLennan, De Ochoa, & Kutas, 2002). In support of this conclusion, Federmeier et al. (2002) found that older adults with larger vocabularies and higher verbal fluency scores showed the young response pattern. However, in other studies, young and older adults showed comparable effects of sentence context on N400 to sentence congruent words (Federmeier et al., 2003; Phillips & Lesperance, 2003, Experiment 2), although the effect was delayed 200 ms in older adults compared to young adults in one study (Federmeier et al., 2003) but not the other. The delay is consistent with Dagerman et al.'s (2006) claim that older adults require more time for sentence context to affect word processing.

In sum, although lexical level semantic processing is at least as strong in older as young adults, there is some evidence that semantic processing of sentences may decline with aging, possibly because of age-related slowing. This is somewhat surprising given the consistent findings that sentential context aids older adults' perceptual processing of language. Further research is needed to determine if age-related changes in ERP during sentence processing are linked to behavioural deficits in older adults and to investigate what semantic properties of sentences constrain older adults' sentence processing and how these properties are related to slowing.

Discourse Comprehension

Discourse comprehension is particularly important for assessing the relative contributions of age-related processing deficits versus age-related increases in language experience. Discourse comprehension places demands on working memory because it requires integrating concepts and maintaining thematic information over multiple sentences. However, discourse comprehension also provides an opportunity for strong top-down influences, guiding comprehension with heuristics and real world knowledge which increases during adulthood. Part of discourse comprehension is the development of a situation model, namely, a multi-dimensional representation of the topic of the text, including information such as space, time, and causal relationships (Zwaan & Radvansky, 1998). A situation model goes beyond the literal content of the text by integrating the text with pre-existing knowledge (e.g., Stine-Morrow, Gagne, Morrow, & DeWall, 2004). Thus, situation model information is often contrasted with the *surface* information (i.e., the specific word content), and *textbase* information (i.e., the specific propositional content).

Older adults typically demonstrate preserved use of situation models. Although one study suggests older adults do not inhibit representations of irrelevant situation models as well as younger adults (Radvansky, Zacks, & Hasher, 2005), most studies demonstrate age constancy in constructing and using situation models during comprehension, for example, by updating them when there are changes to spatial or temporal information (Radvansky, Copeland, & Zwaan, 2003). Indeed, a number of studies indicate a *stronger* influence of situation models on older adults' comprehension than on younger adults'. Radvansky et al. (2001) gave participants history texts to read, and found that older adults had greater memory for situation model information than younger adults. This age-related superiority was eliminated when a narrative text was used, which encouraged all readers to form situation models, but a subsequent study (Radvansky et al., 2003) demonstrated age-related superiority for remembering situation model information even when participants read narratives.

In keeping with these findings, a number of established situation model effects are larger for older adults. Dijkstra, Yaxley, Madden, and Zwaan (2004) had participants read sentences which described objects (e.g., spaghetti), in a context (e.g., bowl/box) which implied specific form information (e.g., cooked/uncooked). Participants then saw a drawing of an object (e.g., cooked or uncooked spaghetti) and had to indicate whether it had been described in the sentence or not. If features of the drawing mismatched the implied features from the sentence, participants were slower to make this decision than when the features matched. Older adults showed a larger mismatch effect than young adults, suggesting that their situation models were stronger and had more of an impact when the model was violated. Another situation model effect demonstrated that reading times were faster and memory was better for text where items had a functional, interactive relationship compared to a non-functional relationship (e.g., Radvansky et al., 2003). This functionality effect was present in both age groups but was larger for older adults. A final situation model effect demonstrates that the further an object described in a passage is from the protagonist, the longer it takes readers to process information about it. For participants with good comprehension, this "distance effect" was larger for older than younger adults (Stine-Morrow, Morrow, & Leno, 2002).

Stine-Morrow, Loveless, and Soederberg (1996) evaluated the relative allocation of resources to surface, textbase, and discourse processing by regressing word-by-word reading times onto different factors associated with surface, textbase, or discourse variables. For example, word length in syllables measured orthographic decoding, the number of propositions was a textbase variable, and the "serial position" gave an indirect measure of the strength of the global representation (which should increase as more of the passage is read). The critical assumption of this approach is that relative reading time allocation reflects relative allocation of cognitive processing. According to this approach, discourse factors influence older adults' processing more than young adults' because older adults' reading time depends more on these factors (e.g., Miller, Stine-Morrow, Kirkorian, & Conroy, 2004; Stine-Morrow, Soederberg Miller, & Leno, 2001; Stine-Morrow et al., 2002). For example, Stine-Morrow et al. (2001) reported that young adults achieved better performance by allocating more time to textbase factors, while better performing older adults allocated more time to both textbase and discourse factors.

A resource model has been applied to older adults' emphasis on discourse-level processing, raising the questions of whether this emphasis is an attempt to make the most of limited resources or is a byproduct of insufficient processing resources. Several results suggest that older adults attempt to optimize their performance. For example, Stine-Morrow et al. (1996) found that older adults who showed the same pattern of reading time allocation as young adults had *worse* subsequent recall, whereas older adults with better recall had allocated more time to "strong schema-based processing". A number of other studies have also found different allocation patterns for older adults in the context of equivalent memory (e.g., Miller et al., 2004; Smiler, Gagne, & Stine-Morrow, 2003; Stine-Morrow et al., 2001) or superior memory performance compared to young (Miller et al., 2004). However, McGinnis and Zelinski (2003) demonstrated that when participants attempted to identify the definition of an unfamiliar word which had appeared in a passage context, older adults over age 75 gave high ratings to precise definitions, but unlike young or young-old adults, also gave high ratings to definitions based on the general themes of the passage and irrelevant definitions. This implies, at least for very older adults, that the preference for discourse-level processing is not necessarily optimal. Additionally, during self-paced listening, younger adults adjusted allocation of listening times to improve memory as task difficulty increased, but older adults were not as flexible in their resources allocation patterns, and demonstrated worse recall than younger adults (Titone, Prentice, & Wingfield, 2000).

Recent research has called into question the underlying assumption that there is a connection between older adults' resource allocation patterns and decreases in available resources, such as working memory. Stine-Morrow et al. (2001) found that age-related changes to allocation patterns were largely independent of working memory capacity (as assessed with reading and listening sentence span tasks), despite an age-related capacity decline. The role of working memory capacity was more directly addressed by Smiler et al. (2003) who had participants read passages with or without a secondary memory task. Older adults had longer "wrap-up" times at the ends of sentences, thought to reflect time allocated to conceptual integration, and this age difference increased in the presence of the secondary memory task. However, working memory capacity (i.e., sentence span) did not predict this pattern, despite the finding that working memory capacity was lower in the older group and did predict performance on the secondary memory task.

If age-related shifts towards discourse-level processing are not responses to decreasing processing resources, a ready alternative is that this shift is due to their greater pool of general knowledge, acquired across their lifespan. However, Radvansky et al. (2001) found no correlation between measures of prior knowledge and measures of situation model use, and many of the situation model effects depend on manipulating and updating situation models based on new information given in the task (e.g., Dijkstra et al., 2004, Radvansky et al., 2003). In fact, under some circumstances, older adults use situation models differentially more than younger adults in the context of new information. For example, both young and older adults increase the time they allocate to the integration of concepts when they have pre-existing expertise on the topic at hand

(Miller, 2003), but only older adults are similarly affected by newly acquired knowledge (Miller et al., 2004). Additionally, Stine-Morrow et al. (2002) demonstrated that when new object information is introduced during text comprehension, only older adults integrate this information into the situation model, while younger adults rely on textbase processing to remember the new information. Finally, when reading a text multiple times, younger adults will tend to emphasize discourse-level processing only in the second reading after establishing a textbase representation in the first reading, whereas older adults focus on discourse-level processing beginning with the first reading (Stine-Morrow et al., 2004), a pattern which also leads to better comprehension performance in the older group.

Thus, older adults may have a bias towards top-down processing per se, but more research is clearly needed to determine why older adults prioritize situation model formation and other discourse-level processing during text comprehension. One possibility is that changes to older adults' performance may be due to their language "expertise". If the primary goal of comprehension is to form a situation model, older adults, who are more practiced at comprehension, may be better at identifying and focusing on the aspects of text that are relevant for forming situation models (Radvansky et al., 2001). In support of this view, Miller et al. (2004) reported that during passage reading older adults applied newly acquired domain knowledge more, which differentially slowed their reading, but they subsequently outperformed younger adults on a comprehension task that required forming inferences. Thus, as suggested by Radvansky et al. (2001), young and older adults may be equally influenced by textbase information during comprehension, but while younger adults retain it, older adults discard this information after using it to form a situation model, which may explain older adults' better inferential memory (Miller et al., 2004), but younger adults' better propositional memory.

In sum, text comprehension in old age appears to involve increased reliance on discourse structures such as situation models. However, recent studies suggest that this shift may be independent of declines in processing resources such as working memory, and may constitute an age-related shift in priorities during comprehension.

Elderspeak and Comprehension

Elderspeak is an adopted speech register used to address older adults that attempts to accommodate anticipated communication difficulties, similar to speech used to small children and foreigners. Elderspeak is characterized by exaggerated intonation, slower speech rates, more repetition and elaboration, and shorter sentences with simpler syntax. Is elderspeak a helpful accommodation to older adults' comprehension abilities? Kemper and Harden (1999) identified helpful and harmful aspects of elderspeak using a referential communication task in which participants were instructed on how to follow a route on a map. Semantic alterations in the speaker's language such as repetitions and elaborations improved performance and reduced older adults' reported communication difficulties. The same was true for some kinds of syntactic simplifications, such as reducing the use of embedded or subordinate clauses, but simply shortening sentences was not helpful. Moreover, changes to prosody such as exaggerated intonation and slowed speech rate increased older adults' reported communication difficulties and under some circumstances impaired performance.

The combination of helpful and harmful characteristics of elderspeak may explain some of the mixed reactions that elderspeak elicits. Older adults resent patronizing speech, and find it insulting and condescending (Ryan, Giles, Bartlucci, & Henwood, 1986). Despite older adults' negative reaction to being spoken to in a patronizing register, they may be blamed for its use, contributing to the view that they are less competent (La Tourette & Meeks, 2000). Moreover, older adults feel that they have more communicative difficulties themselves in response to patronizing speech (Kemper & Harden, 1999), suggesting that elderspeak can lead to a downward spiral that reinforces negative stereotypes (e.g., Nussbaum, Pitts, Huber, Raup Krieger, & Ohs, 2005). However, while patronizing speakers are typically preferred less than speakers who do not use patronizing speech (Brown & Draper, 2003), elderspeak can also be associated with affection and nurturance (Ryan et al., 1986). In fact, when observing a conversation, both young and older adults rate elderspeak higher than neutral speech on both negative and positive characteristics (Gould, Saum, & Belter, 2002). Interventions to reduce the use of elderspeak are motivated by findings that older adults prefer health-care workers who are not condescending (e.g., La Tourette & Meeks, 2000), and that patronizing speech to nursing home residents can encourage dependence and increase social isolation (Williams, Kemper, & Hummert, 2003; Nussbaum et al., 2005). Intervention effectively reduces some aspects of elderspeak but not others (Williams et al., 2003), and some improvements remain stable, but some deteriorate over time (Williams, 2006).

In sum, the way that older adults are spoken to dramatically affects how they feel about themselves and how they are perceived by others. It can also affect their performance on cognitive tasks, improving it under some conditions and impairing it under others. Components of elderspeak are either helpful or harmful, but as Kemper and Kemptes (2000) point out, it is unclear that speakers use helpful components to adjust their speech to the communicative needs of older adults.

Discourse Production

Much of the recent aging research on production of discourse investigates the semantic content, in particular, the number of ideas produced relative to a fixed number of words and the degree to which these ideas are relevant to the topic. The density of ideas declines with age in written autobiographical essays (Kemper, Greiner, Marquis, Prenovost, & Mitzner, 2001a), spoken responses to topics (Kemper & Sumner, 2001; Kemper et al., 2001a) and spoken descriptions of a picture (Mackenzie, 2000a). Juncos-Rabadan, Pereiro, and Rodriquez (2005) presented sequences of pictures and analyzed the semantic content of narratives about them by native speakers of Galician with no more than an eighth grade education. Although the overall content did not vary with age, the density of content declined with age. At present, there is no account of why idea density declines with age, but low idea density is associated with increased all-cause mortality and Alzheimer's disease (Snowdon, Greiner, Kemper, Nanayakkara, & Mortimer, 1999; Snowdon et al., 1996).

There is also evidence that under some conditions older adults produce more speech that is off topic. Arbuckle, Pushkar Gold and colleagues examined the responses of 60 to 95-year-old adults in a life history interview and reported that off-topic verbosity (OTV) increased with aging (e.g., Arbuckle & Pushkar Gold, 1993; Gold, Andres, Arbuckle, & Schwartzman, 1988). High OTV was associated with reduced performance on tests involving the ability to ignore irrelevant information (e.g., Trailmaking test, Stroop test), and the authors attributed OTV to age-related deficits in the ability to inhibit irrelevant information (Arbuckle & Pushkar Gold, 1993; Pushkar Gold & Arbuckle, 1995).

James, Burke, Austin, and Hulme (1998) argued for an alternative pragmatic change account of discourse under which older adults produce more off-topic speech because of a shift in their conversational goals from the concise exchange of information, to an emphasis on personal narratives and identification of significant events in their lives. James et al. found that older adults produced more off-topic speech only during autobiographical storytelling, and although their stories were rated as less focused, they were also rated as more interesting and higher quality than young adults'.

The roles of age, inhibition and pragmatic factors in OTV have become clearer through careful and systematic investigations of Arbuckle, Pushkar Gold and colleagues. They selected adults who were in the top 15% of a panel of 455 older adults in terms of OTV, as well as samples with mid and low levels of OTV. To test the generality of OTV, as predicted by the inhibition deficit account, they used a referential communication task where participants gave descriptions to identify a nonsense figure to a listener. The high OTV group used more words, more hedges and more redundant information than the low or medium OTV groups who did not differ. There was, however, no difference among groups in off-topic speech in the task and little difference in the effect on the performance of the listener (Arbuckle et al., 2000). In a "get acquainted" conversation with other participants, the high OTV participants spent more time talking and provided more information about themselves. In a condition where they received cues signalling listener boredom during the conversation, the high OTV participants still talked more than the other groups but all groups reduced the time they spent talking.

The authors conclude that OTV characterizes only a minority of older adults and that "older people in general are not prone to verbose self-focused talk or to high levels of OTV (p.373)" (Arbuckle et al., 2000; Pushkar et al. 2000). They argue that inhibitory deficits explain OTV, but also suggest that declining cognitive performance may trigger a pragmatic change by shifting conversational goals towards more personal narratives. As Kemper and Mitzner (2001) point out, the inhibitory deficits invoked in OTV differ from the pervasive age-related deficits postulated in the inhibition deficit model (Hasher & Zacks, 1988). The relation between OTV and inhibitory function is found only for older adults in the top 15% of OTV scores, and not for the remaining 85% of older adults. Moreover, even high OTV adults are able to curb off-topic speech in some situations, e.g., referential communication tasks and when conversational partners look bored.

Summary of Semantics

Evidence from studies of lexical semantics, including vocabulary knowledge and semantic priming, suggests that this aspect of the semantic system is well preserved in old age. Declines in vocabulary occur only in very old age and may reflect declines in learning rather than in semantic processing. The bulk of the evidence from studies of semantic processing of sentences and discourse suggests that older adults compute meaning online and use this meaning top-down in subsequent language processing. Some recent ERP findings indicate slower or incomplete computation of meaning of sentences, although supporting behavioral evidence is sparse (but see Dagerman et al., 2006). Older adults' greater language experience is relevant to several age-related changes including semantic priming and frequency effects at the lexical level and the use of situational models at the discourse level. Cognitive aging models of language have yet to address the question of why aging has a beneficial effect on lexical semantic processing but not on processing in other language subsystems. Older adults reduce the density of ideas in their discourse and produce more off-topic speech in autobiographical narratives. Further research is needed to determine if the change in idea density is related to a combination of changes in cognitive function and pragmatic principles as seems to be true for off-topic speech.

SYNTAX

The primary account of syntactic changes in adulthood is that they are driven by a shrinking working memory capacity which limits older adults' ability to process complex hierarchical structures such as those underlying some syntactic constructions. The assumption is that embedded clauses in general and certain types in particular, such as those in left-branching sentences, increase working memory load to a point that sometimes exceeds older adults' capacity, disrupting syntactic processes (Kemper & Kemptes, 1999). Caplan and Waters, however, have argued for a dedicated working memory that is specialized for automatic interpretive processing of sentences and is unrelated to standard working memory measures that show age-related declines. Under this model, the online computation of meaning and syntax during reading or listening is obligatory and shows little variation with age. In contrast, offline postinterpretive language processing such as plausibility or grammaticality judgments involve conscious, controlled processing that reflects age-related decrements in working memory capacity as measured by standard working memory tasks (Caplan & Waters, 1999; Waters & Caplan, 2001, 2005). Investigation of the relation of online and offline language performance to aging and to working memory measures has motivated much recent research on comprehension of syntax.

Comprehension of Syntax

Offline measures of comprehension that require participants to answer questions about a text after it is read have consistently found age-related declines in performance (e.g., Kemper & Sumner, 2001; Van der Linden et al., 1999), especially for text with greater syntactic complexity (Waters & Caplan, 2001, 2005; but see Feier & Gerstman, 1980). Online techniques measure word-by-word or phrase-by-phrase reading or listening time, for example, by using the auditory moving window paradigm in which participants control presentation of successive phrases of the sentence. More time was allocated when the text increased in syntactic complexity, but this slowing of presentation was comparable for young and older adults at the most demanding regions of the sentence (Stine-Morrow et al., 1996; Waters & Caplan, 2001, 2005). Moreover, Waters and Caplan reported that offline but not online measures were correlated with working memory span and that age effects in the offline measures were reduced when span effects were removed. DeDe et al. (2004) tested this pattern of age differences using a structural equation modeling approach. Although the final model showed that the effects of syntactic complexity on listening time were related to age, they were not related to working memory measures. In contrast, offline measures of comprehension were related to age and the age effects were mediated by working memory.

The effects of syntactic complexity can also be seen in sentences with temporary syntactic ambiguity as in garden path sentences: *The experienced soldiers warned about the dangers conducted the midnight raid*. Correct interpretation and avoidance of the garden path requires multiple interpretations of the ambiguous phrase, in particular, transformation of *warned* from main verb to the verb in a relative clause (Kemper, Crow, & Kemptes, 2004). If syntactic processing is related to working memory capacity, then older adults should be less able to hold multiple interpretations in working memory and more likely to show garden path effects. However, the effect of ambiguity on reading time did not differ by age although young adults were more accurate than older adults answering questions about ambiguous sentences, but not unambiguous sentences (Kemptes & Kemper, 1997). In a study tracking eye movements, there were no age differences in the pattern of first pass fixation times for successive words in garden path sentences. First pass fixations are believed to reflect immediate semantic and syntactic processing during reading, and thus these findings are consistent with the Waters and Caplan (2001) model. Regressions back to words already read are believed to represent postinterpretive processes and these were more numerous for older than young adults in garden path sentences, suggesting that older adults were less able to hold the words in memory (Kemper et al., 2004).

Overall, the evidence suggests few age differences in online measures of syntactic processing and age decrements in offline measures of syntactic processing. This pattern is consistent with the Caplan and Waters' (1999) model of a dedicated working memory for online language processing that is unrelated to working memory span. We turn now to production where virtually all measures have been online.

Production of Syntax

Kemper and her colleagues have produced considerable evidence from both longitudinal and cross-sectional research that the syntactic complexity of spoken and written language declines with age. Syntactic complexity, measured by counts of different types of embedded clauses and of clauses per utterance, declined in old age in samples of writing from diaries (Kemper, 1987) and essays (Kemper et al., 2001a) and spoken responses to questions (Kemper & Sumner, 2001; Kemper et al., 2001b). Syntactic complexity was not related to educational attainment or high school grades (Kemper et al., 2001a), but was related to working memory measures (Kemper, Kynette, Rash, Sprott, & O'Brien, 1989; Kemper & Sumner, 2001; Kemper et al., 2001b).

Experimental studies of language production provide more control over pragmatic aspects of language that may influence the structure and content of spontaneous language, and may also vary with age. Davidson, Zacks, and Ferreira (2003) used a constrained production task in which young and older adults constructed a sentence using a visually presented subject pronoun and verb followed by two or three other cue words. The verbs varied in the number of syntactic options they allowed. Having only one option for sentence construction slowed onset latency and increased dysfluencies, with no age difference in these effects. Thus, the ability to use grammatical options to increase efficiency in constructing a sentence is well maintained in old age.

Using a similar constrained production task and presenting two, three or four cue nouns, Kemper, Herman, and Lian (2003a) reported that latency to produce a sentence increased with the number of nouns presented and more so for older than young adults. Despite this apparent greater time planning the sentences when there were more cue words, older adults' grammatical complexity and idea density increased less than young adults' with four words, although there were no age differences with two or three cue words. Parallel findings were obtained when the complexity of a cue verb was varied by comparing complement-taking verbs, e.g., *wished, guessed*, which often yield multiclause sentences, with transitive verbs, e.g., *called, replaced* and intransitive verbs, *smiled, jumped*. Complement taking verbs increased latency more for older than young adults, and increased grammatical complexity and idea density, but again this increase was less for older than young adults. Kemper, Herman, and Lian argued that increasing the number of cue words or the complexity of a cue verb increases memory load. This constrains the complexity of older adults' sentences because their reduced working memory capacity is inadequate with this increased load to generate complex syntax. This conclusion is consistent with results from another constrained production task where sentences were generated from presented stems that cued right-branching or left-branching completions (Kemper, Herman, & Liu, 2004). Young adults' sentences, but not older adults' sentences, were longer, more grammatically complex and more dense in propositions for right-branching than left-branching stems. The authors argued that older adults' reduced working memory capacity creates a "ceiling" on sentence complexity so that it does not vary with verb type.

Consistent with this account, Altmann and Kemper (2006) found that while young adults' word order in sentences was influenced by cue word characteristics such as animacy, older adults tended to construct sentences based on the order in which cue words were presented, perhaps because this reduced memory load. It is somewhat surprising in the context of these results that Kemper, Herman, and Lian (2003b) found that language production of both young and older adults was affected by performance of a concurrent task, for example, walking or finger tapping. Young adults showed greater costs in reduction of grammatical complexity and length of utterance and older adults showed greater costs in slowing of speech rate. Although older adults' baseline language was less fluent and complex than young adults, it is unclear how the pattern of costs is consistent with the working memory account of age difference in grammatical complexity.

Miller and Johnson (2004) identified different types of working memory based on patient data, focusing on "lexical-semantic" short-term memory that is measured, for example, by the difference in memory span for words versus nonwords, and has been related to language production. Participants described the movement pattern of three pictures on a screen which varied so that the response required two nouns in the initial noun phrase "The ball and the tree move above the finger" or one noun in the initial noun phrase "The ball moves above the tree and the finger." Latency to begin the sentence was longer for the two noun initial phrases than the one noun and the size of the effect was the same across age. There were no age differences in measures of lexical-semantic short-term memory, but these measures predicted the complexity effect in onset latency whereas measures of phonological short-term memory did not. These results are compatible with the view that there may be different types of working memory that vary in their relevance to language tasks.

In sum, older adults produce sentences with lower syntactic complexity and propositional density than younger adults in both spontaneous language and constrained language production tasks in the lab. This is readily explained under a working memory model in which older adults are less able to produce sentences with high complexity because of declines in working memory capacity. These conclusions are contrary to the conclusion reached in online comprehension studies that age has small effects on online syntactic processes and there is no relation between these processes and working memory. Clearly, future research needs to consider the reasons for this difference between online production and comprehension. It is unlikely that older adults construct simpler sentences as a pragmatic choice because they produce simpler sentences in constrained laboratory tasks and their reduced complexity compared to younger adults is accompanied by higher error rates (e.g., Kemper et al., 2004), suggesting that the simpler sentences were a response to processing difficulty. A recent attempt to identify different components of working memory that vary in how they are affected by age and in how they influence language production is a promising approach for understanding why some aspects of syntactic complexity are affected by age and others are not (Miller & Johnson, 2004).

CONCLUDING COMMENTS: IMPLICATIONS FOR COGNITIVE AGING RESEARCH

One of the most salient findings emerging from this review of language and aging is the profound effect that age differences in perceptual processing have on cognitive performance. Since Baltes and Lindenberger (1997) noted the paucity of research on the relation between sensory functioning and cognition in older adults, there has been a rapid increase in research activity in this area. On a theoretical level, the interaction between perception and cognition is consistent with interactive language models (see Figure 8.1) in which semantic activation depends on priming transmitted bottom-up from the phonological system; top-down priming from the semantic system is also transmitted to phonological representations during perception aiding perceptual recognition. The permeability of sensory and cognitive systems in these models underscores the significance of age-related changes in sensory processes.

The methodological implications are very clear. The sensory acuity of young and older participants in language research must be measured and reported. Self-reports of acuity have been shown to be inaccurate and unreliable. The research record demonstrates that it is difficult to draw conclusions about age differences in higher level language processes on the basis of behavior that reflects age differences in sensory acuity (see Schneider & Pichora-Fuller, 2000). In recent research older adults' sensory decline has been compensated for by adjusting presentation of stimuli to equate baseline performance or by statistically removing age differences in acuity. These procedures would be useful in a broad range of language research.

Cognitive aging theories have had mixed success in explaining why variables affecting perceptual difficulty, such as background noise or accelerated speed, have a greater effect on older adults' cognitive performance. The degraded signal account explains some but not all of the findings. In particular, even when identification of incoming language is correct so the signal is not degraded, the difficulty of perceptual identification affects subsequent cognitive processes (McCoy et al., 2005). Such effects are often attributed to limits on resource capacity. The resource model, however, continues to be plagued by a lack of specification of the nature of resources and how they affect performance.

The inadequacy of the resource model as currently implemented is not a new criticism (e.g., Light & Burke, 1988; MacKay & James, 2001; McDowd & Shaw, 2000; Navon, 1984; Salthouse & Craik, 2000). One of the most serious problems is the absence of an independent measure of resources creating a problem pointed out by Salthouse and Craik (2000): "when the same empirical results that are 'explained' by reduced resources also serve as the primary evidence for inferring the existence of an age-related reduction of resources" (p. 690). Little progress has been made in identifying an independent measure of resources; indeed, there is additional evidence that is inconsistent with a single pool of processing resources which can be measured by a single general measure (e.g., Waters & Caplan, 2001).

The predictive inadequacy that results from the absence of a behavioral index or a theoretical mechanism for resources can be seen clearly in language research. Consider the effect on performance of difficult perceptual conditions such as background noise or accelerated presentation rate. Older adults' word recognition declines more than young adults', an age difference that has been attributed to difficult perceptual conditions requiring more resources than are available to older adults. When, however, the to-be-identified words are presented in a meaningful sentence context, identification improves compared to a low meaning or no context condition, often with a larger benefit for older than young adults (e.g., Schneider et al., 2005; Sommers & Danielson, 1999; Speranza et al., 2000). This result can be explained under a resource account only if it is assumed that computing a semantic and syntactic representation of the sentence and using this representation top-down during word recognition *reduces* the resources required for the task compared to a no sentence context condition. This assumption is undermined by the findings of Stine-Morrow and others that demonstrate that computation of a mental representation of a sentence requires resources (e.g., Smiler et al., 2003). This assumption is also undermined under resources models that postulate that capacity is the maximum amount of activation available for storage and processing, and this amount is smaller for older than young adults (Just & Carpenter, 1992). Under this account, the activation required for computation and representation of sentence meaning would place a greater burden on older than young adults.

The extent to which semantic processes are maintained in old age presents a provocative challenge to cognitive aging theories more generally. What is required is a principled basis for explaining the asymmetric effects of aging on language, for example, the well-maintained semantic retrieval of word meaning (e.g., Verhaeghen, 2003) and the impaired phonological retrieval of word sounds (James & Burke, 2000), or the preserved response to internal semantic competitors during lexical selection (Stine & Wingfield, 1994) but the impaired response to internal phonological competitors (Sommers & Danielson, 1999). Thus, the challenge is to account for the good news in language research as well as age-related deficits.

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REFERENCES

Aaronson, D. (1974). Stimulus factors and listening strategies in auditory memory: A theoretical analysis. *Cognitive Psychology*, *6*, 108–132.

Abrams, L., & Stanley, J. H. (2004). The detection and retrieval of spelling in older adults. In S. P. Shohov (Ed.), *Advances in psychology research* (Vol. 33, pp. 87–109). Hauppauge, NY: Nova Science.

Ackerman, P. L., & Rolfhus, E. L. (1999). The locus of adult intelligence: Knowledge, abilities and nonability traits. *Psychology & Aging*, *14*, 314–330.

Akutsu, H., Legge, G. E., Ross, J. A., & Schuebel, K. J. (1991). Psychophysics of reading: X. Effects of age-related changes in vision. *Journal of Gerontology: Psychological Sciences*, *46*, 325–331.

Albert, M. S., Heller, H. S., & Milberg, W. (1988). Changes in naming ability with age. *Psychology and Aging*, *3*, 173–178.

Allen, P. A., Lien, M. -C., Murphy, M. D., Sanders, R. E., & McCann, R. S. (2002). Age differences in overlapping-task performance: Evidence for efficient parallel processing in older adults. *Psychology and Aging*, *17*, 505–519.

Allen, P. A., Madden, D. J., & Slane, S. (1995). Visual word encoding and the effect of adult age and word frequency. In P. A. Allen & T. R. Bashore (Eds.), *Age differences in word and language processing* (pp. 30–71). Amsterdam: North-Holland.

Allen, P. A., Madden, D. J., Weber, T. A., & Groth, K. E. (1993). Influence of age and processing stage on visual word recognition. *Psychology and Aging*, *8*, 274–282.

Altmann, L. J. P., & Kemper, S. (2006). Effects of age, animacy and activation order on sentence production. *Language and Cognitive Processes*, *21*, 322–354.

Alwin, D. F., & McCammon, R. J. (2001). Aging, cohorts, and verbal ability. *Journal of Gerontology: Social Sciences*, *56B*, S151–S161.

Anstey, K. J., Hofer, S. M., & Luszcz, M. A. (2003). A latent growth curve analysis of late-life sensory and cognitive function over 8 years: Evidence of specific and common factors underlying change. *Psychology & Aging*, *18*, 714–726.

Anstey, K. J., Luszcz, M. A., & Sanchez, L. (2001). A reevaluation of the common factor theory of shared variance among age, sensory function, and cognitive function in older adults. *Journal of Gerontology: Psychological Sciences*, *56B*, 3–11.

Anstey, K. J., & Smith, G. A. (1999). Interrelationships among biological markers of aging, health, activity, acculturation and cognitive performance in late adulthood. *Psychology and Aging*, *14*, 605–618.
Arbuckle, T. Y., Nohara-LeClair, M., & Pushkar, D. (2000). Effect of off-target verbosity on communication efficiency in a referential communication task. *Psychology and Aging*, *15*, 65–77.
Arbuckle, T. Y., & Pushkar Gold, D. P. (1993). Aging, inhibition and verbosity. *Journal of Gerontology: Psychological Sciences*, *48*, 225–232.
Artal, P., Ferro, M., Miranda, I., & Navarro, R. (1993). Effects of aging in retinal image quality. *Journal of the Optical Society of America* A, *10*, 1656–1662.
Au, R., Joung, P., Nicholas, M., Obler, L. K., Kass, R., & Albert, M. L. (1995). Naming ability across the adult life span. *Aging and Cognition*, *2*, 300–311.
Baddeley, A. D. (1986). *Working memory*. New York: Oxford University Press.
Balota, D. A., Watson, J. . M., Duchek, J. . M., & Ferraro, F. R. (1999). Cross-modal semantic and homograph priming in healthy young, healthy old, and in Alzheimer's disease individuals. *Journal of the International Neuorpsychological Society*, *5*, 626–640.
Baltes, P. B., & Lindenberger, U. (1997). Emergence of a powerful connection between sensory and cognitive functions across the adult life span: A new window to the study of cognitive aging? *Psychology and Aging*, *12*, 12–21.
Baltes, P. B., Staudinger, U. M., & Lindenberger, U. (1999). Life span psychology: Theory and application to intellectual functioning. *Annual Review of Psychology*, *50*, 471–507.
Barresi, B. A., Nicholas, M., Connor, L. T., Obler, L., & Albert, M. L. (2000). Semantic degradation and lexical access in age-related naming failures. *Aging, Neuropsychology, and Cognition*, *7*, 169–178.
Beier, M. E., & Ackerman, P. L. (2001) Current-events knowledge in adults: An investigation of age, intelligence, and nonability determinants. *Psychology & Aging*. *16*, 615–628.
Birren, J. E. (1965). Age changes in speed of behavior: Its central nature and physiological correlates. In A. T. Welford & J. E. Birren (Eds.), *Behavior, aging and the nervous system* (pp. 191–216). Springfield, IL: Thomas.
Bortfeld, H., Leon, S. D., Bloom, J. E., Schober, M. F., & Brennan, S. E. (2001). Disfluency rates in conversation: Effects of age, relationship, topic, role, and gender. *Language and Speech*, *44*, 123–149.
Botwinick J. (1977). Intellectual abilities. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 580–605). New York: Van Nostrand Reinhold.
Botwinick, J. (1984). *Aging and behavior*. New York: Springer.
Brown, A., & Draper, P. (2003). Accommodative speech and terms of endearment: Elements of a language mode often experienced by older adults. *Journal of Advanced Nursing*, *41*, 15–21.
Brown, R., & McNeill, D. (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning Behavior*, *5*, 325–337.
Brown, A. S., & Nix, L. A. (1996). Age-related changes in the tip-of-the-tongue experience. *American Journal of Psychology*, *109*, 79–91.
Brown, S., & Pichora-Fuller, M. K. (2000). Temporal jitter mimicks the effects of aging on word identification and word recall in noise. *Canadian Acoustics*, *28*, 126–128.
Burke, D. M. (1999). Language production and aging. In S. Kemper and R. Kliegl (Eds.), *Constraints on language: Aging, grammar and memory* (pp. 3–28). Boston: Kluwer.
Burke, D. M. (2006). Representation and aging. In E. Bialystok & F. I. M. Craik (Eds.) *Lifespan cognition: Mechanisms of change* (pp. 193–206). New York: Oxford University Press.
Burke, D. M., Locantore, J., Austin, A., & Chae, B. (2004). Cherry pit primes Brad Pitt: Homophone priming effects on young and older adults' production of proper names. *Psychological Science*, *15*, 164–170.

Burke, D. M., & MacKay, D. G. (1997). Memory, language and ageing. *Philosophical Transactions of the Royal Society: Biological Sciences*, *352*, 1845–1856.
Burke, D. M., MacKay, D. G., & James, L. E. (2000). Theoretical approaches to language and aging. In T. Perfect & E. Maylor (Eds.), Models of cognitive aging (pp. 204–237). Oxford: Oxford University Press.
Burke, D. M., MacKay, D. G., Worthley, J. S., & Wade, E. (1991). On the tip of the tongue: What causes word finding failures in younger and older adults. *Journal of Memory and Language*, *30*, 542–579.
Burke, D. M., & Osborne, G. L. (In press). Aging and inhibition deficits: Where are the effects? In D. Gorfein & C. MacLeod (Eds.), On the place of inhibitory processes in cognition. Washington, DC: American Psychological Association Press.
Burke, D. M., & Peters, L. (1986). Word associations in old age: Evidence for consistency in semantic encoding during adulthood. *Psychology and Aging*, *1*, 283–292.
Burke, D. M., & Shafto, M. A. (2004). Aging and language production. *Current Directions in Psychological Science*, *13*, 21–24.
Burke, D. M., Stamatakis, E., Broderick, C., Finan, V., Shafto, M., Osborne, G., et al. (2005, April). *Aging, tip-of-the-tongue experiences, and atrophy of the insula: A voxel-based morphometry study*. Poster presented at the meeting of the Cognitive Neuroscience Society.
Burke, D. M., White, H., & Diaz, D. L. (1987). Semantic priming in young and older adults: Evidence for age constancy in automatic and attentional processes. *Journal of Experimental Psychology: Human Perception and Performance*, *13*, 542–579.
Cameli, L., & Phillips, N. A. (2000). Age-related differences in semantic priming: Evidence from event-related brain potentials. *Brain & Cognition*, *43*, 69–73.
Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences*, *22*, 77–126.
Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, *14*, 177–208.
Caramazza, A., Costa, A., Miozzo, M., & Bi, Y. (2001). The specific-word frequency effect: Implications for the representation of homophones. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 1430–1450.
Carlson, M. C., Hasher, L., Zacks, R. T., & Connelly, S. L. (1995). Aging, distraction, and the benefits of predictable location. *Psychology and Aging*, *10*, 427–436.
Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously. *American Psychologist*, *54*, 165–181.
Carter, A. S., & Wilson, R. H. (2001). Lexical effects on dichotic word recognition in young and elderly listeners. *Journal of the American Academy of Audiology*, *12*, 86–100.
Caza, N., & Moscovitch, M. (2005). Effects of cumulative frequency, but not of frequency trajectory, in lexical decision times of older adults and patients with Alzheimer's disease. *Journal of Memory and Language*, *53*, 456–471.
Cerella, J. (1985). Information processing rates in the elderly. *Psychological Bulletin*, *98*, 67–83.
Cheesman, M. F., (1997). Speech perception by elderly listeners: Basic knowledge and implications for audiology. *Journal of Speech-Language Pathology and Audiology*, *21*, 104–110.
Christensen, H., Mackinnon, A. J., Korten, A., & Jorm, A. F. (2001). The "common cause hypothesis" of cognitive aging: Evidence for not only a common factor but also specific associations of age with vision and grip strength in a cross-sectional analysis. *Psychology and Aging*, *16*, 588–599.
Committee on Hearing and Bioacoustics and Biomechanics (CHABA, 1988). Speech understanding and aging. *Journal of the Acoustical Society of America*, *83*, 859–895.
Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging*, *6*, 533–541.

Connor, L. T., Spiro, A., Obler, L. K., & Albert, M. L. (2004). Change in object naming ability during adulthood. *Journal of Gerontology: Psychological Sciences*, *59B*, P203–P209.

Corso, J. F. (1971). Sensory processes and age effects in normal adults. *Journal of Gerontology*, *26*, 90–105.

Cortese, M. J., Balota, D. A., Sergent-Marshall, S. D., & Buckner, R. L. (2003). Spelling via semantics and phonology: Exploring the effects of age. Alzheimer's disease and primary semantic impairment. *Neuropsychologia*, *41*, 952–967.

Coughlin, M., Kewley-Port, D., & Humes, L. E., (1998). The relation between identification and discrimination of vowels in young and elderly listeners. *Journal of the Acoustical Society of America*, *104*, 3597–3607.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. E. Trehub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum Press.

Craik, F. I. M., & Masani, P. A. (1967). Age differences in the temporal integration of language. *British Journal of Psychology*, *58*, 291–299.

Cross, E. S., & Burke, D. M. (2004). Do alternative names block young and older adults retrieval of proper names? *Brain and Language*, *89*, 174–181.

Cutting, C. J., & Ferreira, V. S. (1999). Semantic and phonological information flow in the production lexicon. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 318–344.

Dagerman, K. S., MacDonald, M. C., & Harm, M. W. (2006). Aging and the use of context in ambiguity resolution: Complex changes from simple slowing. *Cognitive Science*, *30*, 311–345.

Davidson, D. J., Zacks, R. T., & Ferreira, F. (2003). Age preservation of the syntactic processor in production. *Journal of Psycholinguistic Research*, *32*, 541–566.

DeDe, G., Caplan, D., Kemptes, K., & Waters, G. (2004). The relationship between age, verbal working memory, and language comprehension. *Psychology & Aging*. *19*, 601–616.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review*, *93*, 283–321.

Dell, G. S., Chang, E., & Griffin, Z. M. (1999). Connectionist models of language production: Lexical access and grammatical encoding. *Cognitive Science*, *34*, 517–542.

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, *104*, 801–838.

Dijkstra, K., Yaxley, R. H., Madden, C. J., & Zwaan, R. A. (2004). The role of age and perceptual symbols in language comprehension. *Psychology & Aging*, *19*, 352–356.

Dubno, J. R., Dirks, D. D., & Morgan, D. E. (1984). Effects of age and mild hearing loss on speech recognition in noise. *Journal of the Acoustical Society of America*, *76*, 87–96.

Duchek, J. M., Balota, D. A., & Thessing, V. C. (1998). Inhibition of visual and conceptual information during reading in healthy aging and Alzheimer's disease. *Aging, Neuropsychology, and Cognition*, *5*, 169–181.

Dywan, J., & Murphy, W. E. (1996). Aging and inhibitory control in text comprehension. *Psychology and Aging*, *11*, 199–206.

Earles, J. L., Connor, L. T., Frieske, D., Park, D. C., Smith, A. D., & Zwahr, M. (1997). Age differences in inhibition: Possible causes and consequences. *Aging, Neuropsychology, and Cognition*, *4*, 45–57.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, *128*, 309–331.

Evrard, M. (2002). Ageing and lexical access to common and proper names in picture naming. *Brain and Language*, *81*, 174–179.

Faust, M. E., Balota, D. A., & Multhaup, K. S. (2004). Phonological blocking during picture naming in dementia of the Alzheimer type. *Neuropsychology*, *18*, 526–536.

Federmeier, K. D., McLennan, D. B., De Ochoa, E., & Kutas, M. (2002). The impact of semantic memory organization and sentence context on spoken language processing by younger and older adults: An ERP study. *Psychophysiology*, *39*, 133–146.

Federmeier, K. D., Van Petten, C., Schwartz, T. J., & Kutas, M. (2003). Sounds, words, sentences: Age-related changes across levels of language processing. *Psychology and Aging*, *18*, 858–872.

Feier, C. D., & Gerstman, L. J. (1980) Sentence comprehension abilites throughout the life span. *Journal of Gerontology*, *35*, 722–728.

Feyereisen, P. (1997). A meta-analytic procedure shows an age-related decline in picture-naming: Comments on Goulet, Ska, and Kahn. *Journal of Speech and Hearing Research*, *40*, 1328–1333.

Fisher, D. L., Duffy, S. A., & Katsikopoulos, K. V. (2000). Cognitive slowing among older adults: What kind and how much? In T. Perfect & E. Maylor (Eds.), *Models of cognitive aging* (pp. 87–124). Oxford: Oxford University Press.

Fitzgibbons, P. J., & Gordon-Salant, S. (1996). Auditory temporal processing in elderly listeners. *Journal of the American Academy of Audiology*, *7*, 183–189.

Fozard, J. L., & Gordon-Salant, S. (2001). Changes in vision and hearing with aging. In J. E. Birren and K. Warner Schaie (Eds.), *Handbook of the psychology of aging* (pp. 214–266). New York: Academic Press.

Gates, G. A., Feeney, M. P., & Higdon, R. J. (2003). Word recognition and the articulation index in older listeners with probable age-related auditory neuropathy. *Journal of the American Academy of Audiology*, *14*, 574–581.

Ghisletta, P., & Lindenberger, U. (2005). Exploring structural dynamics within and between sensory and intellectual functioning in old and very old age: Longitudinal evidence from the Berlin Aging Study. *Intelligence*, *33*, 555–587.

Giffard, B., Desgranges, B., & Kerrouche, N. (2003). The hyperpriming phenomenon in normal aging: A consequence of cognitive slowing? *Neuropsychology*, *17*, 594–601.

Gilmore, G. C., Spinks, R. A., & Thomas, C. W. (2006). Age effects in coding tasks: Componential analysis and test of the sensory deficit hypothesis. *Psychology and Aging*, *21*, 7–18.

Gold, D., Andres, D., Arbuckle, T., & Schwartzman, A. (1988). Measurement and correlates of verbosity in elderly people. *Journal of Gerontology: Psychological Sciences*, *43*, P27–33.

Gollan, T. H., & Brown, A. S. (2006) From tip-of-the-tongue (TOT) data to theoretical implications in two steps: When more TOTs means better retrieval. *Journal of Experimental Psychology: General*, *135*, 462–483.

Gomez, R. (2002). Word frequency effects in priming performance in young and older adults. *Journal of Gerontology: Psychological Sciences*, *57B*, P233–P240.

Good, C. D., Johnsrude, I. S., Ashburner, J., Henson, R. N. A., Friston, K. J., & Frackowiak, R. S. J. (2001). A voxel-based morphometric study of ageing in 465 normal adult human brains. *Neuroimage*, *14*, 21–36.

Gordon-Salant, S., & Fitzgibbons, P. (1999). Profile of auditory temporal processing in older listeners. *Journal of Speech, Language, and Hearing Research*, *42*, 300–311.

Gordon-Salant, S., & Fitzgibbons, P. J. (2001). Sources of age-related recognition difficulty for time-compressed speech. *Journal of Speech, Language, and Hearing Research*, *44*, 709–719.

Gould, O. N., Saum, C., & Belter, J. (2002). Recall and subjective reactions to speaking styles: Does age matter? *Experimental Aging Research*, *28*, 199–213.

Goulet, P., Ska, B., & Kahn, H. J. (1994). Is there a decline in picture naming with advancing age? *Journal of Speech and Hearing Research*, *37*, 629–644.

Haarmann, H. J., Just, M. A., & Carpenter, P. A. (1997). Aphiasic sentence comprehension as a resource deficit: A computational approach. *Brain and Language*, *59*, 76–120.

Haegerstrom-Portnoy, G., Schneck, M. E., & Brabyn, J. A. (1999). Seeing into old age: Vision function beyond acuity. *Optometry and Vision Science*, *76*, 141–158.

Halling, D. C., & Hume, L. E. (2000). Factors affecting the recognition of reverberant speech by elderly listeners. *Journal of Speech, Language, and Hearing Research*, *43*, 414–439.

Hasher, L., Lustig, C., & Zacks, R. (in press). Inhibitory mechanisms and the control of attention. In A. Conway, C. Jarrold, M. Kane, A. Miyake, & J. Towse (Eds), *Variation in working memory*. New York: Oxford University Press.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General*, *108*, 356–388.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of Learning and Motivation*, *22*, 193–225.

Heine, M. K., Ober, B. A., & Shenaut, G. K. (1999). Naturally occurring and experimentally induced tip-of-the-tongue experiences in three adult age groups. *Psychology & Aging*, *14*, 445–457.

Heller, R., B., & Dobbs, A. R. (1993). Age differences in word finding in discourse and non-discourse situations. *Psychology and Aging*, *8*, 443–450.

Hirsh K. W., & Tree, J. J. (2001). Word association norms for two cohorts of British adults. *Journal of Neurolinguistics*, *14*, 1–44.

Hodgson, C., & Ellis, A. W. (1998). Last in, first to go: Age of acquisition and naming in the elderly. *Brain & Language*, *64*, 146–163.

Hopkins, K. A., Kellas, G., & Paul, S. (1995). Scope of word meaning activation during sentence processing by young and older adults. *Experimental Aging Research*, *21*, 123–142.

Howard, D. V., McAndrews, M. P., & Lasaga, M. I. (1981). Semantic priming of lexical decisions in young and old adults. *Journal of Gerontology*, *36*, 707–714.

Humes, L. E. (1996). Speech understanding in the elderly. *Journal of the American Academy of Audiology*, *7*, 161–167.

Humes, L. E., & Christopherson, L. (1991). Speech identification difficulties of hearing-impaired elderly persons: The contributions of auditory processing deficits. *Journal of Speech and Hearing Research*, *34*, 686–693.

Humes, L. E., Watson, B. U., Christensen, L. A., Cokely, C. G., Halling, D. C., & Lee, L. (1994). Factors associated with individual differences in clinical measures of speech recognition among the elderly. *Journal of Speech and Hearing Research*, *37*, 465–474.

Hummert, M. L., Garstka, T. A., Ryan, E. B., & Bonnesen, J. L. (2004). The role of age stereotypes in interpersonal communication. In J. F. Nussbaum & J. Coupland (Eds.), *Handbook of communication and aging research (2nd ed.* , pp. 91–114). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition*, *92*, 101–144.

Isaacowitz, D. M., Charles, S. T., & Carstensen, L. L. (2000). Emotion and cognition. In F. I. M., Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 593–631). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

James, L. E. (2004). Meeting Mr. Farmer versus meeting a farmer: Specific effects of aging on learning proper names. *Psychology & Aging*, *19*, 515–522.

James, L. E. (2006). Specific effects of aging on proper name retrieval: Now you see them, now you don't. *Journal of Gerontology: Psychological Sciences*, *61*, P180–P183.

James, L. E. &, Burke, D. M. (2000). Phonological priming effects on word retrieval and tip-of-the-tongue experiences in young and older adults. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *26*, 1378–1391.

James, L. E., Burke, D. M., Austin, A., & Hulme, E. (1998). Production and perception of "verbosity" in younger and older adults. *Psychology and Aging*, *13*, 355–367.

James, L. E. & MacKay, D. G. (2001). H. M., word knowledge and aging: Support for a new theory of long-term retrograde amnesia. *Psychological Science*, *12*, 485–492.

Johnson, R. E. (2003). Aging and the remembering of text. *Developmental Review*, *23*, 261–346.

Jones, G. V. (1989). Back to Woodworth: Role of interlopers in the tip of the tongue phenomenon. *Memory and Cognition*, *17*, 69–76.

Juncos-Rabadan, O, Pereiro, A. X., & Rodriquez, M. S. (2005). Narrative speech in aging: Quantity, information content, and cohesion. *Brain and Language*, *95*, 423–434.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *98*, 122–149.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Lawrence Erlbaum Associates, Inc.

Kemper, S. (1987). Life-span changes in syntactic complexity. *Journal of Gerontology*, *42*, 323–328.

Kemper, S. (1992). Language and aging. In F. I. M. Craik & T. A. Salthouse (Eds.) *The handbook of aging and cognition* (pp. 213–270). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Kemper, S. (2006). Language in adulthood. In E. Bialystok & F. I. M. Craik (Eds.) *Lifespan cognition: Mechanisms of change* (pp. 223–238). New York: Oxford University Press.

Kemper, S., Crow, A., & Kemptes, K. (2004). Eye-fixation patterns of high- and low-span young and older adults: Down the garden path and back again. *Psychology and Aging*, *19*, 157–170.

Kemper, S., Finter-Urczyk, A., Ferrell, P., Harden, T., & Billington, C. (1998). Using elder-speak with older adults. *Discourse Processes*, *25*, 55–73.

Kemper, S., Greiner, L. H., Marquis, J. G., Prenovost, K., & Mitzner, T. L. (2001a). Language decline across the life span: Findings from the nun study. *Psychology and Aging*, *16*, 227–239.

Kemper, S., & Harden, T. (1999). Experimentally disentangling what's beneficial about elder-speak from what's not. *Psychology and Aging*, *14*, 656–670.

Kemper, S., Herman, R., & Lian, C. (2003a). Age differences in sentence production. *Journal of Gerontology: Psychological Sciences*, *58B*, P260–P268.

Kemper, S., Herman, R. E., & Lian, C. H. T. (2003b). The costs of doing two things at once for young and older adults: Talking while walking, finger tapping, and ignoring speech or noise. *Psychology and Aging*, *18*, 181–192.

Kemper, S., Herman, R. E., & Liu, C. J. (2004). Sentence production by young and older adults in controlled contexts. *Journal of Gerontology: Psychological Sciences*, *59B*, P220–P224.

Kemper, S., & Kemptes, K. (1999). Limitations on syntactic processing. In S. Kemper & R. Kliegl (Eds.), *Constraints on language: Aging, grammar, and memory* (pp. 79–106). Boston: Kluwer.

Kemper, S., & Kemptes, K. (2000). Aging and message production and comprehension. In D. C. Park & N. Schwarz (Eds.), *Cognitive aging: A primer*. (pp. 197–213). New York: Psychology Press.

Kemper, S., Kynette, D., Rash, S., Sprott, R., & O'Brien, K. (1989). Life-span changes to adults' language: Effects of memory and genre. *Applied Psycholinguistics*, *10*, 49–66.

Kemper, S., & McDowd, J. (2006). Eye movements of young and older adults while reading with distraction. *Psychology and Aging*, *21*, 32–39.

Kemper, S., & Mitzner, T. L. (2001). Language production and comprehension. In In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (5th ed., pp. 378–398). San Diego, CA: Academic Press.

Kemper, S., Rash, S., Kynette, D., & Norman, S. (1990). Telling stories: The structure of adults' narratives. *European Journal of Cognitive Psychology*, *2*, 205–228.

Kemper, S., & Sumner, A. (2001). The structure of verbal abilities in young and older adults. *Psychology and Aging*, *16*, 312–322.

Kemper, S., Thompson, M., & Marquis, J. (2001b). Longitudinal change in language production: Effects of aging and dementia on grammatical complexity and propositional content. *Psychology and Aging*, *16*, 227–239.

Kemptes, K. A., & Kemper, S. (1997). Younger and older adults' on-line processing of syntactically ambiguous sentences. *Psychology and Aging*, *12*, 362–371.

Kliegl, R., & Kemper, S. (1999). Concluding observations. In S. Kemper and R. Kliegl (Eds.), *Constraints on language: Aging, grammar and memory* (pp. 299–307). Boston: Kluwer.

Kutas, M., & Federmeier, K. D. (2001). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Science*, *4*, 463–470.

Lahar, C. J., Tun, P. A., & Wingfield, A. (2004). Sentence-final word completion norms for young, middle-aged, and older adults. *The Journals of Gerontology: Psychological Sciences*, *59*, P7–P10.

Lashley, K. S. (1951). The problem of serial order in behavior. In L. A. Jeffress (Ed.), *Cerebral mechanisms in behavior* (pp. 112–146). New York: Wiley.

La Tourette, T. R., & Meeks, S. (2000). Perceptions of patronizing speech by older women in nursing homes and in the community. Impact of cognitive ability and place of residence. *Journal of Language and Social Psychology*, *19*, 463–473.

Laver, G. D. (2000). A speed-accuracy analysis of word recognition in young and older adults. *Psychology and Aging*, *15*, 705–709.

Laver, G. D., & Burke, D. M. (1993). Why do semantic priming effects increase in old age? A meta-analysis. *Psychology and Aging*, *8*, 34–43.

Lazzara, M. M., Yonelinas, A. P., & Ober, B. A. (2002). Implicit memory in aging: Normal transfer across semantic decisions and stimulus format. *Aging. Neuropsychology, and Cognition*, *9*, 145–156.

Ledoux, K., Camblin, C. C., Swaab, T. Y., & Gordon, P. C. (2006). Reading words in discourse: The modulation of lexical priming effects by message-level context. *Behavioral and Cognitive Neuroscience Reviews*, *5*, 107–127.

Levelt, W. J. M. (2001). Spoken word production: A theory of lexical access. *Proceedings of the National Academy of Science*, *98*, 13464–13471.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–75.

Li, L., Daneman, M., Qi, J. G., & Schneider, B. A. (2004). Does the information content of an irrelevant source differentially affect spoken word recognition in younger and older adults? *Journal of Experimental Psychology: Human Perception and Performance*, *30*, 1077–1091.

Li, K. Z. H., Hasher, L., Jonas, D., May, C. P., & Rahhal, T. A. (1998). Distractibility, circadian arousal, and aging: A boundary condition? *Psychology and Aging*, *13*, 574–583.

Li, K. Z., & Lindenberger, U. (2002). Relations between aging sensory/sensorimotor and cognitive function, *Neuroscience and Biobehavioral Reviews*, *26*, 777–783.

Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology*, *42*, 333–376.

Light, L., & Burke, D. (1988). Patterns of language and memory in old age. In L. Light, & D. Burke (Eds.), *Language, memory and aging* (pp. 244–271). New York: Cambridge University Press.

Light, L. L., Valencia-Laver, D., & Zavis, D. (1991). Instantiation of general terms in young and older adults. *Psychology and Aging*, *6*, 337–351.

Lima, S. D., Hale, S., & Myerson, J. (1991). How general is general slowing? Evidence from the lexical domain. *Psychology and Aging*, *6*, 416–425.

Lindenberger, U., & Baltes, P. (1994). Sensory functioning and intelligence in old age: A strong connection. *Psychology and Aging*, *9*, 339–355.
Lindenberger, U., & Baltes, P. B. (1997). Intellectual functioning in old and very old age: Cross-sectional results from the Berlin Aging Study. *Psychology and Aging*, *12*, 410–432.
Lindenberger, U., Scherer, H., & Baltes, P. B. (2001). The strong connection between sensory and cognitive performance in old age: Not due to sensory acuity reductions operating during cognitive assessment. *Psychology and Aging*, *16*, 196–205.
Little, D. M., Prentice, K. J., & Wingfield, A. (2004). Adult age differences in judgments of semantic fit. *Applied Psycholinguistics*, *25*, 135–143.
Logan, J. M., & Balota, D. A. (2003). Conscious and unconscious lexical retrieval blocking in young and older adults. *Psychology and Aging*, *18*, 537–550.
Lovelace, E. A., & Twohig, P. T. (1990). Healthy older adults' perceptions of their memory functioning and use of mnemonics. *Bulletin of the Psychonomic Society*, *28*, 115–118.
Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear & Hearing*, *19*, 1–36.
Lustig, C., & Hasher, L. (2001). Implicit memory is not immune to interference. *Psychological Bulletin*, *127*, 618–628.
MacDonald, M. C., & Christiansen, M. H. (2002). Reassessing working memory: Comment on Just and Carpenter (1992) and Waters and Caplan (1996). *Psychological Review*, *109*, 35–54.
MacKay, A. I., Connor, L. T., Albert, M. L., & Obler, L. K. (2002). Noun and verb retrieval in healthy aging. *Journal of the International Neuropsychological Society*, *8*, 764–770.
MacKay, D. G. (1987). *The organization of perception and action: A theory for language and other cognitive skills*. New York: Springer-Verlag.
MacKay, D. G. (2006). Aging, memory and language in amnesic HM. *Hippocampus*, *16*, 491–495.
MacKay, D. G., & Abrams, L. (1996). Language, memory, and aging: Distributed deficits and the structure of new-versus-old connections. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (4th ed., pp. 251–265). San Diego, CA: Academic Press.
MacKay, D. G., & Abrams, L. (1998). Age-linked declines in retrieving orthographic knowledge: Empirical, practical, and theoretical implications. *Psychology and Aging*, *13*, 647–662.
MacKay, D. G., Abrams, L., & Pedroza, M. J. (1999). Aging on the input versus output side: Theoretical implications of age-linked asymmetries between detecting versus retrieving orthographic information. *Psychology and Aging*, *14*, 3–17.
MacKay, D. G., & Burke, D. M. (1990). Cognition and aging: New learning and the use of old connections. In T. M. Hess (Ed.), *Aging and cognition: Knowledge organization and utilization* (pp. 213–263). Amsterdam: North Holland.
MacKay, D. G., Hadley, C. B., & Abrams, L. (2006a). *Beyond soup stones: Testing the core assumptions of age-linked resource-capacity theories*. Manuscript submitted for publication.
MacKay, D. G., & James, L. E. (2001). The binding problem for syntax, semantics, and prosody: H. M. 's selective sentence-reading deficits under the theoretical-syndrome approach. *Language and Cognitive Processes*, *16*, 419–460.
MacKay, D. G., & James, L. E. (2004). Sequencing, speech production, and selective effects of aging on phonological and morphological speech errors. *Psychology and Aging*, *19*, 93–107.
MacKay, D. G., Taylor, J. K., & Marian, D. E. (2006b). *Unsuspected age-linked acuity deficits and research on reading: Practical and empirical implications*. Manuscript submitted for publication.
Mackenzie, C. (2000a). Adult spoken discourse: The influences of age and education. *International Journal of Language and Communication Disorders*, *35*, 269–285.

Mackenzie, C. (2000b). The relevance of education and age in the assessment of discourse comprehension. *Clinical Linguistics and Phonetics*, *14*, 151–161.
Madden, D. J. (1988). Adult age differences in the effects of sentence context and stimulus degradation during visual word recognition. *Psychology and Aging*, *3*, 167–172.
Madden, D. J. (1992). Four to ten milliseconds per year: Age-related slowing of visual word identification. *Journal of Gerontology: Psychological Sciences*, *47*, P59–68.
Madden, D. J. (2001). Speed and timing of behavioral processes. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (5th ed., pp. 288–312). San Diego, CA: Academic Press.
Madden, D. J., Langley, L. K., Denny, L. L., Turkington, T. G., Provenzale, J. M., & Hawk, T. C. (2002). Adult age differences in visual word identification: Functional neuroanatomy by positron emission tomography. *Brain and Cognition*, *49*, 297–321.
Madden, D. J., Pierce. T. W., & Allen, P. A. (1993). Age-related slowing and the time course of semantic priming in visual word identification. *Psychology and Aging*, *8*, 490–507.
Madden, D. J., & Whiting, W. L. (2004). Age-related changes in visual attention. In P. T. Costa & I. C. Siegler (Eds.) *Recent advances in psychology and aging* (pp. 41–88). Amsterdam: Elsevier.
Madden, D. J., Whiting, W. L., & Huettel, S. A. (2005). Age-related changes in neural activity during visual perception and attention. In R. Cabeza, L. Nyberg, & D. Park (Eds.), *Cognitive neuroscience and aging: Linking cognitive and cerebral aging* (pp. 157–185). New York: Oxford University Press.
Manenti, R., Repetto, C., Bentrovato, S., Marcone, A., Bates, E., & Cappa, S. F. (2004). The effects of ageing and Alzheimer's disease on semantic and gender priming. *Brain*, *127*, 2299–2306.
Margolin, S. J. & Abrams, L. (in press). Individual differences in young and older adults' spelling: Do good spellers age better than poor spellers? *Aging, Neuropsychology, & Cognition*.
Marner, L., Nyengaard, J. R., Tang, Y., & Pakkenberg, B. (2003). Marked loss of myelinted nerve fibers in the human brain with age. *Journal of Comparative Neurology*, *462*, 144–152.
Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology*, *10*, 29–63.
Maylor, E. A. (1990). Recognizing and naming faces: Aging, memory retrieval and the tip of the tongue state. *Journal of Gerontology: Psychological Sciences*, *45*, P215–P225.
Maylor, E. A. (1997). Proper name retrieval in old age: Converging evidence against disproportionate impairment. *Aging, Neuropsychology, and Cognition*, *4*, 211–226.
McClelland, J. K., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Pt. 1. An account of the basic findings. *Psychological Review*, *88*, 375–407.
McCoy, S. L., Tun, P. A., Cox, L. C., Colangelo, M., Stewart, R. A., & Wingfield, A. (2005). Hearing loss and perceptual effort: Downstream effects on older adults' memory for speech. *The Quarterly Journal of Experimental Psychology*, *58A*, 22–33.
McDowd, J. M., & Shaw, R. J. (2000). Aging and attention: A functional perspective. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 221–292). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
McGinnis, D., & Zelinski, E. M. (2000). Understanding unfamiliar words: The influence of processing resources, vocabulary knowledge, and age. *Psychology & Aging*, *15*, 335–350.
McGinnis, D., & Zelinski, E. M. (2003). Understanding unfamiliar words in young, young-old, and old-old adults: Inferential processing and the abstraction-deficit hypothesis. *Psychology and Aging*, *18*, 497–509.
McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology*, *41*, 175–192.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*, 81–97.
Miller, L. M. S. (2003). The effects of age and domain knowledge on text processing. *Journal of Gerontology: Psychological Sciences*, *58B*, 217–P223.
Miller, L. M. S., Stine-Morrow, E. A. L., Kirkorian, H. L., & Conroy, M. L. (2004). Adult age differences in knowledge-driven reading. *Journal of Educational Psychology*, *96*, 811–821.
Miller, M. D., & Johnson, J. S. (2004). Phonological and lexical-semantic short-term memory and their relationship to sentence production in older adults. *Aging, Neuropsychology, and Cognition*, *11*, 395–415.
Miozzo, M., & Caramazza, A. (1997). Retrieval of lexical-syntactic features in tip-of-the-tongue states. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1410–1423.
Mitchell, D. B. (1989). How many memory systems? Evidence from aging. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*, 31–49.
Morrison, C. M., Hirsh, K. W., & Duggan, G. B. (2003). Age of acquisition, ageing, and verb production: Normative and experimental data. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *56*, 705–730.
Mortensen, L., Meyer, A. S., & Humphreys, G. W. (2006). Age-related slowing of object naming: A review. *Language and Cognitive Processes*, *21*, 238–290.
Murphy, D. R., Craik, F. I. M., Li, K. Z. H., & Schneider, B. A. (2000). Comparing the effects of aging and background noise on short-term memory performance. *Psychology and Aging*, *15*, 323–334.
Murphy, D. R., Daneman, M., & Schneider, B. A. (2006). Why do older adults have difficulty following conversations? *Psychology and Aging*, *21*, 49–61.
Murphy, D. R., McDowd, J. M., & Wilcox, K. A. (1999). Inhibition and aging: Similarities between younger and older adults as revealed by the processing of unattended auditory information. *Psychology and Aging*, *14*, 44–59.
Myerson, J., Ferraro, F. R., Hale, S., & Lima, S. D. (1992). The role of general slowing in semantic priming and word recognition. *Psychology and Aging*, *7*, 257–270.
Myerson, J., Hale, S., Wagstaff, D., Poon, L. W., & Smith, G. A. (1990). The information-loss model: A mathematical theory of age-related cognitive slowing. *Psychological Review*, *97*, 475–487.
Navon, D. (1984). Resources—a theoretical soupstone? *Psychological Review*, *91*, 216–234.
Nelson, H. E. (1985). *National Adult Reading Test (NART): Test manual*. Windsor: National Foundation for Educational Research.
Newsome, M. R., & Glucksberg, S. (2002). Older adults filter irrelevant information during metaphor comprehension. *Experimental Aging Research*, *28*, 253–267.
Nicholas, M., Obler, L. K., Albert, M. L., & Goodglass, H. (1985). Lexical retrieval in healthy aging. *Cortex*, *21*, 595–606.
Nussbaum, J. F., Pitts, M. J., Huber, F. N., Raup Krieger, J. L., & Ohs, J. E. (2005). Ageism and ageist language across the life span: Intimate relationships and non-intimate interactions. *Journal of Social Issues*, *61*, 287–305.
Ohnishi, T., Matsuda, H., Tabira, T., Asada, T., & Uno, M. (2001). Changes in brain morphology in Alzheimer disease and normal aging: Is Alzheimer disease an exaggerated aging process? *American Journal of Neuroradiology*, *22*, 1680–1685.
Paul, S. T. (1996). Search for semantic inhibition failure during sentence comprehension by younger and older adults. *Psychology and Aging*, *11*, 10–20.
Parkin, A. J., & Java, R. I. (2000). Determinants of age-related memory loss. In T. Perfect & E. Maylor (Eds.), *Models of cognitive aging* (pp. 188–203). Oxford: Oxford University Press.
Peelle, J. E., & Wingfield, A. (2005). Dissociations in perceptual learning revealed by

adult age differences in adaptation to time-compressed speech. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 1315–1330.

Persson, J., Sylvester, C. -Y. C., Nelson, J. K., Welsh, K. M., Jonides, J., & Reuter-Lorenz, P. A. (2004). Selection requirements during verb generation: Differential recruitment in older and young adults. *Neuroimage*, *23*, 1382–1390.

Phillips, N. A., & Lesperance, D. (2003). Breaking the waves: Age differences in electrical brain activity when reading text with distractors. *Psychology and Aging*, *18*, 126–139.

Phillips, S. L., Gordon-Salant, S., Fitzgibbons, P. J., & Yeni-Kombshian, G. (2000). *Journal of Speech, Language, and Hearing Research*, *43*, 217–228.

Pichora-Fuller, M. K., Schneider, B. A., & Daneman, M. (1995). How young and old adults listen to and remember speech in noise. *Journal of the Acoustical Society of America*, *97*, 593–608.

Pichora-Fuller, M. K., & Singh, G. (2006). Effects of age on auditory and cognitive processing: Implications for hearing aid fitting and audiologic rehabilitation. *Trends in Amplification*, *10*, 29–59.

Prull, M. W., Godard-Gross, C., & Karas, E. M. (2004, April). *How verb generation repetition priming in adulthood is influenced by age and response competition*. Poster presented at the Cognitive Aging Conference, Atlanta, GA.

Pushkar, D., Basevitz, P., Arbuckle, T. Y., Nohara-LeClair, M., Lapidus, S., & Peled, M. (2000). Social behavior and off-target verbosity in elderly people. *Psychology & Aging*, *15*, 361–374.

Pushkar Gold, D. P., & Arbuckle, T. Y. (1995). A longitudinal study of off-target verbosity. *Journal of Gerontology: Psychological Sciences*, *50B*, P307–315.

Rabbitt, P. M. (1968). Channel-capacity, intelligibility and immediate memory. *Quarterly Journal of Experimental Psychology*, *20*, 241–248.

Rabbitt, P., Maylor, E., McInnes, L., Bent, N., & Moore, B. (1995). What goods can self-assessment questionnaires deliver for cognitive gerontology? *Applied Cognitive Psychology*, *9*, S127–S152.

Radvansky, G. A., Copeland, D. E., & Zwaan, R. A. (2003). Aging and functional spatial relations in comprehension and memory. *Psychology and Aging*, *18*, 161–165.

Radvansky, G. A., Zacks, R. T., & Hasher, L. (2005). Age and inhibition: The retrieval of situation models. *The Journals of Gerontology: Psychological Sciences*, *60*, P276–P278.

Radvansky, G. A., Zwaan, R. A., Curiel, J. M., & Copeland, D. E. (2001). Situation models and aging. *Psychology and Aging*, *16*, 145–160.

Rapp, B., & Goldrick, M. (2000). Discreteness and interactivity in spoken word production. *Psychological Review*, *107*, 460–499.

Rastle, K. G., & Burke, D. M. (1996). Priming the tip of the tongue: Effects of prior processing on word retrieval in young and older adults. *Journal of Memory and Language*, *35*, 586–605.

Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F. I. M. Craik and T. A. Salthouse (Eds.), *Handbook of aging and cognition* (2nd ed., pp. 1–90). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Rendell, P. G., Castel, A. D., & Craik, F. I. M. (2005). Memory for proper names in old age: A disproportionate impairment? *The Quarterly Journal of Experimental Psychology*, *58A*, 54–71.

Resnick, S. M., Pham, D. L., Kraut, M. A., Zonderman, A. B., & Davatzikos, C. (2003). Longitudinal magnetic resonance imaging studies of older adults: A shrinking brain. *Journal of Neuroscience*, *23*, 3295–3301.

Riegel, K. F., & Riegel, R. M. (1964). Changes in associative behavior during later years of life: A cross-sectional analysis. *Vita Humana*, *7*, 1–32.

Roe, K., Jahn-Samilo, J., Juarez, L., Mickel, N., Royer, I., & Bates, E. (2000). Contextual effects on word production: A lifespan study. *Memory and Cognition*, *28*, 756–765.

Rogers. T. T., & McClelland, J. L. (2004). *Semantic cognition: A parallel distributed processing approach*. Cambridge, MA: MIT Press.
Ryan, E. B., Giles, H., Bartlucci, G., & Henwood, K. (1986). Psycholinguistic and social psychological components of communication by and with the elderly. *Language and Communication*, *6*, 1–24.
Ryan, E. B., See, S. K., Meneer, W. B., & Trovato, D. (1994). Age-based perceptions of conversational skills among younger and older adults. In M. L. Hummert, J. M. Wiemann, & J. N. Nussbaum (Eds.), *Interpersonal communication in older adulthood* (pp. 15–39). Thousand Oaks, CA: Sage.
Saffran, E. M., Dell, G. S., & Schwartz, M. F. (2000) Computational modeling of language disorders. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (pp. 933–948). Cambridge, MA: MIT Press.
Salthouse, T. A. (1985). *A theory of cognitive aging*. Amsterdam: North-Holland.
Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403–428.
Salthouse, T. A. (2000). Steps towards the explanation of adult age differences in cognition. In T. Perfect & E. Maylor (Eds.), *Models of cognitive aging* (pp. 19–49). Oxford: Oxford University Press.
Salthouse. T. A. . & Craik. F. I. M. (2000). Closing comments. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 689–703). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
Salthouse, T. A., Hambrick, D. Z., & McGuthry, K. E. (1998). Shared age-related influences on cognitive and non-cognitive variables. *Psychology and Aging*, *13*, 486–500.
Salthouse, T. A., Hancock, H. E., Meinz, E. J., & Hambrick, D. Z. (1996). Interrelations of age, visual acuity, and cognitive functioning. *Journal of Gerontology*, *51B*, 317–330.
Salthouse, T. A., Toth, J., Daniels, K., Parks, C., Pak, R., Wolbrette, M., et al. (2000). Effects of aging on efficiency of task switching in a variant of the trail making test. *Neuropsychology*, *2000*, 102–111.
Schacter, D. L., Osowiecki, D., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1994). Source memory: Extending the boundaries of age-related deficits. *Psychology and Aging*, *9*, 81–89.
Schaie, K. W. (1994). The course of adult intellectual development. *American Psychologist*, *49*, 304–313.
Schaie, K. W. (2005). *Developmental influences on adult intelligence*. Oxford: Oxford University Press.
Schmitter-Edgecombe, M., Vesneski, M., & Jones, D. (2000). Aging and word finding: A comparison of discourse and nondiscourse tests. *Archives of Clinical Neuropsychology*, *15*, 479–493.
Schneider, B. (1997). Psychoacoustics and aging: Implications for everyday listening. *Journal of Speech-Language Pathology and Audiology*, *21*, 111–124.
Schneider, B. A., Daneman, M., & Murphy, D. R. (2005). Speech comprehension difficulties in older adults: Cognitive slowing or age-related changes in hearing? *Psychology and Aging*, *20*, 261–271.
Schneider, B. A., Daneman, M., Murphy, D. R., & Kwong See, S. (2000) Listening to discourse in distracting settings: The effects of aging. *Psychology and Aging*, *15*, 110–125.
Schneider, B. A., Daneman, M., & Pichora-Fuller, M. K. (2002). Listening in aging adults: From discourse comprehension to psychoacoustics. *Canadian Journal of Experimental Psychology*, *56*, 139–152.
Schneider, B. A., & Pichora-Fuller, M. K. (2000). Implications of perceptual deterioration for cognitive aging research. In F. I. M. Craik & T. A. Salthouse (Eds.), *Handbook of aging and cognition* (pp. 155–220). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Schneider, B. A., & Pichora-Fuller, M. K. (2001). Age-related changes in temporal processing: Implications for listening comprehension. *Seminars in Hearing*, *22*, 227–239.

Schneider, B. A., Pichora-Fuller, M. K., Kowalchuk, D., & Lamb, M. (1994). Gap detection and the precedence effect in young and old adults. *Journal of the Acoustical Society of America*, *95*, 980–991.

Schneider, B., Speranza, F., & Pichora-Fuller, M. K. (1998). Age-related changes in temporal resolution: Envelope and intensity effects. *Canadian Journal of Experimental Psychology*, *52*, 184–191.

Schwartz, M. F., Dell, G. S., Martin, N., Gahl, S., & Sobel, P. (2006). A case-series test of the interactive two-step model of lexical access: Evidence from picture naming. *Journal of Memory and Language*, *54*, 228–264.

Schweich, M., Van der Linden, M., Brédart, S., Bruyer, R., Nelles, B., & Schils, J. P. (1992). Daily-life difficulties in person recognition reported by young and elderly subjects. *Applied Cognitive Psychology*, *6*, 161–172.

Scialfa, C. T. (2002). The role of sensory factors in cognitive aging research. *Canadian Journal of Experimental Psychology*, *56*, 153–163.

Scialfa, C. T., Hamaluk, E., Pratt, J., & Skaloud, P. (1999). Age differences in saccadic averaging. *Psychology and Aging*, *14*, 695–699.

Shaw, N. A. (1992). Age-dependent changes in central somatosensory conduction time. *Clinical Electroencephalography*, *23*, 105–110.

Singer, T., Verhaeghen, P., Ghisletta, P., Lindenberger, U., & Baltes, P. B. (2003). The fate of cognition in very old age: Six year longitudinal findings in the Berlin Aging Study (BASE). *Psychology of Aging*, *18*, 318–331.

Smiler, A. P., Gagne, D. D., & Stine-Morrow, E. A. L. (2003). Aging, memory load, and resource allocation during reading. *Psychology of Aging*, *18*, 203–209.

Snell, K. B., Mapes, F. M., Hickman, E. D., & Frisina, D. R. (2002). Word recognition in competing babble and the effects of age, temporal processing, and absolute sensitivity. *Journal of the Acoustical Society of America*, *112*, 720–727.

Snowdon, D. A., Greiner, L., Kemper, S., Nanayakkara, N., & Mortimer, J. A. (1999). Linguistic ability in early life and longevity: Findings from the Nun study. In J. M. Robine, B. Forette, C. Franchesci, & M. Allard (Eds.), *The paradoxes of longevity* (pp. 103–113). Amsterdam: Springer.

Snowdon, D. A., Kemper, S., Mortimer, J. A., Greiner, L. H., Wekstein, D. R., & Markesbery, W. R. (1996). Cognitive ability in early life and cognitive function and Alzheimer's disease in late life: Findings from the Nun study. *Journal of the American Medical Association*, *275*, 528–532.

Sommers, M. S. (1996). The structural organization of the mental lexicon and its contribution to age-related declines in spoken-word recognition. *Psychology and Aging*, *11*, 333–341.

Sommers, M. S., & Danielson, S. M. (1999). Inhibitory processes and spoken word recognition in young and older adults: The interaction of lexical competition and semantic context. *Psychology and Aging*, *14*, 458–472.

Sowell, E. R., Peterson, B. S., Thompson, P. M., Welcome, S. E., Henkenius, A. L., & Toga, A. W. (2003). Mapping cortical change across the human life span. *Nature Neuroscience*, *6*, 309–315.

Speranza, F., Daneman, M., & Schneider, B. A. (2000). How aging affects the reading of words in noisy backgrounds. *Psychology and Aging*, *15*, 253–258.

Spieler, D. H., & Balota, D. A. (2000). Factors influencing word naming in younger and older adults. *Psychology and Aging*, *15*, 225–231.

Steenbekkers, L. P. A. (1998). Visual contrast sensitivity. In L. P. A. Steenbekkers & C. E. M. Beijsterveldt (Eds.), *Design-relevant characteristics of ageing users. Backgrounds and guidelines for product innovation* (pp. 131–136). Delft: Delft University Press.

Stine, E. A. L., & Wingfield, A. (1994). Older adults can inhibit high-probability competitors in speech recognition. *Aging and Cognition*, *1*, 152–157.

Stine, E. L., Wingfield, A., & Poon, L. W. (1986). How much and how fast: Rapid processing of spoken language in later adulthood. *Psychology and Aging*, *1*, 303–311.

Stine-Morrow, E. A. L., Gagne, D. D., Morrow, D. G., & DeWall, B. H. (2004). Age differences in rereading. *Memory and Cognition*, *32*, 696–710.

Stine-Morrow, E. A. L., Loveless, M. K., & Soederberg, L. M. (1996). Resource allocation in on-line reading by younger and older adults. *Psychology and Aging*, *11*, 475–486.

Stine-Morrow, E. A. L., Morrow, D. G., & Leno, R. (2002). Aging and the representation of spatial situations in narrative understanding. *Journals of Gerontology: Psychological Sciences*, *57*, 91–P97.

Stine-Morrow, E. A. L., Soederberg Miller, L. M., & Leno, R. (2001). Patterns of on-line resource allocation to narrative text by younger and older readers. *Aging, Neuropsychology and Cognition*, *8*, 36–53.

Strouse, A., Ashmean, D. H., Ohde, R. N., & Grantham, D. W. (1998). Temporal processing in the aging auditory system. *Journal of the Acoustical Society of America*, *104*, 2385–2399.

Sunderland, A., Watts, K., Baddeley, A. D., & Harris, J. E. (1986). Subjective memory assessment and test performance in elderly adults. *Journal of Gerontology*, *41*, 376–384.

Tainturier, M. J., Tremblay, M., & Lecours, A. R. (1989). Aging and the word frequency effect: A lexical decision investigation. *Neuropsychologia*, *27*, 1197–1203.

Takayanagi, S., Dirks, D. D., & Moshfegh, A. (2002). Lexical and talker effects on word recognition among native and non-native listeners with normal and impaired hearing. *Journal of Speech, Language and Hearing Research*, *45*, 585–597.

Tang, Y., Nyengaard, J. R., Pakkenberg, B., & Gundersen, H. J. (1997). Age-induced white matter changes in the human brain: a stereological investigation. *Neurobiology of Aging*, *18*, 609–615.

Tanosaki, M., Ozaki, I., Shimamura, H., Baba, M., & Matsunaga, M. (1999). Effects of aging on central conduction in somatosensory evoked potentials: Evaluation of onset versus peak methods. *Clinical Neurophysiology*, *110*, 2094–2103.

Taylor, J. K., & Burke, D. M. (2000, April). *Slips of the tongue: An examination of language production in old age*. Poster presented at the Cognitive Aging Conference, Atlanta.

Taylor, J. K., & Burke, D. M. (2002). Asymmetric aging effects on semantic and phonological processes: Naming in the picture-word interference task. *Psychology and Aging*, *17*, 662–676.

Thornton, R., & Light, L. L. (2006). Language comprehension and production in normal aging. In J. E. Birren and K. Warner Schaie (Eds.), *Handbook of the psychology of aging* (pp. 262–287). Burlington, MA: Elsevier.

Titone, D., Prentice, K. J., & Wingfield, A. (2000). Resource allocation during spoken discourse processing: Effects of age and passage difficulty as revealed by self-paced listening. *Memory & Cognition*, *28*, 1029–1040.

Trainor, L. J., & Trehub, S. E. (1989). Aging and auditory temporal sequencing: Ordering the elements of repeating tone patterns. *Perception and Psychophysics*, *45*, 417–426.

Tree, J. J., & Hirsh, K. W. (2003) Sometimes faster, sometimes, slower: Associative and competitor priming in picture naming with young and elderly participants, *Journal of Neurolinguistics*, *16*, 489–514.

Tremblay, K. L., Piskosz, M., & Souza, P. (2002). Aging alters the neural representation of speech cues. *Neuroreport*, *13*, 1865–1870.

Tun, P. A. (1998). Fast noisy speech: Age differences in processing rapid speech with background noise. *Psychology and Aging*, *13*, 424–434.

Tun, P. A., O'Kane, G., & Wingfield, A. (2002). Distraction by competing speech in young and older adult listeners. *Psychology and Aging*, *17*, 453–467.

Tun, P. A., & Wingfield, A. (1999). One voice too many: Adult age differences in language processing with different types of distracting sounds. *Journals of Gerontology: Psychological Sciences*, *54B*, 317–327.

Tun, P. A., Wingfield, A., Stine, E. A. L., & Mecsas, C. (1992). Rapid speech processing and divided attention: Processing rate versus processing resources as an explanation of age effects. *Psychology and Aging*, *7*, 546–550.

Uttl, B. (2002). North American Adult Reading Test: Age norms, reliability, and validity. *Journal of Clinical and Experimental Neuropsychology*, *24*, 1123–1137.

Uttl, B., & Van Alstine, C. L. (2003). Rising verbal intelligence scores: Implications for research and clinical practice. *Psychology and Aging*, *18*, 616–621.

Van der Linden, M., Hupet, M., Feyereisen, P., Schelstraete, M., Bestgen, Y., Bruyer, R. et al. (1999). Cognitive mediators of age-related differences in language comprehension and verbal memory performance. *Aging, Neuropsychology and Cognition*, *6*, 32–55.

van Rooij, J. C. G. M., & Plomp, R. (1990). Auditive and cognitive factors in speech perception by elderly listeners. II. Multivariate analyses. *Journal of the Acoustical Society of America*, *88*, 2611–2624.

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology & Aging*, *18*, 332–339.

Vitevitch, M. S., & Sommers, M. S. (2003). The facilitative influence of phonological similarity and neighborhood frequency in speech production in younger and older adults. *Memory & Cognition*, *31*, 491–504.

Vousden, J. I., & Maylor, E. A. (2006). Speech errors across the lifespan. *Language and Cognitive Processes*, *21*, 48–77.

Waters, G., & Caplan, D. (2001). Age, working memory and on-line syntactic processing in sentence comprehension. *Psychology and Aging*, *16*, 128–144.

Waters, G. S., & Caplan, D. (2005). The relationship between age, processing speed, working memory capacity, and language comprehension. *Memory*, *13*, 403–413.

Wheeldon, L. R., & Monsell S. (1994). Inhibition of spoken word production by priming a semantic competitor. *Journal of Memory and Language*, *33*, 332–357.

White, K. K., & Abrams, L. (2002). Does priming specific syllables during tip-of-the-tongue states facilitate word retrieval in older adults? *Psychology and Aging*, *17*, 226–235.

White, K. K., & Abrams L. (2004a). Free associations and dominance ratings of homophones for young and older adults. *Behavior Research Methods, Instruments, & Computers*, *36*, 408–420.

White, K. K., & Abrams, L. (2004b). Phonologically mediated priming of preexisting and new associations in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 645–655.

Whiting, W. L., Madden, D. J., Langley, L. K., Denny, L. L., Turkington, T. G., Provenzale, J. M., et al. (2003). Lexical and sublexical components of age-related changes in neural activation during word identification. *Journal of Cognitive Neuroscience*, *15*, 475–487.

Williams, K. N. (2006). Improving outcomes of nursing home interactions. *Research in Nursing & Health*, *29*, 121–133.

Williams, K., Kemper, S., & Hummert, M. L. (2003). Improving nursing home communication: An intervention to reduce elderspeak. *The Gerontologist*, *43*, 242–247.

Wingfield, A. (1996). Cognitive factors in auditory performance: Context, speed of processing, and constraints of memory. *Journal of the American Academy of Audiology*, *7*, 175–182.

Wingfield, A., & Ducharme, J. L. (1999). Effects of age and passage difficulty on listening-rate preferences for time-altered speech. *Journal of Gerontology: Psychological Sciences*, *54*, 199–202.

Wingfield, A., Lindfield, K. C., & Goodglass, H. (2000). Effects of age and hearing sensitivity on the use of prosodic information in spoken word recognition. *Journal of Speech, Language, and Hearing Research*, *43*, 915–925.

Wingfield, A., McCoy, S. L., Peelle, J. E., Tun, P. A., & Cox, L. C. (in press). Effects of adult age and hearing loss on comprehension of rapid speech varying in syntactic complexity. *Journal of the American Academy of Audiology*.

Wingfield, A., Peelle, J. E., & Grossman, M. (2003) Speech rate and syntactic complexity as multiplicative factors in speech comprehension by young and older adults. *Aging Neuropsychology and Cognition*, *10*, 310–322.

Wingfield, A., Poon, L. W., Lombardi, L., & Lowe, D. (1985). Speed of processing in normal aging: effects of speech rate, linguistic structure, and processing time. *Journal of Gerontology*, *40*, 579–585.

Wingfield, A., & Stine-Morrow, E. A. L. (2000). Language and speech. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (2nd ed., pp. 359–416). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Wingfield, A., Tun, P. A., Koh, C. K., & Rosen, M. J. (1999). Regaining lost time: Adult aging and the effect of time restoration on recall of time-compressed speech. *Psychology and Aging*, *14*, 380–389.

Wingfield, A., Tun, P. A., & McCoy, S. L. (2005). Hearing loss in older adulthood: What it is and how it interacts with cognitive performance. *Current Directions in Psychological Science*, *14*, 144–148.

Zacks, R. T., & Hasher, L. (1997). Cognitive gerontology and attentional inhibition: A reply to Burke and McDowd. *Journal of Gerontology: Psychological Sciences*, *52*, 274–283.

Zacks, R. T., & Hasher, L. (2006). Aging and long-term memory: Deficits are not inevitable. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 162–177). Oxford: Oxford University Press.

Zipin, L. M., Tompkins, C. A., & Kasper, S. C. (2000). Effects of foregrounding on predictive inference generation by normally ageing adults. *Aphasiology*, *14*, 115–131.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, *123*, 162–185.