Age-related effects on language production

A combined psycholinguistic and neurocognitive perspective

Andrea Marini | University of Udine, Italy
Sara Andreetta | Claudiana – Landesfachhochschule für Gesundheitsberufe, Bozen, Italy

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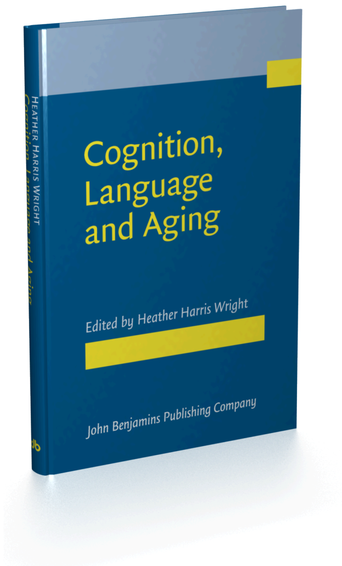

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CHAPTER 3

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A combined psycholinguistic and neurolinguistic perspective

Andrea Marini[*,**] and Sara Andreetta[*]
* University of Udine, Italy / ** Claudiana – Landesfachhochschule für Gesundheitsberufe, Bozen, Italy

This chapter focuses on the effects of aging on the process of language production from a psycholinguistic, and neurolinguistic perspective. The first section of the chapter provides a detailed description of the language production system by outlining the notions of micro- (i.e., lexical and grammatical) and macrolinguistic (i.e., pragmatic and discourse level) processing and introducing to some of the most influential psycholinguistic models of message production. The second part focuses on psycholinguistic investigations assessing age-related variations in the ability to produce a verbal message. A conclusive section outlines the complex interplay between the neural changes induced by aging and the (re)organization of the language production system.

Introduction

Language processing is the expression of a complex cognitive function (e.g., Caplan, 1992) that goes through major modifications during the lifespan. It develops quite rapidly and efficiently in early infancy and through childhood (Kuhl et al., 2010), keeps relatively stable after the end of adolescence and during adulthood, and is characterized by a gradual decline in the elderly (Thornton & Light, 2006). These age-related alterations might depend either on the intrinsic deterioration of the linguistic system or on a more general cognitive decline, which affects working and long-term memory, attentional skills, and executive control (Connor, 2001; Wingfield & Tun, 2001). However, the overall effects of aging on language processing are likely the result of a complex interplay between these two extremes. Difficulties in working memory, attention, and executive functions might hamper the ability to organize the information at the text level in older adults (e.g., Collette et al., 2007). During the production or the comprehension

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of a discourse or conversation a reduction in the efficiency of working memory might affect the storage and manipulation of information, syntactic processing, and the stages of message planning and monitoring (e.g., Wingfield & Stine-Morrow, 2000). In a similar way, attentive deficits and impairments in executive functions might prevent older adults from inhibiting the selection of inappropriate information (leading, for example, to the production of verbose speech samples and off-topic utterances; e.g., Zacks & Hasher, 1997; Mozeiko et al., 2011).

In this chapter we will review the complex relation between aging and language production from a combined linguistic, psycholinguistic and neurolinguistic perspective. The chapter is divided in three major sections. The first section will outline the language production system. The second section will focus on psycholinguistic investigations assessing age-related variations in linguistic production. The final section will discuss the age-related neural changes that affect the ability to produce verbal messages across the adult lifespan.

Psycholinguistic accounts of language production

Language production relies on the interaction between several processing levels. These can be analyzed along two dimensions (Glosser & Deser, 1990; Caplan, 1992; Marini et al., 2011a). The microlinguistic dimension of analysis focuses on intra-sentential (i.e., within-utterance) organization of discourse production by assessing those phonetic, phonological and morphological skills that are required to produce well-formed words (lexical processing) and those morphosyntactic and syntactic abilities that eventually lead to the generation of well-formed sentences (syntactic processing). The macrolinguistic dimension analyses inter-sentential (i.e., between-utterances) processing by assessing the speaker's ability to produce contextually appropriate words and utterances (pragmatic processing), connect different utterances by means of cohesive and coherent ties in order to formulate the main theme of a narrative discourse or the gist of a conversation, and integrate its linguistic and conceptual features while taking into account the conversational expectations of the interlocutors (Grice, 1975; Kintsch & van Dijk, 1978; Kintsch, 1994; Garrod & Pickering, 2004).

During every-day communicative interactions, the different levels of linguistic processing are constantly interacting with each other. A number of psycholinguistic models have been proposed to describe such interactions. For example, according to Fromkin (1971) and Garrett (1975), speech production is a multistage process, which requires the speaker to first generate the meaning of the message to be conveyed and then formulate its syntactic organization, determine its prosodic contour, select the target words, and identify their phonological characteristics.

Other models, such as the connectionist model proposed by Dell (1986), hypothesize the existence of different nodes (phonological, semantic, etc.) that interact with each other and process the information in parallel. According to one of the most influential psycholinguist models (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999), the process of language production undergoes at least three major stages: a pre-linguistic conceptual phase; a phase of linguistic formulation; a phase of linguistic expression.

In the **pre-linguistic conceptual phase** the speaker needs to generate the motivation to speak and a mental or situation model of the intended message, a multi-dimensional representation which contains information about space, time, causality, intentionality, and currently relevant individuals (e.g., Johnson-Laird, 1980, 1983; Zwaan & Radvansky, 1998). S(he) generates such mental models by retrieving the appropriate conceptual frame structure from long-term episodic memory (e.g., by selecting the appropriate discourse genre) and by embedding it with the available conceptual information (e.g., participants, setting, etc.). Furthermore, the speaker must integrate what (s)he intends to say with what has previously been said (linguistic context) and the particular situation, place and time in which the communicative exchange takes place (extra-linguistic context, Levinson, 1983). It has been hypothesized that at this stage a pivotal role is played by a supervisory attentional system (SAS: Norman & Shallice, 1986; Green, 1998) that monitors the selection of the appropriate communicative intention, if the amount of information is adequate and if it is relevant to the linguistic context (Grice, 1975; Sperber & Wilson, 1986).

In order to be eventually transferred to an interlocutor, this preverbal message must be converted into a speech plan. This process takes place in the second stage of message production: the **phase of linguistic formulation**. Here, the system needs to match the intended meaning formulated in the pre-linguistic phase with the corresponding lexical items stored in the mental lexicon. This operation is performed through a phase of lexical selection and one of lexical access. The process of lexical selection allows speakers to select the lexical items that correspond to the intended meanings (Levelt et al., 1999). This selection is likely achieved through an activation/inhibition mechanism. Each word is supposed to have its own specific activation thresholds as a function of the frequency of its use and time elapsed since its last activation: The lower the threshold level, the easier the access; the higher the threshold level, the more difficult the access. The activation of the target word is achieved through the simultaneous inhibition of semantically related competitors (Green, 1986, 1998). This inhibition may be obtained by raising the competitors' activation thresholds. For example, if the speaker's intention is to speak out the word "table", the activated concept corresponding to the idea of TABLE enters the lexicon where a selection mechanism is needed in order to select the target word ("table") among all other semantically related lexical items ("chair", "sofa", etc.). Consequently, the activation threshold of the competitors *is raised* while the target word gets selected. At the end of the process of lexical selection, the target word has been activated and the system gains access to its morphosyntactic and morphological features (lemma level of word representation) and then to its syllabic and phonological form. In the case of single word production this phonological information is then transmitted to the systems responsible for motor planning and execution, where articulatory configurations corresponding to the phonemes to be uttered are programmed and then implemented. In the case of sentence production, such as in connected speech, the process of lexical selection and the access to a word's lemma form the "functional level" of sentence processing, where the morphosyntactic information required by the selected word (i.e., its argumental structure) guides the process of sentence generation by means of thematic roles' assignment and phrase generation. At the second level of sentence processing, the "positional level", i.e. the information contained in the lemmas of the selected words, is used to generate the grammatical relations among the phrases and to build up well-formed syntactic representations (Chomsky, 1995; Garrett, 1980). It is now possible to have access to the syllabic and phonological representation(s) of the selected word(s) and this information is eventually sent to the output system where articulatory configurations corresponding to the phonemes to be uttered are programmed and then implemented (**phase of linguistic expression**). At the end of this stage verbalization actually takes place. During a conversation, these stages must be continuously processed in order to guarantee an efficient interaction between the interlocutors. Indeed, conversation is a joint activity (Clark, 1996) that requires a largely unconscious interactive alignment (Garrod & Pickering, 2004; Pickering & Garrod, 2004) between the concepts selected and organized in the mind of the speaker and those that the receiver needs to deduct from the message.

Cognitive functions affecting the process of message production

Attention is assumed to play an important role in the pre-linguistic conceptual phase. Obviously, the role played by attention cannot be limited to just this stage of linguistic production but extends also to the phases of linguistic formulation and expression.

Furthermore, the process of message production is also intimately linked to other cognitive skills such as executive functions and memory (e.g., Mozeiko et al., 2011; Miyake et al., 2000; Tucker & Hanlon, 1998; Ylvisaker et al., 2001). Indeed, according to Mozeiko et al. (2011), three major types of executive functions seem to play an important role in efficient discourse processing: *shifting*, involved in the generation of complete episodes within a narrative discourse and in the selection of informative words; *updating*, required to recall former episodes or episodic contents for an accurate organization of the story; *inhibition*, important for monitoring the production of extraneous comments and derailments while generating a story.

As for memory, according to the Declarative/Procedural model (Ullman, 2004), language learning and representation are subserved by two anatomically and functionally distinct systems of long-term memory (declarative and procedural, respectively). Procedural memory subserves implicit linguistic competence. It is a form of implicit memory implemented in frontal/basal ganglia circuits as well as in portions of the parietal cortex, superior temporal cortex, and the cerebellum (Ullman, 2001). During first language acquisition, procedural memory is involved in the process of learning and executing sensory-motor and cognitive skills such as those involved in the articulation of the sounds of a language and in syntax. Declarative (or explicit) memory is implemented in bilateral medial and temporo-parietal structures, including the hippocampal region and the parahippocampal cortex (Ullman, 2001). It is implicated in conscious learning of facts and events and consists of at least two subtypes: semantic and episodic memory. *Semantic memory* is the system storing one's encyclopedic knowledge of the world (e.g., knowledge about the meaning of words, as well as knowledge about historical events, geographical notions, and social facts). *Episodic memory* refers to one's past experiences that can be consciously recalled. It is assumed that grammar (i.e., implicit syntactic and morphosyntactic competence) is acquired incidentally through procedural memory, whereas lexical-semantic explicit knowledge is consciously learned and stored in declarative memory. For example, procedural memory is involved in the acquisition and use of implicit procedures of syntactic parsing (Frazier & Fodor, 1978). Moreover, once the access to a lexical item is granted, implicit memory procedures automatically generate the argument structure of that particular word and assign the thematic roles to the required arguments (morphosyntactic processing). As to phonetics, the articulatory sequences necessary to produce the target phones of a language become automatized and are transferred to procedural memory, so that the speaker does not need to think about all the articulatory movements required by the process of speaking.

Psycholinguistic investigations assessing age-related variations in linguistic processing

A core feature of healthy aging is a general slowing in a variety of cognitive functions (e.g., Salthouse, 1996). The studies that investigated age-related linguistic differences have provided controversial results. According to Burke, Mackay, and James (2000), aging affects comprehension and production asymmetrically. The quality of discourse production declines with age. On the contrary, text comprehension is basically spared by aging. Indeed, the poorer performance in discourse comprehension shown by older adults is often linked to hearing disturbances (Schneider, Daneman, & Murphy, 2000; Schneider, Daneman, & Pichora-Fuller, 2002) rather than more central processes involved in the ability to derive an appropriate mental model during comprehension (Radvansky, Copeland, & Zwaan, 2003; Radvansky, Greard, Zacks, & Hasher, 1990). In this section of the chapter we will analyze the impact of aging at both micro- and macrolinguistic levels of language production. Most of the studies that focused on age-related effects on language processing have analyzed specific aspects of linguistic production. This led to several reports about age effects on selective linguistic skills without providing a comprehensive account of the patterns of linguistic change across the lifespan. This is a particularly delicate issue, as some studies have reported some null effect of age (e.g., in phonological processing), some effects with a sharp drop in performance only over 70 years of age (e.g., in the production of semantic substitutions and morpho-syntactic weakening), and some others effects suggesting a gradual decrease in performance across age-groups (e.g., Marini et al., 2005).

Age-related effects on microlinguistic aspects of message production

Studies reporting age-related effects on selective aspects of microlinguistic processing have often yielded controversial results. For example, some of these reported declines in older adults in lexical retrieval (Au et al., 1995; Bowles & Poon, 1985; Nicholas, Obler, Albert, & Goodglass, 1985; see also Chapter 8 for language changes in oldest-old) and in syntactic complexity (Shadden, 1997), whereas others failed to detect any age-related difference between younger and older adults in these abilities (e.g., Lyketsos, Chen, & Anthony, 1999). We will now discuss more deeply the effects of aging on lexical and grammatical processing, respectively.

Age-related effects on lexical processing

A positive aspect associated with aging is that the mental lexicon keeps on growing and that there is little loss of word knowledge with the exception of the oldest individuals (Verhaegen, 2003). Older adults have larger vocabularies than younger ones (Rastle & Burke, 1996; Schroeder & Salthouse, 2004; Thornton & Light, 2006) even if this lexical knowledge begins to slowly decline in people in their 80s and 90s (Lindenberger & Baltes, 1997).

Older people often experience word-finding difficulties (Albert et al., 2009; Connor et al., 2004; Griffin & Spieler, 2006). Such problems have been detected in studies using different paradigms. For example, one line of evidence of this reduction in the ability to retrieve words from the mental lexicon derives from the observation that older persons achieve lower scores on tests assessing rapid naming skills (e.g., the Boston Naming Test [Kaplan et al., 1983] or verbal fluency tasks) (Goral, Spiro, Albert, Obler, & Connor, 2007; MacKay, Connor, Albert, & Obler, 2002). However, not all studies that employed naming tasks to assess age-related changes in lexical retrieval have found deteriorated naming skills in older adults (for a critical review see Goulet, Ska, & Kahn, 1994). Several factors might have affected the results of these experiments, including the selection of highly familiar items, the inclusion of few naming trials and of heterogeneous age-groups with younger participants ranging from 18 to 65 and older ones from 59 to 85 years old (see also Verhaegen & Poncelet, 2012). Those studies that assessed naming performance in healthy adult participants of different ages showed a mild decrease in participants in their 50s (e.g., Connor et al., 2004) and a more important decline over the age of 70 (Feyereisen, 1997). Verhaegen and Poncelet (2012) showed that, with respect to younger participants, those in their 50s had increased naming latencies, whereas adults in their 60s and 70s had decreased accuracy and increased latency scores. Interestingly, these findings are further corroborated by other studies that showed reduced speech rates in the elderly (e.g., Duchin & Mysak, 1987; Fozo & Watson, 1998).

A second source of information about age-related weakening in lexical retrieval comes from those studies that analyzed Tip-of-the-Tongue states (TOT; Brown & McNeill, 1966; for comprehensive review of TOT see also Chapter 2). These are characterized by a selective inability to produce a word stored in the mental lexicon also when speakers have access to word-related grammatical information (e.g., Badecker, Miozzo, & Zanuttini, 1995; Vigliocco, Garrett, & Antonini, 1997) and even to some residual phonological and syllabic information (Brown, 1991). Therefore, from a cognitive point of view, TOT states seem to reflect a temporary disturbance in the process of phonological access rather than a disturbance in the process of lexical selection (James & Burke, 2000). TOT frequency, especially for proper names, increases with age (e.g., James & Burke, 2000; James, 2004).

Overall, then, studies assessing naming skills and TOT states in healthy aging show that the ability to retrieve words from memory weakens after the age of 50 but significantly deteriorates in people in their 70s. Furthermore, they suggest that this pattern does not reflect a deterioration in lexical knowledge. It does not reflect a deterioration of lexical selection skills either. Rather, it seems plausible that older people experience a problem in the retrieval of specific bits of lexical information: not grammatical but phonological in nature. A few major hypotheses have been formulated to explain these findings. According to one of these hypotheses, some language processes become less efficient with aging because of a more general cognitive slowing (Salthouse, 1996) that might affect the cognitive processes involved in lexical retrieval. Alternatively, these problems might be the consequence of reduced working memory skills (Carpenter et al., 1994) or in the ability to inhibit the activation of irrelevant lexical nodes (Zacks & Hasher, 1997). A final possibility is that age-related changes in lexical retrieval stems from weakened connections among lexical-semantic and phonological representations in the mental lexicon that might eventually lead to more lexical retrieval difficulties in the elderly (Transmission Deficit Hypothesis – e.g., Burke & Shafto, 2004).

A final consideration relates to the need for ecological tests to assess lexical skills. Schmitter-Edgecombe et al. (2000) compared word-finding skills in three groups of adults. They administered the Boston Naming Test and a spontaneous discourse production test. Interestingly, the group of older adults (aged 73–95 years old) produced more errors than younger participants in the latter task. In the picture naming task, however, they were surprisingly more accurate than younger controls. These findings have important theoretical and clinical implications, indicating that a test of spontaneous discourse production may prove more informative about the actual linguistic difficulties experienced by a given individual. Therefore, "clinicians should consider stimuli type when measuring discourse ability" (Capilouto et al., 2005, p. 431).

Age-related effects on grammatical processing

Investigations focusing on the syntactic level of message production have shown that grammatical skills also decline gradually with age (Kemper et al., 2001). For example, when compared to younger subjects, older adults tend to produce fewer complex sentences (e.g., Kemper & Anagnopoulos, 1989; Shadden, 1997), have more difficulties in the retrieval of pronouns and closed-class words (Heller & Dobbs, 1993) and in the generation of subject-verb agreement links between words (Thornton et al., 2004). Interestingly, the grammatical difficulties observed in persons in their 70s apparently correlate with scores obtained on tasks assessing the functionality of working memory such as the digit span test (Kemper & Sumner, 2001). This suggests that the age-related weakening of their grammatical skills might be (partly) related to a more general cognitive decline affecting short-term and working memory. Kemper et al. (2004) compared the ability to generate complex sentences in a group of thirty-four young adults aged 18 to 28 years and one of thirty-nine older ones aged 70 to 80 years. The participants were instructed to produce, as fast as they could, sentences using previously memorized sentence fragments formed by three words. Overall, older adults produced less complex sentences than young adults. Interestingly, the performance of younger adults was affected by the complexity of the syntactic manipulation whereas that of the older ones was not. According to the authors, processing limitations including reduced working memory might impose a "ceiling" on older adults' performance, not allowing them to retain the information necessary for further processing.

The possibility of an age-induced morpho-syntactic and grammatical weakening is further supported by the results from studies using more ecological tasks. For example, in a study where the picture descriptions of healthy adults of different age-ranges were analyzed, Marini et al. (2005) reported weakened morphological processing (in terms of the production of paragrammatic errors) and lower levels of syntactic complexity in a group of participants in their 70s. Interestingly, however, Glosser and Deser (1992) did not find any significant age-related difference between middle-aged and older individuals on microlinguistic measures, neither for syntactic complexity, nor for lexical production errors. This discrepancy might depend on the use of different tasks to elicit the linguistic production. Glosser and Deser's analysis was based on informal interviews, whereas the method of speech elicitation in Marini et al. (2005) was a picture description task. In informal interviews it is more difficult to evaluate the appropriateness of word choice and the completeness of syntactic structures than in picture description tasks. Another possible reason for these differences in results could be that, in contrast to English, Italian is a morphologically rich language with requirements for gender and number agreement on nouns, adjectives, verbs and even prepositions within and across utterances. As morphological agreement becomes harder to maintain, speakers would start to make more errors and might also tend to produce less complex sentences in order to avoid ungrammaticality. Overall, these findings highlight the importance of conducting studies in languages with different typological structures but also reaffirm the need for using highly ecological and reliable methods for eliciting speech samples to assess specific age-related changes in language production.

Age-related effects on macrolinguistic aspects of message production

Age-related changes have been reported also for macrolinguistic aspects of linguistic processing. As noted earlier, discourse production is a complex procedure, which relies on several cognitive functions (e.g., working and long-term memory, attention, executive functions). Interestingly, the investigations focusing on age-related differences in these high level skills have provided a complex picture. Older adults have been shown to possess higher structural abilities in the construction of a text. For example, their written diaries and personal narratives may include more embedded episodes than those produced by younger adults (e.g., Kemper, 1990; Pratt & Robins, 1991). However, their discourse is characterized by augmented verbosity (Gold & Arbuckle, 1995), decreased levels of cohesiveness and of both local and global coherence (e.g., Marini et al., 2005). Cohesiveness reflects the structural connectivity across contiguous utterances, whereas local coherence is related to their conceptual connectivity. Cohesive errors might include the misuse of cohesive ties such as anaphoric pronouns, errors in number and gender agreement between pronouns or noun phrases across utterances, misuse of either cohesive function words or semantically related content words, and abrupt interruptions of utterances. Similarly, problems with local coherence might induce speakers to produce words with ambiguous referents or interrupt the flow of concepts in a discourse or conversation by leaving some topics incomplete while introducing new pieces of information. This ability has been found weakened in the elderly (Juncos-Rabadán et al. 2005; Ulatowska et al. 1986). More specifically, Marini et al. (2005) reported a sharp decrease in the ability to coherently link individual utterances in individuals older than 75. These individuals produced a significantly higher rate of local coherence errors than the younger adults in terms of more missing or ambiguous referents and topic shifts which undermined the levels of local coherence of their picture descriptions. The absence of significant differences between the oldest group's performance and that of the middle-aged and the young elderly suggests that the production of local coherence errors is a gradual side-effect of aging, which is likely to start already in the middle-aged group.

Aging weakens global coherence as well. Global coherence refers to the ability to semantically relate remote utterances in the framework of a given discourse or written text. Consequently, errors of global coherence might include the production of tangential utterances, utterances conceptually incongruent with the story, or simply fillers. Indeed, when older adults are involved in spontaneous conversation, they produce more off-topic speech than younger adults (Arbuckle & Gold, 1993; James et al., 1998; Trunk & Abrams, 2009; Wills et al., 2012): they may initially provide relevant pieces of information but then introduce additional information that can be loosely related or even entirely unrelated to the main topic of the conversation and/or discourse. For all these reasons, the speech output of older people is often perceived as vague and incoherent.

As already seen for lexical and grammatical processing, the narrative difficulties observed in the elderly might not depend on a linguistic disturbance *per se*. Indeed, according to the *inhibition deficit hypothesis* (Hasher & Zacks, 1988) older adults might be less able to suppress irrelevant pieces of information than younger ones because of a decline in their ability to monitor the process of message production. This might eventually trigger the introduction of extraneous comments and derailments while generating a story (Thornton et al., 2004). Important components of the ability to inhibit irrelevant information are selective and shifting attention (Drag & Bieliauskas, 2010; Wager, Jonides, & Reading, 2004). For this reason, some studies have investigated the potential interconnections between declines in attention and augmented off-topic verbosity in narrative production tasks (Arbuckle & Gold, 1993; James et al., 1998; Trunk & Abrams, 2009; Wills et al., 2012). Arbuckle and Gold (1993) analyzed attentional skills and off-topic verbosity in the biographical recounts produced by a large sample of 196 adults aged 61 to 90. Attentional measures included a test tapping shifting attention (Trail-Making Test) and one measuring inhibition and perseveration (Wisconsin Card-Sorting Test, WCST). In this study, age had a significant impact on both attention skills and production of off-topic speech. Furthermore, the performance on the WCST predicted participants' off-topic verbosity; this finding clearly supports the inhibition deficit hypothesis. In a second study, James et al. (1998) asked 20 younger and 20 older adults to recount personal events and perform a picture description task. The older group produced more off-topic speech only when producing personal narratives but not while performing the picture description task. As autobiographical recounts might trigger the activation of several irrelevant topics that a well-functioning cognitive system should inhibit in the phase of message planning, the authors considered this result as an indirect support to the inhibition deficit hypothesis.

In a pilot study, Wills et al. (2012) administered to five small groups of healthy adults ranging from 40 to 80 years of age (six participants per cohort) a series of tasks assessing attention (the Comprehensive Trail-Making Test and the STROOP Color and Word Test) and a series of discourse production tasks eliciting recounts of personal events. In this study, the age groups differed in the measures of attention. On the other side, no age-related differences were found in the production of off-topic speech and the measures of attention and off-topic verbosity were not correlated. However, this is just a pilot study and the results are based on cohorts of participants that are too small to draw firm conclusions. Therefore, it seems plausible that the increased macrolinguistic difficulties are at least partially related to a more general cognitive decline induced by aging. Healthy aging does not affect all individuals in the same way. With age, the inter-individual variability increases significantly. This means that, in theory, a specific ability might be preserved in one person but weakened in another. For example, Obler et al. (1994) reported a marked increase in variability with age in narrative length. Similarly, in Marini et al. (2005) the group of participants in their late70s–mid80s showed a relevant intra-group variation in almost all measures assessing microlinguistic, macrolinguistic, and informative aspects of discourse production. However, this variability was significantly lower in the levels of syntactic complexity, in the degree of global coherence, and in a measure of thematic informativeness. This suggests that the ability to build syntactically well-formed sentences, organize a narrative discourse following rules of global coherence, and extract the expected concepts from the story were consistently affected in the group of individuals in their mid70s–early80s.

Effects of aging on the neural networks subserving the process of linguistic production

As we have seen in the former paragraphs, language is a complex cognitive function prone to changes along the lifespan. Importantly, such changes are selective and subject to high inter-individual variability. Some abilities (e.g., articulatory skills) appear to be less affected by the process of aging than others (e.g., lexical selection and/or access) but not in all individuals or at the same rate. A good way to enhance our understanding of the mechanisms involved in linguistic deterioration during aging stems from the analysis the neural correlates of message production in the elderly.

Initially, the way to study the cerebral organization of language had been the observation of patients with specific lesions resulting in selective linguistic disturbances. This neuropsychological approach allowed scholars to identify in the left hemisphere a number of cortical areas potentially involved in lexical processing (e.g., Geschwind, 1970). Over the past 20 years, the development and massive use of functional neuroimaging techniques (e.g., Positron- Emission Tomography, PET; Functional Magnetic Resonance Imaging, *f*MRI; Near-Infrared Spectroscopy, NIRS; Diffusion Tensor Imaging tractography, DTI) has dramatically advanced our knowledge about the neural underpinnings of language processing in healthy individuals (e.g., Catani et al., 2012; Marini & Urgesi, 2012; Vigneau et al., 2006). Overall, these studies have suggested the possibility to pinpoint the neural networks recruited during the different phases of message production outlined in paragraph 2 (e.g., Indefrey & Levelt, 2000; 2004; Indefrey, 2011).

During the **pre-linguistic conceptual phase**, where the speaker needs to conceptualize the preverbal message and eventually extract the corresponding lexical concepts, vast areas in bilateral frontal lobes, deeply interconnected via inter- and intra-hemispheric pathways, are recruited. These include neural networks linked to the generation of the motivation to speak (i.e., anterior cingulate cortex – Brodmann's area [BA] 24; orbitofrontal cortex – BAs 47 and 11; supplementary motor area – BA 6), and those in areas linked to executive abilities such as those involved in planning, monitoring and inhibiting (i.e., the dorso-lateral prefrontal cortex – BAs 8, 9, 45, 46; Fletcher et al., 1995). This suggests that the frontal lobes, particularly prone to age- induced functional and structural modifications (Cabeza et al., 2002; Grady et al. 2003), play a key role in this first stage of message production. Indeed, altered patterns of activation and reduced inter-hemispheric asymmetry for older people during the execution of cognitive tasks have been widely documented for both prefrontal and anterior cingulate cortex (Grady & Craik, 2000; Madden et al., 1999; Park et al., 2003; Sharp et al., 2006). Two studies, in particular, showed in older participants reduced patterns of activation in the left prefrontal cortex on a task of episodic memory encoding (Cabeza et al., 1997) and in the left inferior frontal gyrus on a task assessing the self-initiated encoding of words (Logan et al., 2002). As these two abilities are obviously linked to the phases of message generation and lexical selection, the mentioned studies provide indirect support to the possibility that the reduced functionality of the frontal lobes of elder individuals might exert a significant impact on their message production skills. Furthermore, as both anterior cingulate and dorsolateral prefrontal cortices play a role in cognitive control, these alterations are likely linked to the difficulty that most elder people experience when they need to plan, monitor, inhibit a new action, schema or narrative discourse. From a linguistic point of view, this explains both the reduced levels of lexical appropriateness and the production of global coherence errors observed in healthy older adults (Marini et al., 2005) and persons with frontal lesions (e.g., persons with Traumatic Brain Injuries, Marini et al., 2011b).

The **phases of lexical selection and access** require the coordination of an articulated cohort of cortical and subcortical areas. The selection of the appropriate word is linked to the activation of portions of the left temporal lobe (temporal pole – BA38; posterior aspect of the inferior temporal lobe – BA37; mid-portions of the inferior and middle temporal gyri – BAs 21 and 20), the posterior aspect of left pars opercularis (BA44), the precentral sulcus (BA 6) and the dentate nucleus of the right cerebellar hemisphere (Damasio et al., 1996; Fiez et al., 1996; Marini & Urgesi, 2012; Price & Friston, 1997). Indeed, the right cerebellar hemisphere is connected to the frontal lobes though a cortical-ponto-cerebellar and cerebellar-thalamo-cortical loop (Schmahmann & Pandya, 1997) also dedicated to lexical production (Sach et al., 2004). As such, it may play a role in word search, whereas the prefrontal cortex seems to underlie the selection of words from among competing alternatives (Marvel et al., 2004). Similarly, the **phase of lexical access to the word's morphosyntactic information** involves the posterior aspect of left pars opercularis (BA44), whereas the one of **phonological encoding** is implemented in areas in the left auditory cortex and *planum temporale* together with the posterior aspects of the left superior temporal gyrus (Hickok et al., 2003; Levelt et al., 1998). As we have seen, the increase of TOT phenomena with aging and other lexical difficulties suggest that the phases of lexical selection and access undergo significant changes in many older individuals. Indeed, word retrieval difficulties in older people have been found associated with atrophy in neural networks implicated in lexical selection and access, including white matter integrity (Stamatakis et al., 2011). In an fMRI investigation, Peelle et al. (2013) asked a group of younger and one of older healthy adults to judge whether two object names matched on a particular semantic feature. The results showed that both groups had similar performance levels but older adults were more variable. Namely, the authors could distinguish between a high- and a low-performing subgroup, with the former having the same performance as the younger group but increased overall activity in bilateral premotor cortex and left lateral occipital cortex. This suggests that with aging, the brain of elder people may cope with the atrophic processes by reshaping some of the neural connections previously employed in specific tasks. For example, the left lateralized activity observed in prefrontal areas while performing tasks of word-retrieval has been found to occur with additional activations in the right prefrontal cortex in older individuals (Meinzer et al., 2009; Persson et al., 2004; Wierenga et al., 2008). After the phases of lexical selection and access to morphosyntactic and phonological information, the speaker gains access to the **phases of syllabification and phonetic encoding**. Several studies show that these processes recruit a cohort of cortical and subcortical areas (left inferior frontal gyrus – BA44; ventral aspect of left precentral gyrus – BA6; mid-portion of bilateral superior temporal gyri; posterior aspect of left fusiform gyrus – BAs 21 and 37; left thalamus; mid-portion of right cerebellar hemisphere) (Hagoort et al., 1999; Indefrey & Levelt, 2004). Finally, the **phase of articulation** is implemented in areas involved in articulatory planning (supplementary motor area) and control (primary motor cortex – BA4; cerebellum; left thalamus; basal ganglia) (Price et al., 1999; Rieker et al., 2005). Overall, then, the phases of phonological and phonetic encoding, and that of articulation recruit different cortical and subcortical networks. Importantly, aging apparently reshapes these neural networks as older individuals show additional activations in specific areas (e.g., ventral premotor cortex, supplementary motor area, prefrontal cortex) but reduced activity in other regions (e.g., posterior superior temporal gyrus) (e.g., Soros et al., 2011).

Tremblay et al. (2013) analyzed the cortical activations in younger and older adults during audio-visual speech perception and production tasks. As for production, their study showed that the wide bilateral network of motor and premotor areas that are recruited for the phase of speech planning and production was not affected by age. However, other areas implicated in the same process such as the Supplementary Motor Area showed reduced activation in the elderly.

The before-mentioned aging-induced structural and functional changes in both grey and white matter (Davis et al., 2009; Good et al., 2001; Raz et al., 2005; Resnick et al., 2003; Tyler et al., 2010) are likely the result of brain plasticity in response to neural loss. However, as we have seen, the impact of healthy aging on cognitive functioning is characterized by high inter- and intra-individual variability. An intriguing issue regards the reason why some older individuals still have good performance on tasks tapping language skills in spite of the general age-related atrophy that affects both grey and white matter. As a result of these neural alterations, several investigations have noticed different patterns of activation between younger and older adults, with older adults showing more widespread and less focused activation while processing specific tasks (e.g., Ghisletta & Lindenberger, 2003; Park et al., 2004). It seems, then, that aging, at least in part, modifies the array of neural structures employed for message production in healthy adults. Overall, these observations support the possibility that as neural structures decline with age other areas are recruited to preserve the function (Meunier et al., 2014). One possibility is that the brain implements compensatory mechanisms to establish new connections between preexisting neural networks and new ones during aging. For example, the **HAROLD model** (Hemispheric Asymmetry Reduction in Older Adults) formulated by Cabeza et al. (2002) hypothesizes that aging would reduce the functional hemispheric asymmetry and therefore compensatory neural networks in both hemispheres would process most cognitive functions. For example, this compensatory mechanism has been observed in older adults in tasks tapping their skills of verbal working memory and inhibitory control, cognitive skills that significantly affect the phases of message planning and monitoring (Cabeza et al., 2002; Ska et al., 2009). When it comes to language, as previously noted, some steps of the process of message production are assumed to be mostly left lateralized in healthy adults (at least in the vast majority of left-handers; Risse et al., 1997). However, when compared to younger individuals, increased bilateral activity has been observed in older persons with good performance on lexical (naming and verbal generation) and syntactic tasks (Persson et al., 2004; Obler et al., 2010; Tyler et al., 2010; Wierenga et al., 2008). A second type of compensatory mechanism, this time not inter- but intra-hemispheric, that has been hypothesized is the **Posterior-Anterior Shift in Aging (PASA) model** (Davis et al., 2008). In the fMRI study by Davis et al. (2008)

a group of younger and one of older adults were scanned during episodic retrieval and visual perceptual tasks. The authors reported age-related changes in brain activity common to both tasks that were not linked to task difficulty.

Furthermore, the age-related increases in frontal activity were positively correlated with performance and negatively correlated with the age-related occipital decreases. The authors hypothesized a reorganization of activation from the occipito-temporal to the frontal cortex as it is also suggested by the results from a preceding study by Grossman et al. (2002) who showed increased prefrontal activity in a group of older individuals with good performance on a language comprehension task. Finally, a third hypothesis (labelled **Cognitive Reserve**; Stern, 2009) focuses on the inter-individual differences found on cognitive tasks in the elderly and suggests that these might depend on differences in cognitive processing and neural implementation that would allow some people to cope better than others with aging and/or brain lesions.

Conclusions and future directions

This chapter has shown the complex features of linguistic production in aging. It presents results from both psycholinguistic and neurolinguistic perspectives. Indeed, different hypotheses tried to explain changes in the linguistic processing of older adults. From a psycholinguistic point of view, several investigations focused on the hypothesis of a general slowing in a variety of cognitive functions in healthy aging. For instance, studies focusing on lexical retrieval skills revealed that there is a positive aspect associated with aging: the mental lexicon keeps on growing with age. However, older people often go through word finding difficulties. This may be associated with (1) a general cognitive slowing, (2) reduced working memory skills, or (3) a problem in the retrieval of specific lexical information. Also, according to another hypothesis, connections among lexical-semantic and phonological representations in the mental lexicon might get weaker with age. A general increasing of grammatical difficulties also characterizes the linguistic production of older adults. This aspect as well may be associated with a general cognitive decline, affecting in particular short-term and working memory. The macrolinguistic dimension of linguistic production in older adults presents decreased levels of cohesiveness and both local and global coherence that, as for microlinguistic patterns, might not be simply due to a linguistic weakening but to a more general cognitive slowing. In particular, difficulties on narrative organization may be associated to the *inhibition deficit hypothesis* (Hasher & Zacks, 1988), revealing a minor ability for older adults to inhibit irrelevant information.

From a neurolinguistic point of view, several studies tried to support the hypothesis of neural changes in older adults' brains. They revealed reduced activation in areas involved in message production and lexical retrieval (Cabeza et al., 1997; Logan et al., 2002) and a general atrophy in neural networks implicated in lexical access (Stamatakis et al., 2011). Furthermore, some hypotheses have been formulated to interpret such findings (e.g., the HAROLD model, the PASA model and the Cognitive Reserve hypothesis). According to these hypotheses, the brain goes through major changes with aging. However, it also copes with these changes by reorganizing its neural connections and this has consequences on cognitive processing.

To summarize, older adults' linguistic production is influenced by a general cognitive decline as well as by physiological neural changes as a response to brain atrophy. It is important to take into account the typology of tasks used to elicit language production. In fact, sometimes results can be controversial because experiments are based on different administrations, aiming at assessing different features. In general, the use of ecological tests (such as procedures of discourse analysis) is desirable. Findings coming from neural investigations confirm the important role of neuroimaging techniques, which nowadays are fundamental for both research and clinical practice. However, further investigations are needed to deepen our understanding of the neural underpinnings and the cognitive characteristics of language production in the elderly.

References

Albert, M. L., Spiro, A., Sayers, K. J., Cohen, J. A., Brady, C. B., Goral, M., & Obler, L. K. (2009). Effects of health status on word finding in aging. *Journal of the American Geriatrics Society*, 57, 2300–2305. doi:10.1111/j.1532-5415.2009.02559.x

Arbuckle, T. Y., & Gold, D. P. (1993). Aging, inhibition, and verbosity. *Journal of Gerontology*, 48(5), 225-232. doi:10.1093/geronj/48.5.P225

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, 302–311.

Badecker, W., Miozzo, M., & Zanuttini, R. (1995). The two stage model of lexical retrieval: Evidence from a case of anomia with selective preservation of grammatical gender. *Cognition*, 57, 193–216. doi:10.1016/0010-0277(95)00663-J

Bowles, N. L., & Poon, L. W. (1985). Aging and retrieval of words in semantic memory. *Journal of Gerontology*, 40(1), 71–77. doi:10.1093/geronj/40.1.71

Brown, R., & McNeill, D. (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior*, 5, 325–337. doi:10.1016/S0022-5371(66)80040-3

Brown, A. S. (1991). A review of the tip-of-the-tongue experience. *Psychological Review*, 109, 204–223.

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., & Shafto, M. A. (2004). Aging and language production. *Current Directions in Psychological Science*, 13(1), 21–24. doi:10.1111/j.0963-7214.2004.01301006.x

Cabeza, R., Grady, C. L., Nyberg, L., McIntosh, A. R., Tulving, E., Kapur, S., Jennings, J. M., Houle, S., & Craik, F. I. M. (1997). Age-related differences in neural activity during memory encoding and retrieval: A Positron Emission Tomography Study. *The journal of Neuroscience*, 17(1), 391–400.

Cabeza, R., Anderson, N. D., Locantore, J. K., & McIntosh, A. R., (2002). Aging gracefully: compensatory brain activity in high-performing older adults. *Neuroimage*, 17, 1394-1402. doi:10.1006/nimg.2002.1280

Caplan, D. (1992). *Language: Structure, processing and disorders*. Cambridge, MA: The MIT Press.

Capilouto, G., Wright, H. H., & Wagovich, S. (2005). CIU and main event analyses of the structured discourse of older and younger adults. *Journal of Communication Disorders*, 38(6), 431–444. doi:10.1016/j.jcomdis.2005.03.005

Carpenter, P. A., Miyake, A., & Just, M. A. (1994). Working memory constraints in comprehension: Evidence from individual differences, aphasia, and aging. In M. A. Gernsbacher, (Ed.), *The handbook of psycholinguistics* (pp. 1075-1122). San Diego, CA: Academic Press.

Catani, M., Dell'Acqua, F., Bizzi, A., Forkel, S. J., Williams, S. C., Simmons, A., Murphy, D. G., & Thiebaut de Schotten, M. (2012). Beyond cortical localisation in clinico-anatomical correlation. *Cortex*, 48(10), 1262–1287. doi:10.1016/j.cortex.2012.07.001

Chomsky, N. (1995). *The minimalist program*. Cambridge, MA: The MIT Press.

Clark, H. H. (1996). *Using Language*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511620539

Collette, F., Schmidt, C., Scherrer, C., Adam, S., & Salmon, E. (2007). Specificity of inhibitory deficits in adult aging and Alzheimer's disease. *Neurobiology of Aging*, 30, 875–889. doi:10.1016/j.neurobiolaging.2007.09.007

Connor, L. (2001). Memory in old age: Patterns of decline and preservation. *Seminars in Speech and Language*, 22(2), 117–125. doi:10.1055/s-2001-13936

Connor, L. T., Spiro, A., Obler, L. K., & Albert, M. L. (2004). Change in object naming ability during adulthood. *The Journals of Gerontology: Series B*, 59(5), 203–209. doi:10.1093/geronb/59.5.P203

Damasio, H., Grabowski, T. J., Tranel, D., Hichwa, R., & Damasio, A. R. (1996). A neural basis for lexical retrieval. *Nature*, 380, 499–505. doi:10.1038/380499a0

Davis, S. W., Dennis, N. A., Daselaar, S. M., Fleck, M. S., & Cabeza, R. (2008). Que PASA? The Posterior-Anterior Shift in aging. *Cerebral Cortex*, 18(5), 1201–1209. doi:10.1093/cercor/bhm155

Davis, S. W., Dennis, N. A., Buchler, N. G., White, L. E., Madden, D. J., & Cabeza, R. (2009). Assessing the effects of age on long white matter tracts using diffusion tensor tractography. *Neuroimage*, 46, 530–541. doi:10.1016/j.neuroimage.2009.01.068

Dell G. S. (1986). A spreading activation theory of retrieval and sentence production. *Psychological Review*, 93, 283–321 doi:10.1037/0033-295X.93.3.283

Drag, L. L., & Bieliauskas, L. A. (2010). Contemporary review 2009: Cognitive aging. *Journal of Geriatric Psychiatry and Neurology*, 23, 75–93.

Duchin, S. W., & Mysak, E. D. (1987). Disfluency and rate characteristics of young adult, middle-aged, and older males. *Journal of Communication Disorders*, 20, 245–257. doi:10.1016/0021-9924(87)90022-0

Feyereisen, P. (1997). A meta-analytic procedure shows an age-related decline in picture naming: Comments on Goulet, Ska, and Kahn (1994). *Journal of Speech, Language, and Hearing Research*, 40(6), 1328–1333. doi:10.1044/jslhr.4006.1328

Fiez, J. A., Raichle, M. E., Balota, D. A., Tallal, P., & Petersen, S. E. (1996). PET activation of posterior temporal regions during auditory word presentation and verb generation. *Cerebral Cortex*, 6, 1–10. doi:10.1093/cercor/6.1.1

Fletcher, P. C., Happé, F., Baker, S. C., Dolan, R. J., Frackowiak R. S. J., & Frith, C. D. (1995). Other minds in the brain: A functional imaging study of "Theory of Mind" in story comprehension. *Cognition*, 57, 109–128. doi:10.1016/0010-0277(95)00692-R

Fozo, M. S., & Watson, B. C. (1998). Task complexity effect on vocal reaction time in aged speakers. *Journal of Voice*, 12, 404–414. doi:10.1016/S0892-1997(98)80049-0

Frazier L., & Fodor J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, 6, 291–325. doi:10.1016/0010-0277(78)90002-1

Fromkin, V. A. (1971). The nonanomalous nature of anomalous utterances. *Journal of Linguistics*, 4, 47–68. doi:10.1017/S002222670000164X

Garrett, M. (1975). The analysis of sentence production. In G. Bower (Ed.), *Psychology of learning and motivation* (Vol. 9). New York, NY: Academic Press.

Garrett, M. F. (1980). Levels of processing in sentence production. In B. Butterworth (Ed.), *Language production: Speech and talk* (Vol. 1; pp. 177–220). London: Academic Press.

Garrod, S., & Pickering, M. J. (2004). Why is conversation so easy? *Trends in Cognitive Sciences*, 8(1), 8–11. doi:10.1016/j.tics.2003.10.016

Geschwind, N. (1970). The organization of language and the brain. *Science*, 170, 940–944. doi:10.1126/science.170.3961.940

Ghisletta, P., & Lindenberger, U. (2003). Age-based structural dynamics between perceptual speed and knowledge in the Berlin Aging Study: direct evidence for ability dedifferentiation in old age. *Psychology and Aging*, 18, 696–713. doi:10.1037/0882-7974.18.4.696

Glosser, G., & Deser, T. (1990). Patterns of discourse production among neurological patients with fluent language disorders. *Brain and Language*, 40(1), 67–88. doi:10.1016/0093-934X(91)90117-J

Gold, D., & Arbuckle, T. Y. (1995). A longitudinal study of off-target verbosity. *Journal of Gerontology: Psychological Sciences*, 50B, 307–315. doi:10.1093/geronb/50B.6.P307

Good, C. D., Johnsrude, I. S., Ashburner, J., Henson, R. N., Friston, K. J., & Frackoviak, S. J. (2001). A voxel based morphometric study of ageing in 465 normal adult human brains. *Neuroimage*, 14, 21–36. doi:10.1006/nimg.2001.0786

Goral, M., Spiro, A. I., Albert, M. L., Obler, L. K., & Connor, L. T. (2007). Change in lexical skills in adulthood: Not a uniform decline. *Mental Lexicon*, 2, 215–238. doi:10.1075/ml.2.2.05gor

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(3), 629–644. doi:10.1044/jshr.3703.629

Grady, C. L., & Craik, F. I. (2000). Changes in memory processing with age. *Current Opinions in Neurobiology*, 10, 224-231. doi:10.1016/S0959-4388(00)00073-8

Grady, C. L., McIntosh, A. R., & Craik, F. I. (2003). Age-related differences in the functional connectivity of the hippocampus during memory encoding. *Hippocampus*, 13, 572–586.

Green, D. W. (1986). Control, activation and resource. *Brain and Language*, 27, 210–223. doi:10.1016/0093-934X(86)90016-7

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, 1, 67–81. doi:10.1017/S1366728998000133

Grice, H. P. (1975). Logic and conversation. In P. Cole, and J. P. Morgan (Eds.), *Syntax and semantics: Speech acts* (pp. 41–58). New York, NY: Academic Press.

Griffin, Z. M., & Spieler, D. H. (2006). Observing the what and when of language production for different age groups by monitoring speakers' eye movements. *Brain and Language*, 99(3), 272–288. doi:10.1016/j.bandl.2005.08.003

Grossman, M., Cooke, A., DeVita, C., Chen, W., Moore, P., Alsop, D., & Gee, J. (2002). Sentence processing strategies in healthy seniors with poor comprehension: An fMRI study. *Brain and Language*, 80, 296–313. doi:10.1006/brln.2001.2581

Hagoort, P., Indefrey, P., Brown, C., Herzog, H., Steinmetz, H., & Seitz, R. J. (1999). The neural circuitry involved in the reading of German words and pseudowords: A pet study. *Journal of Cognitive Neuroscience*, 11, 383–398. doi:10.1162/089892999563490

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. doi:10.1016/S0079-7421(08)60041-9

Heller, R. B., & Dobbs, A. R. (1993). Age differences in word finding in discourse and nondiscourse situations. *Psychology and Aging*, 8, 443–450. doi:10.1037/0882-7974.8.3.443

Hickok, G., Buchsbaum, B., Humphries, C., & Muftuler, T. (2003). Auditory-motor interaction revealed by fMRI: Speech, music, and working memory in area SPT. *Journal of Cognitive Neuroscience*, 15, 673–682. doi:10.1162/089892903322307393

Indefrey, P., & Levelt, W. J. M. (2000). The neural correlates of language production. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (2nd ed.; pp. 845–865). Cambridge, MA: The MIT Press.

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition*, 92, 101–144. doi:10.1016/j.cognition.2002.06.001

Indefrey, P. (2011). The spatial and temporal signatures of word production components: A critical update. *Frontiers in Psychology*, 2, 255. Epub 2011 Oct 12. doi:10.3389/fpsyg.2011.00255

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. doi:10.1037/0882-7974.13.3.355

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. doi:10.1037/0278-7393.26.6.1378

James, L. E. (2004). Meeting Mr. Farmer versus meeting a farmer: Specific effects of aging on learning proper names. *Psychology and Aging*, 19, 515–522. doi:10.1037/0882-7974.19.3.515

Johnson-Laird, P. N. (1980). Mental models in cognitive science. *Cognitive Science*, 4, 71–115. doi:10.1207/s15516709cog0401_4

Johnson-Laird, P. N. (1983). *Mental models: Toward a cognitive science of language, inference and consciousness*. Cambridge, MA: Harvard University Press.

Juncos-Rabadán, O., Pereiro, A. X., & Rodríguez, M. S. (2005). Narrative speech in aging: Quantity, information content, and cohesion. *Brain and Language*, 95, 423–434. doi:10.1016/j.bandl.2005.04.001

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston naming test*. Philadelphia, PA: Lea and Febiger.

Kemper, S., & Anagnopoulos, C. (1989). Language and ageing. *Annual Review of Applied Linguistics*, 10, 37–50. doi:10.1017/S0267190500001203

Kemper, S. (1990). Adults' diaries: Changes to written narratives across the life span. *Discourse Processes*, 13, 207–223. doi:10.1080/01638539009544754

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, 220–224. doi:10.1093/geronb/59.5.P220

Kemper, S., Greiner, L. H., Marquis, J. G., Prenovost, K., & Mitzner, T. (2001). Language decline across the life span: Findings from the Nun study. *Psychology and Aging*, 16, 227–239. doi:10.1037/0882-7974.16.2.227

Kemper, S., & Sumner, A. (2001). The structure of verbal abilities in young and older adults. *Psychology and Aging*, 16, 312–322. doi:10.1037/0882-7974.16.2.312

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, 49, 294–303. doi:10.1037/0003-066X.49.4.294

Kintsch, W., & van Dijk, T. (1978). Toward a model of text comprehension and production. *Psychological Review*, 85, 363–394. doi:10.1037/0033-295X.85.5.363

Kuhl, P. K. (2010). Brain mechanisms in early language acquisition. *Neuron Review*, 67, 713–727. doi:10.1016/j.neuron.2010.08.038

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: The MIT Press.

Levelt, W. J. M., Praamstra, P., Meyer A. S., Helenius, P., & Salmelin, R. (1998). A MEG study of picture naming. *Journal of Cognitive Neuroscience*, 10, 553–567. doi:10.1162/089892998562960

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, 22, 1–38.

Levinson, S. C. (1983). *Pragmatics*. Cambridge: Cambridge University Press.

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. doi:10.1037/0882-7974.12.3.410

Logan, J. M., Sanders, A. L., Snyder, A. Z., Morris, J. C., & Buckner, R. L. (2002). Under-recruitment and nonselective recruitment: Dissociable neural mechanisms associated with aging. *Neuron*, 33, 827–840. doi:10.1016/S0896-6273(02)00612-8

Lyketsos, C. G., Chen, L. S., & Anthony, J. C. (1999). Cognitive decline in adulthood: An 11.5-year follow-up of the Baltimore Epidemiologic Catchment Area study. *American Journal of Psychiatry*, 156(1), 58–65. doi:10.1176/ajp.156.1.58

MacKay, A., Connor, L. T., Albert, M. L., & Obler, L. K. (2002). Noun and verb retrieval in healthy aging. *Journal of the International Neuropsychological Society*, 8(1), 764–770. doi:10.1017/S1355617702860040

Madden, D. J., Turkington, T. G., Provenzale, J. M., Denny, L. L., Hawk, T. C., Gottlob, L. R., & Coleman, R. E. (1999). Adult age differences in the functional neuroanatomy of verbal recognition memory. *Human Brain Mapping*, 7, 115–135. doi:10.1002/(SICI)1097-0193(1999)7:2<115::AID-HBM5>3.0.CO;2-N

Marini A., Boewe A., Caltagirone, C. & Carlomagno, S. (2005). Age-related differences in the production of textual descriptions. *Journal of Psycholinguistic Research*, 34(5), 439–463. doi:10.1007/s10936-005-6203-z

Marini, A., Andreetta, S., Del Tin, S., & Carlomagno, S. (2011a). A multi-level approach to the analysis of narrative language in aphasia. *Aphasiology*, 25(11), 1372–1392. doi:10.1080/02687038.2011.584690

Marini, A., Galetto, V., Zampieri, E., Vorano, L., Zettin, M., & Carlomagno, S. (2011b). Narrative language in traumatic brain injury. *Neuropsychologia*, 49, 2904–2910. doi:10.1016/j.neuropsychologia.2011.06.017

Marini, A., & Urgesi, C. (2012). Please, get to the point! A cortical correlate of linguistic informativeness. *Journal of Cognitive Neuroscience*, 24(11), 2211–2222. doi:10.1162/jocn_a_00283

Marvel, C. L., Schwartz, B. L., & Isaacs, K. L. (2004). Word production deficits in Schizophrenia. *Brain and Language*, 89, 182–191. doi:10.1016/S0093-934X(03)00366-3

Meinzer, M., Flaisch, T., Wilser, L., Eulitz, C., Rockstroh, B., Conway, T., Gonzalez-Rothi, L., & Crosson, B. (2009). Neural signatures of semantic and phonemic fluency in young and old adults. *Journal of Cognitive Neuroscience*, 21, 2007–2018. doi:10.1162/jocn.2009.21219

Meunier, D., Stamatakis, E. A., & Tyler, L. K. (2014). Age-related functional reorganization, structural changes, and preserved cognition. *Neurobiology of Aging*, 35, 42–54. doi:10.1016/j.neurobiolaging.2013.07.003

Miyake, A., Emerson, M. J., & Friedman, N. P. (2000). Assessment of executive functions in clinical settings: Problems and recommendations. *Seminars in Speech and Language*, 21, 169–183. doi:10.1055/s-2000-7563

Mozeiko, J., Le, K., Coelho, C., Krueger, F., & Grafman, J. (2011). The relationship of story grammar and executive function following TBI. *Aphasiology*, 25, 826–835. doi:10.1080/02687038.2010.543983

Nicholas, M., Obler, L., Albert, M. S., & Goodglass, H. (1985). Lexical retrieval in healthy aging. *Cortex*, 21, 595–606. doi:10.1016/S0010-9452(58)80007-6

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (Vol. 4; pp. 1–18). New York, NY: Plenum. doi:10.1007/978-1-4757-0629-1_1

Obler, L. K., Au, R., Kugler, J., Melvold, J., Tocco, M., & Albert, M. L. (1994). Intersubject variability in adult normal discourse. In R. L. Bloom, L. K. Obler, S. D. Santi, & J. S. Ehrlich (Eds.), *Discourse analysis and applications. Studies in adult clinical population* (pp. 15–27). Hillsdale, NJ: Lawrence Erlbaum Associates.

Obler, L. K., Rykhlevskaia, E., Schnyer, D., Clark-Cotton, M. R., Spiro, A., Hyun, J., Kim, D. S., Goral, M., & Albert, M. L. (2010). Bilateral brain regions associated with naming in older adults. *Brain and Language*, 113(603), 113–123. doi:10.1016/j.bandl.2010.03.001

Park, D. C., Welsh, R. C., Marshuetz, C., Gutchess, A. H., Mikels, J., Polk, T. A., Noll, D. C., & Taylor, S. F. (2003). Working memory for complex scenes: Age differences in frontal and hippocampal activations. *Journal of Cognitive Neuroscience*, 15, 1122–1134. doi:10.1162/089892903322598094

Park, D. C., Polk, T. A., Park, R., Minear, M., Savage, A., & Smith, M. R. (2004). Aging reduces neural specialisation in ventral visual cortex. *Proceedings of the National Academy of Science*, 101, 13091–13095. doi:10.1073/pnas.0405148101

Peelle, J. E., Chandrasekaran, K., Powers J., Smith, E. E., & Grossman, M. (2013). Age-related vulnerability in the neural systems supporting semantic processing. *Frontiers in Aging Neuroscience*, 5, 46, 1–11. doi:10.3389/fnagi.2013.00046

Persson, J., Ching-Yune, C., Sylvester, J. K., Nelson, J. K., Welsh, K. M., Jonides, J., & Reuter-Lorenz, P. A. (2004). Selection requirements during verb generation: differential recruitment in older and younger adults. *Neuroimage*, 23, 1382–1390. doi:10.1016/j.neuroimage.2004.08.004

Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences*, 27(2), 169–190.

Pratt, M. W., & Robins, S. L. (1991). That's the way it was: Age differences in the structure and quality of adults' personal narratives. *Discourse Processes*, 14, 73–85. doi:10.1080/01638539109544775

Price, C. J., & Friston, K. J. (1997). Cognitive conjunctions: A new approach to brain activation experiments. *Neuroimage*, 5, 261–270. doi:10.1006/nimg.1997.0269

Price, C. J., Indefrey, P., & van Tourennout, M. (1999). The neural architecture underlying the processing of written and spoken word forms. In C. M. Brown & P. Hagoort (Eds.), *The Neurocognition of language* (pp. 211–240). Oxford: Oxford University Press.

Radvansky, G. A., Gerard, L. D., Zacks, R. T., & Hasher, L. (1990). Younger and older adults' use of mental models as representations for text materials. *Psychology and Aging*, 5, 209–214. doi:10.1037/0882-7974.5.2.209

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. doi:10.1037/0882-7974.18.1.161

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, 585–605. doi:10.1006/jmla.1996.0031

Raz, N., Lindenberger, U., Rodrigue, K. M., Kennedy, K. M., Head, D., Williamson, A., Dahle, C., Gerstorf, D., & Acker, J. D. (2005). Regional brain changes in aging healthy adults: General trends, individual differences and modifiers. *Cerebral Cortex*, 15, 1676–1689. doi:10.1093/cercor/bhi044

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.

Riecker, A., Mathiak, K., Wildgruber, D., Erb, M., Hertrich, I., Grodd, W., & Ackerman H. (2005). fMRI reveals two distinct cerebral networks subserving speech motor control. *Neurology*, 64, 700–706. doi:10.1212/01.WNL.0000152156.90779.89

Risse, G. L., Gates, J. R., & Fangman, M. C. (1997). A reconsideration of bilateral language representation based on the intracarotid amobarbital procedure. *Brain and Cognition*, 33, 118–132. doi:10.1006/brcg.1997.0887

Sach, M., Seitz, R. J., & Indefrey, P. (2004). Unified inflectional processing of regular and irregular verbs: A PET study. *Neuroreport*, 15(3), 533–537. doi:10.1097/00001756-200403010-00030

Salthouse, T. A. (1996). Constraints on theories of cognitive aging. *Psychology and Aging*, 3, 287–299.

Schmahmann, J. D., & Pandya, D. N. (1997). The cerebro-cerebellar system. *International Review of Neurobiology*, 41, 31–60. doi:10.1016/S0074-7742(08)60346-3

Schneider, B. A., Daneman, M., Murphy, D. R., & See, S. K. (2000). Listening to discourse in distracting settings: The effects of aging. *Psychology and Aging*, 15, 110–125. doi:10.1037/0882-7974.15.1.110

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. doi:10.1037/h0087392

Schmitter-Edgecombe, M., Vesneski, M., & Jones, D. W. (2000). Aging and word-finding: A comparison of spontaneous and constrained naming tests. *Archives of clinical neuropsychology: The official journal of the National Academy of Neuropsychologists*, 15(6), 479–493.

Schroeder, D. H., & Salthouse, T. A. (2004). Age-related effects on cognition between 20 and 50 years of age. *Personality and Individual Differences*, 36, 393–404. doi:10.1016/S0191-8869(03)00104-1

Shadden, B. (1997). Discourse behaviours in older adults. *Seminar in Speech and Language*, 18(2), 156–147. doi:10.1055/s-2008-1064069

Sharp, D. J., Scott, S. K., Mehta, M. A., & Wise, R. J. S. (2006). The neural correlates of declining performance with age: Evidence for age-related changes in cognitive control. *Cerebral Cortex*, 16, 1739–1749. doi:10.1093/cercor/bhj109

Ska, B., Scherer, L. C., Flores, O. C., de Oliveira, C. R., Netto, T. M., & Fonseca, R. P. (2009). Theoretical, behavioral and neuroimaging evidence on discourse processing in aging. *Psychology and Neuroscience*, 2, 101–109. doi:10.3922/j.psns.2009.2.002

Soros, P., Bose, A., Sokoloff, L. G., Graham, S. J., & Stuss, D. T. (2011). Age-related changes in the functional neuroanatomy of overt speech production. *Neurobiology of Aging*, 32(8), 1505–1513.

Sperber, D., & Wilson, D. (1986). *Relevance. Communication and cognition*. Oxford: Blackwell.

Stamatakis, E. A., Shafto, M. A., Williams, G., Tam, P., & Tyler, L. K. (2011). White matter changes and word finding failures with increasing age. *PlosOne*, 6(1), e14496. doi:10.1371/journal.pone.0014496

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*, 47, 2015–2028. doi:10.1016/j.neuropsychologia.2009.03.004

Thornton, R., Skovbroten, K., & Burke, D. M. (2004). Grammatical agreement processes in young and older adults. Presented at the *Forty-Fifth Annual Meeting of the Psychonomic Society*. Minneapolis, MN.

Thornton, R., & Light, L. L. (2006). Language comprehension and production in normal aging. In J. E. Birren & Schaie K.W. (Ed.), *Handbook of the psychology of aging* (pp. 261–287). San Diego CA: Academic Press. doi:10.1016/B978-012101264-9/50015-X

Tremblay, P., Deschamps, I., & Gracco, V. (2013). Regional heterogeneity in the processing and the production of speech in the human planum temporale. *Cortex*, 49(1), 143–157.

Trunk, D. L., & Abrams, L. (2009). Do younger and older adults' communicative goals influence off-topic speech in autobiographical narratives? *Psychology and Aging*, 24(2), 324–337. doi:10.1037/a0015259

Tucker, F. M., & Hanlon, R. E. (1998). Effects of mild traumatic brain injury on narrative discourse production. *Brain Injury*, 12, 783–792. doi:10.1080/026990598122179

Tyler, L. K., Shafto, M. A., Randall, B., Wright, P., Marslen-Wilson, W. D., & Stamatakis, E. A. (2010). Preserving syntactic processing across the adult life span: The modulation of the frontotemporal language system in the context of age related atrophy. *Cerebral Cortex*, 20, 352–364. doi:10.1093/cercor/bhp105

Ulatowska, H. K., Hayashi, M. M., Cannito, M. P., & Fleming, S. G. (1986). Disruption of reference in aging. *Brain and Language*, 28(1), 24–41. doi:10.1016/0093-934X(86)90088-X

Ullman, M. T. (2001). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research*, 30(1), 37–69. doi:10.1023/A:1005204207369

Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, 92, 231–270. doi:10.1016/j.cognition.2003.10.008

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology and Aging*, 18, 332–339. doi:10.1037/0882-7974.18.2.332

Verhaegen, C., & Poncelet, M. (2012). Changes in naming and semantic abilities with aging from 50 to 90 years. *Journal of the International Neuropsychological Society*, 19, 119–126. doi:10.1017/S1355617712001178

Vigliocco, G., Garrett, M. F., & Antonini, T. (1997). Grammatical gender is on the tip of Italian tongues. *Psychological Science*, 8, 314–317. doi:10.1111/j.1467-9280.1997.tb00444.x

Vigneau, M., Beaucousin, V., Hervé, P. Y., Duffau, H., Crivello, F., Houdé, O., Mazoyer, B., & Tzourio-Mazoyer, N. (2006). Meta-analyzing left hemisphere language areas: Phonology, semantics, and sentence processing. *Neuroimage*, 30, 1414–1432. doi:10.1016/j.neuroimage.2005.11.002

Wager, T. D., Jonides, J., & Reading, S. (2004). Neuroimaging studies of shifting attention: A meta-analysis. *Neuroimage*, 22, 1679–1693.

Wierenga, C. E., Benjamin, M., Gopinath, K., Perlstein, W. M., Leonard, C. M., Rothi, L. J., Conway, T., Cato, M. A., Briggs, R., & Crosson, B. (2008). Age-related changes in word retrieval: role of bilateral frontal and subcortical networks. *Neurobiology of Aging*, 29, 436–451. doi:10.1016/j.neurobiolaging.2006.10.024

Wills, C. L., Capilouto, G. J., & Wright, H. H. (2012). Attention and off-topic speech in the recounts of middle-age and elderly adults: A pilot investigation. *Contemporary Issues in Communication Sciences & Disorders*, 39, 105–112.

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

Wingfield, A., & Tun, P. (2001). Spoken language comprehension in older adults: Interactions between sensory and cognitive change in normal aging. *Seminars in Hearing*, 22(3), 287–301. doi:10.1055/s-2001-15632

Ylvisaker, M., Szekeres, S. F., & Feeney, T. (2001). Communication disorders associated with traumatic brain injury. In R. Chapey (Ed.), *Language intervention strategies in aphasia and related neurogenic communication disorders* (pp. 745–800). Baltimore, MD: Williams and Wilkins.

Zacks, R. T., & Hasher, L. (1997). Cognitive gerontology and attentional inhibition: A reply to Burke and McDowd. *Journal of Gerontology: Psychological Sciences*, 52B, 274–283. doi:10.1093/geronb/52B.6.P274

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, 123, 162–185. doi:10.1037/0033-2909.123.2.162