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Discourse Processing and Development through the Adult Lifespan

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Participation in the discourse world in its varied forms (e.g., reading a novel or newspaper, watching a movie, or engaging in conversation) is essential to effective functioning throughout the adult lifespan. Adult development is characterized by multidimensional change in cognition, encompassing both gain and loss (Baltes, 1987; Linderberger, 2014), which can impact the way in which language and discourse are processed (Radvansky & Dijkstra, 2007; Stine-Morrow, Miller, & Hertzog, 2006). The possibility that discourse understanding might be compromised with aging, or otherwise change in quality, is a practically important issue given the fact of population aging. It has been recognized for some time in the scholarly literature and popular press that increased life expectancy is contributing to a dramatic increase in the relative proportion of older adults (United Nations Department of Economic and Social Affairs Population Division, 2013). While the percentage of the world's population aged 60 and over was 12% in 2013 (up from 8% in 1950), the projection is that this will increase to 21% by 2050.

Thus, understanding how discourse processing functions in late life is not only a matter of scientific accuracy, but also of interest in translational applications for promoting effective communication (e.g., media, workplace training, and health care). Moreover, individual trajectories of cognitive development are themselves shaped by experiences and activities (Hertzog, Kramer, Wilson, & Lindenberger, 2008), among which are literacy practices and habitual engagement with discourse. This dynamic is intriguing, and yet, understudied, and population aging heightens the urgency of understanding this reversal in causal effects – how engagement in discourse processing impacts the experience of aging. Our goals in the next few pages, then, are to explore the myriad ways in which age-related change in cognition can impact discourse comprehension and production, and to consider how engagement

in discourse processing may impact cognition and well-being. We conclude by identifying knowledge gaps that suggest fruitful areas for further exploration.

Change and Stability in Discourse Processing with Age

Age differences in memory for information from text are well documented, whereas evidence for age differences in comprehension is more mixed (Johnson, 2003; Meyer & Pollard, 2006; Wingfield & Stine-Morrow, 2000). Most of this research has depended on extreme-group designs in which the performance of younger adults (typically, college students) is compared with that of adults over the age of 60. The relatively few studies that have examined the effects of age as a continuous variable are not consistent, at times suggesting that such declines may occur relatively late, with middle-aged to young-old adults performing quite well but others suggesting more continuous change through the lifespan (Ferstl, 2006; Payne et al., 2014; Stine-Morrow, Miller, Gagne, & Hertzog, 2008). An approach to understanding this complexity depends on an appreciation of both the multifaceted nature of aging as well as of discourse processing, and how these map onto one another.

The Nature of Cognitive Aging

Age declines in processing speed, working memory capacity, reasoning, executive control, and other fluid abilities are normative, with effect sizes for cross-sectional differences between the ages of 20 and 80 estimated to be as high as two standard deviations (Salthouse, 2010); estimates for within-person change are more modest, up to about one standard deviation (Schaie, 2005). Knowledge-based processes, such as acquired skill, semantic memory, and crystallized verbal ability (e.g., vocabulary) are quite well preserved at least into the eighth decade (Baltes, 1997; Li et al., 2004).

Domain-specific knowledge also shows stability into late life, as well as the capacity to grow, dependent on the habitual engagement with the domain (Ackerman & Rolfhus, 1999). Some evidence suggests that older adults engage in more gist-based processing (Chapman et al., 2002; Koustaal & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998). Insofar as gist-based processing, in part, reflects efforts at semantic elaboration that support memory, it may have some adaptive value (Schacter, Guerin, & St. Jacques, 2011). While cognition shows multidimensional change through the adult lifespan, its role in relation to other psychological systems may also change. Some researchers have suggested that cognition becomes more tightly integrated with socioemotional concerns (Carstensen, Mikels, & Mather, 2006). Also, because cognitive processes can become more resource-consuming with age, effort may be engaged more selectively (Hess, 2014). This dynamic in gain and loss in cognitive processes, as well as the changing role of cognition in relation to other psychological systems, can impact language and discourse processing.

The Nature of Discourse Processing

Like any meaningful task, discourse processing requires the coordination and cooperation of multiple systems (e.g., van Dijk & Kintsch, 1983). Much adult developmental work has been concerned with differential effects of age-graded influences on three levels of processing, namely, the surface form, textbase, and situation model levels. Briefly, the surface form encompasses the exact words and syntactic phrasing of the discourse. Successful discourse processing requires that individuals be fairly accurate for most of this information

for either production or comprehension. This level of representation is the most transitory of the three, with information being lost from memory soon after it is used (Kintsch, Welsch, Schmalhofer, & Zimny, 1990).

While small errors in processing can be tolerated, the majority of the critical elements of the surface form need to be successfully processed so that the comprehender can access the relevant background knowledge and develop a reasonably accurate understanding. At the same time, as we will discuss later, individuals can use the larger context of discourse to circumvent some of the lower-level processing demands. While there is some evidence that successful discourse processing can be attenuated by age-related declines in hearing and vision (Wingfield & Lash, in press), for our purposes we will assume that younger and older adults are able to encode surface form information to a reasonable degree.

At the intermediate level is the textbase, the integrated collection of propositions that represent the semantic content actually conveyed in the discourse (e.g., Kintsch, 1998; van Dijk & Kintsch, 1983). A proposition is essentially an idea, defined as a relationship among concepts. For example, the text *Liz raved about the stout*, *but G.A. preferred the merlot*, conveys three ideas, two defining a relationship between characters and a beverage, and a contrastive relationship between the first two ideas. So, like the surface form, this information is tied to the actual discourse itself. The textbase is important for a discourse comprehender to get the gist of what is being communicated without being tied to the actual words and linguistic structure involved. This information is retained in memory for a longer time than the surface form (e.g., one might later recall that *G.A. likes merlot*, which is consistent with the ideas conveyed even if expressed differently). Nevertheless, it is still forgotten within a short period of time, relative to the more enduring representation given by the situation model.

Of most primary relevance in models of discourse understanding is the situation model level of processing (Zwaan & Radvansky, 1998), also known as the mental model level (Johnson-Laird, 1983; Morrow, Bower, & Greenspan, 1989) or the event model level (Radvansky & Zacks, 2014). Situation models differ from the surface form and textbase levels in that they are not representations of the text itself, but are referential representations of the circumstances described by the text. That is, situation models capture not what the text is, but what the text is about. This includes information that may be in a text, as well as any inferences a person may draw using general world knowledge (e.g., based on the ideas conveyed above about Liz and G.A., one might infer that they were at a restaurant). In narratives, situation models are typically built around the protagonist(s) and their interactions that are tracked in space and time, so as to constitute a mental simulation of events; in expository texts, situation models can comprise lines of argumentation and mental simulations of systems. Also, unlike the surface form and textbase levels, situation models are more enduring in memory. That is, they may remain highly available and relatively unaltered even a week later (Radvansky et al., 2001). This may be because the representations capture our interactions with and understandings of the world, whereas the surface form and textbase levels comprise the actual expression and ideas that are a means for transferring the situation model understanding in one person's mind to another person's.

The importance of the situation model level is evident if one takes a broader view of comprehension and memory. Specifically, think of all of the stories/narratives a person is tracking at any time. This includes events transpiring in their own lives (autobiographical memory) and the lives of others in their family, work, friends, etc., the stories they are tracking terms of the books they are reading, the television and film series they are watching, and so on.

The situation model is the representational level on which the comprehension and memory of these diverse kinds of events depend for encoding and retrieval.

Age Effects on the Memory and Comprehension of Discourse Content

Undoubtedly, age-related changes in the speed of processing, working memory capacity, and executive control can impact the ability to construct a robust and distinctive textbase representation, so that learning from text can be compromised (Borella, Ghisletta, & de Ribaupierre, 2011; Payne et al., 2014; Thomas & Hasher, 2012). Interestingly, while sentence processing is reliably affected by these mechanisms, the more language becomes forms of discourse (i.e., interconnected sentences that cohere into larger information structures, such as argument exposition or stories), the less the involvement of working memory, and the less consistent age declines become (Shake, Noh, & Stine-Morrow, 2009; Stine & Wingfield, 1990b; Stine-Morrow et al., 2008).

There is some evidence that the ability to extract the gist or interpretive meaning of a text may be preserved (Adams, 1991; Adams, Labouvie-Vief, Hobart, & Dorosz, 1990; Adams, Smith, Nyquist, & Perlmutter, 1997), but the story here is likely to be complex. Chapman et al. (2006) has distinguished between the *transformed gist*, which is the interpretative meaning of a text that is based in world knowledge (e.g., the ability to extract a moral) and the *main-idea gist*, which is the differential recall of main ideas. Chapman et al. showed that while transformed gist is relatively preserved with age, main-idea gist is more likely to show declines.

These paradoxical findings perhaps speak to the difference between the representation of discourse as a set of ideas as compared to a mental simulation of events that is integrated into larger knowledge structures and personal meanings. The ability of older adults to selectively retain the main ideas of a text can vary with text demands. For example, while older adults often show good discrimination in memory among ideas that vary in importance (i.e., showing better recollection for major over minor ideas, just as younger adults do), when the density of ideas within sentences is increased or discourse structures don't afford cues to organization, the ability to select out the more important ideas (i.e., main-idea gist) can be compromised (Stine & Wingfield, 1988, 1990a). As discussed below, the ability to create mental simulations of events, which would presumably support memory for transformed gist, appears to be quite well maintained into old age (Dijkstra et al., 2004; Radvansky & Dijkstra, 2007). The relative preservation of the situation model even when the retention of particular ideas is compromised has been explained in terms of a scaffolding metaphor in which older adults construct a more fragile textbase representation to support the construction of a situation model that endures with decay of the textbase (Radvansky, Zwaan, Curiel, & Copeland, 2001).

Age Effects on Understanding Situations from Discourse

While there is a great deal of evidence to suggest that age-related declines in fluid abilities may bring difficulty with sentence processing (i.e., parsing complex syntax, proposition assembly; Wingfield & Grossman, 2006; Payne & Stine-Morrow, 2016), to a large extent, situation model processing appears to be intact in later adulthood, leading to the suggestion that older adults are often more reliant on, or attend more to this level of representation (Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Morrow et al., 1997; Radvansky, Copeland, Berish, & Dijkstra, 2003; Radvansky, Copeland, & Zwaan, 2003;

Radvansky & Curiel, 1998; Radvansky, & Dijkstra, 2007; Radvansky, Gerard, Zacks, & Hasher, 1990; Radvansky et al., 2001; Stine-Morrow, Gagne, Morrow, & DeWall, 2004; Stine-Morrow, Miller, & Leno, 2001; Stine-Morrow, Morrow, & Leno, 2002). We address this suggestion by considering how aging influences situation model use during the process of event segmentation and comprehension.

The first issue we consider is the ability to segment a stream of action into separate situation models. For example, when a person is comprehending a story there is often a series of events, rather than a static description of a scene. For comprehension to be successful, people need to track those changes. This ability is important because it allows the comprehender to strategically organize material as it is being comprehended. If event segments are missed, then a person is left trying to handle too much information as part of a single unit. If segmentation occurs at inappropriate places, then this leaves a person's understanding unnecessarily fragmented or inappropriately disjointed. In considering how aging affects event segmentation, we first consider work involving the explicit segmentation of information followed by work in which evidence of segmentation is more ongoing and implicit.

The explicit marking of event boundaries is often done using a version of the Newtson task (e.g., Newtson, 1973; Newtson & Engquist, 1976; Magliano & Zacks, 2011; Zacks & Swallow, 2007). In this task, people are given a narrative to comprehend. This can be either a written narrative or a narrative film. The task is to indicate, in some way, when a person thinks that a new event has started. Despite this seemingly vague instruction, people are actually quite consistent at doing this, both within and across individuals. For simplicity, we assume that at each point a person marks as an event boundary, this is the point at which a new situation model is created.

While this is a simple and straight-forward task, the results regarding the influence of aging on event segmentation are somewhat mixed. On the one hand, there is some evidence that aging does not have much of an influence on event segmentation. In a study by Magliano, Kopp, McNerney, Radvansky, and Zacks (2012), younger and older adults were asked to segment text and picture versions of stories. Younger and older adults were similar in their event segmentations, although the older adults showed some proclivity for identifying smaller segments than did the younger adults. That said, there is some evidence from Kurby and Zacks (2011) of age-related differences in the event segmentation of videos of everyday activities. Specifically, the older adults' segmentation was more variable and different from normative segmentations produced by younger adults. Why is there a difference between studies investigating age differences in event segmentation? While a systematic assessment of this difference has not yet been produced, it likely has something to do with the fact that in the Magliano et al. study the events were more drawn out, with larger changes from one event to another (such as a changes in spatial location or characters). In comparison, in the Kurby and Zacks study, the videos were of single, continuous activities, with much more subtle markers of different events. As such, there are fundamental differences in the types of events that are being assessed in these studies, and it may be that while older adults have trouble with the more fine-grained segmentation of individual activities, they do not appear to have much trouble with the segmentation of larger events.

Aside from methods that explicitly ask people to segment a stream of information, there are also less disruptive, more natural ways to assess the segmentation of a stream of information into events. Perhaps one of the most well known of these is an analysis of reading times. In particular, reading times tend to show an increase when readers encounter event boundaries (e.g., Zwaan et al., 1995, 1998). For example, when a comprehender reads that the story protagonist went from the gym out to the parking lot, there is a change in spatial location.

As such, this is an event boundary that separates the event of being in the gym from the event of being in the parking lot. The increase in reading time at this point is thought to reflect the increased effort needed to update one's situation models, such as by shifting to a new model. In terms of aging, younger and older adults appear to perform similarly (Radvansky, Zwaan, Curiel, & Copeland, 2001), showing similar increases in reading time at event boundaries. Together with the explicit segmentation data, this supports the idea that there are small to no age-related changes in the basic process of detecting changes from one event to another. As such, one would expect younger and older adults to create similar situation models, at least in terms of the extent to which people interpret one event to end and another to begin.

For processing at the situation model level to be successful, a person needs not only to detect when one event ends and another begins, but also to update the representation of the information relative to the developing events. That is, information that is tied to prior events should become less available in working memory so that it does not intrude on one's understanding of the current event. This is particularly relevant in terms of issues of aging, as it is well known that older adults have greater difficulty removing newly irrelevant information from the current stream of processing (Hasher & Zacks, 1988).

Despite this, there are a variety of sources of evidence suggesting that older adults manage the contents of their situation models as effectively as do younger adults. For example, Radvansky, Copeland, Berish, and Dijkstra (2003) found that when there were changes in the spatial or temporal framework of described events, such as when a story character moved from one location to another, or there was a big jump in time in the story (e.g., a day later), younger and older adults were similarly able to remove event-specific information from their situation models. For example, if a story protagonist moved from the gym to the parking lot, then information about the lighting in the gym would no longer be relevant, and if information about the lighting were probed at that point, it would be similarly unavailable for younger and older adults. This comprehension process is not isolated to linguistic materials. Radvansky, Pettijohn, and Kim (2015) have found that when younger and older adults move from one room to another in a virtual environment, there is a similar decline in the availability of information about objects with which the person interacted in a prior room. Thus, there is substantial evidence that older adults do not show any broad-based decline in the ability to update their understanding of unfolding events.

Keeping that in mind, there is some evidence that older adults can have difficulty with some aspects of situation model processing. First, there is a study by Noh and Stine-Morrow (2009) in which younger and older adults were asked to read texts that involved multiple characters. Under these circumstances, where the demand on the processing of the situation model is increased, older adults have difficulty tracking the larger number of event entities. Another source of evidence is a study by Copeland and Radvansky (2007), which assessed younger and older adults' ability to integrate information in brief, unfolding descriptions. When discontinuous orders were presented, in which people needed to wait to learn how all of the elements could be integrated together, older adults showed difficulty integrating the information, particularly when the information was presented in the form of sentences and word diagrams (although not when presented in the form of picture diagrams). Again, as in the Noh and Stine-Morrow study, when the older adults needed to coordinate multiple sources of information within and across situation models, they were less effective than the younger adults. This difficulty may be a result of decline in working memory capacity as there is a need to manage multiple sources of information in these tasks.

Aging and the Use of Discourse Context in Language Understanding

Age-related declines in speed of processing in working memory impact language understanding, in particular, by decreasing the rate of propositional coding (Hartley et al., 1994; Stine & Hindman, 1994). However, older readers take disproportionate use of discourse context to support the comprehension and encoding of lower-level information (Miller & Stine-Morrow, 1998), such that while such deficits are readily detected in sentence processing, they are much reduced, and often undetectable, in discourse processing. For example, measuring "reading efficiency" as the time allocated to reading relative to the number of propositional idea unit recalled (ms/idea), Miller, Cohen, and Wingfield (2006) showed that older readers took longer than younger adults to encode information from ambiguous texts, but differentially improved in efficiency when the text was preceded by a title that made the discourse coherent. Such effects were exaggerated among those with relatively low working memory capacity, as well as by a dual-task condition that was designed to reduce working memory demands. These findings support the view that creating a textbase representation of the ideas from a text is resource-consuming, especially so with aging, but that these processes can be supported by the larger discourse context (Stine & Wingfield, 1990b; Stine-Morrow et al., 2008).

Discourse context can facilitate processing for older adults through a number of routes. Shake and Stine-Morrow (2011) measured eye movements while younger and older adults read texts containing a pronoun that referenced a noun that was either matched or mismatched in stereotypical gender roles to the pronoun (e.g., The firefighter pulled himself/herself up the ladder). When such sentences were read in isolation, younger adults took a little extra time on the pronoun when it did not match their expectations (in this case, *herself*). Older adults, on the other hand, did not slow down on the pronoun, but were more likely to regress back from a subsequent word when there was a mismatch. In other words, younger readers immediately recognized the mismatch (e.g., features of *firefighter*, including gender, were activated and within two words integrated with the features of the pronoun to create an error signal), but older readers were not able to do this until they were past the pronoun. When these sentences were embedded in a short narrative that provided some context for the sentence, older readers responded immediately to the mismatch just as the younger adults did – regardless of whether the context revealed the gender of the referent. Discourse context, then, appeared to enable the older adults to instantiate the character in the narrative and be prepared to process the distinctive feature of gender within a single sentence. Also instructive were the age differences in processing in the discourse condition as a function of whether it revealed the gender of the character or not. In the gender-disambiguating condition, both groups of readers still took a little extra time on the mismatch, but younger and older readers showed virtually identical effects. In the gender-neutral condition that allowed the reader to instantiate the character in the narrative without revealing the gender, the older adults took much longer to process the target sentence. Thus, older adults can exploit the richer semantic representation afforded by discourse, both for instantiating discourse entities into the narrative (which then enables faster elaboration), and to constrain possible specific meanings.

Aging and the Effects of Knowledge on Discourse Processing

One of the great advantages of growing older is the opportunity for knowledge growth, both in terms of shared cultural and world knowledge, but also in particularized knowledge

that can be derived from the investment in work and leisure activities that are more person-specific (Ackerman & Rolfhus, 1999). Older adults are often shown to differentially rely on domain-specific and schematic knowledge, which can be a double-edged sword (Umanath & Marsh, 2014).

On one hand, there is considerable evidence that knowledge can have beneficial effects on discourse processing with age. Crystallized knowledge, typically measured as vocabulary level, develops in part through habitual engagement with print (Stanovich, West, & Harrison, 1995). As we discuss below, such knowledge may have broad effects on cognition, but more proximally, verbal skill can have a number of positive effects on language and discourse processes. It has been recognized for some time that underdeveloped word recognition skills can compromise comprehension processes among both children (Perfetti & Hogaboam, 1975) and college-aged adults (Bell & Perfetti, 1994), but variation in word knowledge can have continuing effects into later adulthood. Older adults with higher levels of vocabulary and/or print exposure are more efficient in word processing during reading and allocate more effort to semantic integration processes (Payne et al., 2012; Stine-Morrow et al., 2008), and are more tuned to the statistical properties of attachment in language (Payne et al., 2014). Age deficits in discourse memory are very often found to be reduced or eliminated among those with high levels of verbal ability (Johnson, 2003; Meyer & Pollard, 2006), which may be attributable in part to deeper semantic and situational processing that is afforded by verbal efficiency.

Experience more generally may afford advantages with discourse processing among older adults. Interestingly, it has been shown that college professors, who presumably spend much of their lives engaged with processes of knowledge acquisition and organization, show no age deficits at all in discourse memory with texts outside of their domain of expertise (Shimamura et al., 1995). Younger adults reading narratives that include erroneous factual details (e.g., a story about someone going to St. Petersburg, the capital of Russia) are likely to inadvertently "learn" this information and later endorse it as factual in the context of a general knowledge questionnaire. As we discuss in more detail below, Umanath and Marsh (2012) have found that older adults are less vulnerable to false information, arguing that this is a consequence of the protective effects of a more developed knowledge base.

Domain-specific knowledge very typically is shown to produce enhanced discourse memory for texts among both younger and older adults in various domains of expertise, including aviation (Morrow, Leirer, & Altieri, 1992), baseball (Hambrick & Engle, 2002), and cooking (Miller, 2003). There is surprisingly little evidence that domain-related knowledge reduces age differences in recall in this literature (i.e., knowledge does not appear to differentially enhance memory performance among older adults). However, domain-related expertise has been shown to mitigate aging effects in other aspects of performance. For example, knowledge about cooking has been shown to differentially enhance the efficiency with which information is encoded from expository texts about cooking techniques and recipes (Miller, 2009). Also, Morrow et al. (2009) showed that relative to novices, expert pilots reading scenarios of aviation-related problems allocated particular attention to problem-relevant information, and then generated more effective solutions; interestingly, the solutions generated by the older experts were just as effective as those developed by the younger pilots, in contrast to the age difference observed among the novices. Domain knowledge may also differentially enhance inferencing processes among older readers (Miller, Stine-Morrow, Kirkorian, & Conroy, 2004).

In general, crystallized verbal knowledge is correlated with domain knowledge (because high-verbal people are likely to use these skills to learn new things), but verbal

and domain-related knowledge can have distinctive effects on text processing. For example, Chin et al. (2015) showed in a sample of older adults that verbal ability enhanced conceptual integration for both health-related and domain-general texts, but controlling for verbal ability, health knowledge produced specific advantages for conceptual integration for health texts. Conceptual integration, in turn, enhanced later recall performance.

On the other hand, when discourse understanding depends on overriding well-learned schemas, older adults can be put at a disadvantage. For example, older adults have differential difficulty learning narratives that are variations on well-learned fairy tales (Attali & Dalla Barba, 2013; Dalla Barba, Attali, & La Corte, 2010).

Aging, Resource Allocation, and Engagement in Discourse Processing

Reading time is remarkably sensitive to demands that the text places on decoding the surface form, constructing the propositional textbase, and the need to repair discontinuities in the situation model. Statistical decomposition of reading time has been used to show that older adults are especially attentive to situation model features, and often less so to binding concepts into propositional idea units (Radvansky et al., 2001; Stine-Morrow et al., 2004; Stine-Morrow et al., 2008).

A consequence of reduced allocation to propositional analysis is that it may appear that older adults engage in more shallow and superficial processing of materials during comprehension. That is, there is not as much processing effort devoted to the comprehension of the meaning of exactly what is read. As a result, older adults are more likely to miss inconsistencies or irregularities in the language that is being comprehended. For example, in a series of studies, Umanath and Marsh (2012, 2014) assessed the performance of younger and older adults on semantic illusions, such as the Moses illusion. The Moses illusion is the finding that when asked the question, "How many animals of each kind did Moses take on the ark?," people will often respond with the answer, "2," even though nearly all of them know that it was Noah, not Moses, who took the animals on the ark. What they found was that older adults were more likely to fall prey to this illusion and give the inappropriate answer.

In another demonstration, older adults read texts that contained factually inaccurate information, such as a sentence that contained the phrase ". . . paddling across the largest ocean, the Atlantic, . . ." Here, younger and older adults were similarly disrupted during their comprehension. However, for both of these studies, when world knowledge was subsequently tested, older adults were less likely than younger adults to fall prey to the misinformation from the earlier part of the study. Instead, older adults were more likely to rely on their correct, long-term semantic knowledge. Thus, while there is some evidence that older adults may be compromised in terms of the depth with which they process information during comprehension, the long-lasting negative consequences for their long-term semantic memories is more limited than that for younger adults.

Older adults may generally adopt a heuristic of relying more on knowledge-based understanding of the situation with concomitant shallow processing of the surface form. For example, at syntactic levels of processing, work by Christianson, Williams, Zacks, and Ferreira (2006) had younger and older adults read garden paths sentences, such as "While Anna dressed the baby played in the crib." Younger and older adults were similarly disrupted in online comprehension, as measured by reading times, and both age groups were often likely to misinterpret the sentence, endorsing that "Anna dressed the baby." However, older adults endorsed the inappropriate interpretations at a higher rate, relative to control sentences, than did the younger adults. Christianson et al. argued that readers

maintain the original interpretation while also encoding that the baby was playing in the crib (in fact, participants are also likely to endorse this meaning as well) even though the co-existence of these two meanings is not allowed by the sentence structure. They suggest that rather than deriving meaning strictly based on the rules of language, that we use heuristics to create situational representations that are consistent with world knowledge. Because older adults tend to rely on knowledge-based heuristics, they are more likely to engage in such shallow processing.

Another example of this, at a more complex level of representation, was demonstrated by Hamm and Hasher (1992). In this study, people read passages in which the readers were led to interpret the situation in a particular way, and then were given further information that rendered that original interpretation incorrect. For example, people might be reading a story about a big game hunter out on the savanna who sees the animal he has been looking for, and how he is getting ready to take a shot. Then the person reads about the shutter clicking. At that point the reader needs to shift from the schematic/implied interpretation that the hunter is on a hunting safari to the interpretation that the hunter is on a photographic safari. While younger and older adults drew inferences about the revised interpretation at the same rate, older adults were also more likely to continue to maintain the original, incorrect interpretation. Thus, in both of these studies, younger and older adults seem similarly able to detect when some modification of their understanding is needed. However, older adults appear to hang on to inappropriate representations and understanding after it has become very clear that they are wrong.

Note that these findings may appear to differ from those of Umanath and Marsh described earlier in showing that older adults retain the "misinformation," but there is a subtle, but important, difference in these bodies of research. In the Umanath and Marsh work, the surface form and textbase introduce information that is inconsistent with well-established knowledge. The tendency for older adults to be more knowledge-driven and less likely to attend to propositional analysis results in less attention to the "revised" information and to rely on their stored knowledge. In the studies by Christianson, and by Hamm and Hasher, the pieces of conflicting information are both encoded from the text so that their relative value cannot be adjudicated based on existing knowledge.

Another issue that arises for older adults when comprehending is the degree to which they can stay engaged in the materials. Given that, according to many studies, they have reduced cognitive resources, it would intuitively be expected that they would be less likely to maintain focus on the comprehension task itself, and be more likely to have thoughts drift to off-topic ideas. The disengagement of normal comprehension, and the movement to off-topic, internally generated thoughts, is called *mind-wandering* (Barron, Riby, Greer, & Smallwood, 2011; Giambra, 1995; Smallwood & Schooler, 2006, 2015). The classical illustration of this is when one is reading a page and realizes when the bottom is reached that there is no memory for what was just read. Mind-wandering has been linked to a shift in cortical activity toward the default mode network (DMN) (e.g., Buckner, Andrews-Hanna, & Schacter, 2008; Weissman, Roberts, Visscher, & Woldorff, 2006).

Again, the expectation based on work on cognitive control is that older adults should mind wander more than younger adults when they are comprehending because they are less able to control their attention. However, what is interesting is that there are several studies showing that older adults actually mind wander either at the same rate as younger adults (Giambra & Arenberg, 1993), or *less* so (Jackson & Balota, 2012; Krawietz, Tamplin, & Radvansky, 2012). For example, in a study by Krawietz et al., younger adults were asked to read the first

five chapters of *War and Peace* (Tolstoy, 1869). During reading, people were occasionally interrupted with probes asking if they were mind-wandering. Using this method, they found that older adults were less likely to report mind-wandering. Supporting these claims, they also found that older adults were as able as younger adults to answer questions about the text when they reported not mind-wandering, suggesting that some active comprehension was occurring. More generally, this is further evidence that during comprehension, older adults can perform as well as or better than younger adults, particularly when comprehension is being assessed in terms of more global, situation model levels of understanding.

That said, there is also evidence of preservation with age in the use of surface form cues to selectively focus on discourse elements. One way this is accomplished is through syntactic form. For example, notice the difference in emphasis when a story begins, "*It was Paul who lost his daughter*," as opposed to, "*What Paul lost was his daughter*." This is a syntactic device, called *clefting*, which puts the focus on Paul in the first case and on his daughter in the second case, and leads to certain expectations about how the story will proceed. Price and Sanford (2012) conducted a series of experiments in which older and younger adults were presented with passages in which cleft constructions were used to manipulate the focus of entities in the discourse. As the story continued with the sentence, "*He/She had wandered off in the shop*," reading time was facilitated when the continuation matched the focus implied by the syntactic form. Older adults were just as able as young adults to use these syntactic cues to guide their attention to the focused elements and maintain them in working memory, thus facilitating comprehension and enhancing episodic memory for the focused elements.

Similarly, older adults have been shown to be able to use stress patterns in spoken discourse as a cue to selectivity. Fraundorf, Watson, and Benjamin (2012) presented younger and older adults with short spoken narratives with target sentences (e.g., "*The family decided to visit the Rockies in the fall*"), in which they systematically manipulated the prosodic pattern so as to differentially emphasize the importance of certain discourse elements. So the sentence was spoken with the stress accent on one element (e.g., "*The family decided to visit the **Rockies** in the fall*"), or the other (e.g., "*The family decided to visit the Rockies in the **fall***"), both (e.g., ***Rockies** . . . **fall***), or neither (e.g., *Rockies . . . fall*). In a delayed memory task, both younger and older adults were more likely to remember the concepts that had been spoken with a stress accent (cf. also Cohen & Faulkner, 1986). However, Fraudorf et al. showed that age-related declines in working memory may set limits on how much information can be focused on at once. While younger participants showed a benefit for each focused item regardless of the number of accented items in the text, the benefit for older adults was decreased when both items were accented, a phenomenon they called the "other accent penalty." Because low-span younger adults also showed the other accent penalty, they argued that working memory resources are required to manage the elements held in focus and that age-related declines in working memory reduced older adults' ability to maintain multiple elements in focus. Thus, older adults appear to be quite good at using cues to process the discourse more selectively, but there may be boundary conditions on this ability. Selectivity in discourse focus is only useful inasmuch as it allows individuals to manage information given their existing working memory capacity.

Collectively, these studies indicate that older adults are able, and perhaps in some cases, more able than younger adults to selectively attend to the larger discourse situation rather than the individual idea units. They are also able to use focus cues in discourse to guide their more limited working memory capacities toward important information.

Aging and Conversation

Conversation with other people serves myriad functions throughout the lifespan. We use conversation both to exchange information, and to establish and maintain social relationships that nurture our emotional lives. We can consider how aging impacts this critical function from different angles.

One consideration is the impact of sensory hearing loss on understanding conversation. Age-related declines in auditory function can impact comprehension directly through decreased sensitivity and through a compromised ability to discriminate among speech sounds, but there is growing evidence that the secondary effects are also significant. Aging listeners are often quite good at using top-down control to compensate for an impoverished speech signal, but this can require cognitive resources so that attention needed to create the textbase and situational representations are diminished (Wingfield & Lash, in press). In fact, comprehension among older adults is especially compromised in noisy environments (Schneider, Daneman, Murphy, & Kwong See, 2000). Older adults also have particular difficulty in following multi-talker conversations, and the ability to engage top-down control mechanisms can depend on complex interactions between the quality of the acoustic environment (e.g., separation between speakers and/or extraneous noise) as well as the cognitive resources of the individual (Avivi-Reich, Daneman, & Schneider, 2014).A substantial body of work has investigated age-related changes in language production, which would be expected to impact participation in conversation. It has long been known that language production shows a shift toward simpler syntactic forms with age, and to a lesser degree, reduced informational density, measured as idea units per utterance (Kemper et al., 2001; Kemper, Thompson, & Marquis, 2001). That said, older adults are sometimes found to be quite comparable to the young in producing informationally rich stories (Wright, Capilouto, Srinivasan, & Fergadiotis, 2011). Furthermore, there is considerable variability among individuals, with greatest effects related to late-life cognitive pathologies. Simplification in surface form (and perhaps, in propositional content) may, in part, represent a shift in attention toward higher order discourse forms, given evidence that older adults produce narratives that are structurally more complex (Kemper, Rash, Kynette, & Norman, 1990).

Another aspect of production that can impact conversation is the ability to maintain a coherent flow of topics. Findings on this using structured interviews or personal recollections are somewhat mixed, with some studies showing less coherent production among older adults relative to young (Glosser & Deser, 1992), and others suggesting a great deal of variability as a function of the structure of the task and the cognitive abilities of the participants (Wright, Koutsoftas, Capilouto, & Fergadiotis, 2014). Some have argued that age-related changes in executive control make older adults more vulnerable to engaging in off-topic speech (Arbuckle & Gold, 1993), conforming to the unfortunate stereotype of the verbose older adults. However, other work has demonstrated that older adults are more likely to produce elaborations off the main story line ("asides") when recounting personal narratives, but not when describing a picture (James, Burke, Austin, & Hulme, 1998) or when recounting a narrative that was learned in the laboratory session (Bluck, Alea, Baron-Lee, & Davis, 2016). Such findings strongly imply that any cohort differences in "verbosity" may serve a social function, rather than reflecting age-related changes in cognition.

Finally, participating in conversation requires sensitivity to the listener, tailoring production to the partner's understanding. One way in which this has been investigated is with the referential communication task, in which conversational partners work together to arrange

ambiguous items without access to the other's viewpoint. Participants take turns serving as the director, who can see the arrangement of items, and the partner, who has the items but has to create the arrangement based on conversation with the director. A key challenge to this task is developing a common terminology with which to refer to the ambiguous items that must be arranged. Older partners often take longer to achieve the common arrangement because it takes them longer to achieve terms of reference, which has been attributed to memory deficits (Hupet, Chantraine, & Nef, 1993; Lysander & Horton, 2012).

For example, Horton and Spieler (2007) manipulated the familiarity of the partner in a second session after common ground had been established in a referential communication task and found that while younger adults took advantage of the earlier experience to selectively abbreviate communication with familiar partners with whom common ground had already been established, older adults did not. They argue that older adults were less likely to engage in such "audience design," because of difficulties in encoding listener-specific perspectives and then retrieving them on the fly in the new situation. Other research, however, suggests that older adults can be quite sensitive in tailoring conversation to the listener. Adams et al. (2002) found that when retelling a narrative to a child, as opposed to an adult experimenter, older adults were better than the young in simplifying the story for the child. Incidentally, the typical text memory deficits for older adults that were observed with the experimenter listener were also eliminated when the listener was a child, suggesting that socioemotional dimensions of motivation may offset declines in cognitive resources in recalling discourse, which is certainly likely to play a role in conversation.

Aging and Discourse Processing in New Ecologies

The little work that has been conducted in multimedia environments with younger and older adults suggests similar age-related patterns to those found with conventional text studies. For example, Cavanaugh (1983) compared younger and older adults' memory for television programs and found that older adults showed the same advantage in memory for points central to the plot as did the young; and interestingly, as we have discussed earlier in connection with text, age effects depended on verbal ability such that it was only the older adults with lower verbal ability who showed deficits in memory.

The contexts in which discourse processing and development is studied are expanding. For example, there are increases in the study of conversations. Also, nonlinguistic aspects of communication, such as gesture, are being more deeply considered, and the time is ripe for these new discoveries and theories to be applied to older adult populations. What is particularly notable are the recent expansions into new media in which discourse can occur. Specifically, this can include work on the comprehension that occurs when watching videos and other multimedia, as well as interacting with virtual environments. In terms of film, there has been a dramatic increase in work assessing how people process and comprehend narrative film. Some of this work is being done by researchers whose background is in discourse processing, and they bring the perspective and tools of discourse analysis to the study of narrative film (e.g., Magliano, Miller, & Zwaan, 2001; Zacks, Speer, & Reynolds, 2009). The results of this work reveal that many of the same principles that guide comprehension for narrative texts can be extended to the comprehension of narrative film. In terms of aging, it may be that older adults are more adept at processing narrative film than narrative texts. For example, a study by Kurby, Asiala, and Mills (2014) found no age differences in older and younger adults' event segmentation of a narrative film.

More recent cognitive science advances in computer technology have led to an explosion of research using virtual environments in which a participant can actively navigate and interact with objects and entities in multi-space settings. This technology allows for the assessment of various aspects of human cognition. Aside from the obvious studies of spatial navigation and memory (e.g., Richardson, Montello, & Hegarty, 1999; Riecke, Cunningham, & Bülthoff, 2007), there are also studies that assess how the structure of the environment influences memory processing in that environment.

One example of this is the finding that walking through doorways causes forgetting (Radvansky & Copeland, 2006; Radvansky, Krawietz, & Tamplin, 2011; Radvansky, Tamplin, & Krawietz, 2010). Essentially, in this paradigm, people are asked to navigate through a virtual environment picking up and setting down objects as they move through the space. The critical finding is that people are less accurate at remembering what objects they are currently carrying if they move from one room to another as compared to if they simply move across a large room of the same distance. This work was inspired by and parallels work in discourse comprehension that has found that the availability of objects mentioned previously in a text grows worse as a story protagonist moves away from the object in the story world (e.g., Glenberg, Meyer, & Lindem, 1987; Morrow, Bower, & Greenspan, 1987). Similarly, like the finding that younger and older adults similarly update their event models during written discourse processing by removing no longer relevant objects from their event models, work using these virtual environments has found that older adults are similar to younger adults in terms of how they update their understanding of the unfolding interactive environment. Given these parallels, one can think of written or spoken discourse as a means for comprehenders to create vicarious autobiographical experiences, as the same cognitive mechanisms seem to be involved in both.

With the rise of electronic media (e.g., Internet, electronic books), another feature of new discourse ecologies is that readers play more of a role in selecting texts and managing multiple sources (Pirolli, 2005). In such a context, discourse understanding depends not only on textbase and situation model processes, but also skills in search, and strategies for selective investment of attentional resources into particular sources. To the extent that such processes are age-sensitive, one might expect age differences in how older adults process discourse in such environments. On the one hand, age declines in executive control might be expected to compromise performance with age when navigational demands are high, but at the same time, self-regulation afforded in these new ecologies may yield special advantages for older adults. For example, older adults' search strategies for obtaining health information in web environments has been characterized as more top-down relative to those of younger adults in relying on existing knowledge (Chin, Fu, & Kannampallil, 2009).

Other research indicates that older adults may be especially adaptive in responding to the constraints of a search environment. In a recent study by Liu et al. (submitted) younger and older adults were asked to learn about a topic by selecting a series of short texts to read on an electronic tablet. Programmed into the tablet was a short random delay between when the participant selected the text and when it appeared, during which a spinning wheel appeared (indicating the tablet was loading the text). There were two conditions in which the total amount of study time was controlled but the presentation delay (a "switch cost" in moving from one passage to another) was varied (0–2 sec vs. 6–8 sec). It can be shown that optimal information gain from the whole environment requires that the learner increase persistence within a text as the switch cost increases. In fact, both younger and older adults adopted this strategy, and showed benefits in recall as a result. Older adults were somewhat

more adaptive to the change in switch cost, so that age differences in delayed recall were eliminated when switch cost was high.

How Discourse Processing Can Shape Aging

While the myriad ways in which aging impacts discourse processing have been of interest in the scientific literature for some time, questions about how engagement with language and discourse impacts aging are only recently coming into focus (Stine-Morrow, Hussey, & Ng, 2015). Even with the normative age-related declines in some aspects of cognition that we have already discussed, there is also evidence of great plasticity and considerable interest in the pathways to promote cognitive resilience with aging (Hertzog et al., 2008; Stine-Morrow & Chui, 2012), in particular through engagement with everyday activities (Carlson et al., 2011; Stine-Morrow et al., 2014). Habitual engagement with discourse through sustained literacy practices is quite plausibly an activity with the potential to promote cognitive health. Because self-reports of reading habits can be inflated by demand characteristics, habits of engagement with print are typically measured with tasks requiring recognition of the names of authors or magazines (Mol & Bus, 2011). Such measures tend to correlate with self-reports and other measures that plausibly reflect a predilection toward engagement with written discourse (e.g., number of books in the home, the ability to name a favorite author).

Print exposure has been found to account for age-related growth in vocabulary and crystallized ability (Stanovich et al., 1995). Early in the lifespan, the magnitude of cross-sectional correlations between print exposure and language abilities tend to increase with age, and cross-lagged correlations between measures of these constructs in longitudinal data have prompted some to argue for a causal spiral between print exposure that contributes to more fluent reading, on the one hand, and abilities that afford access to an ever wider range of texts, on the other (e.g., Mol & Bus, 2011). Older readers with higher levels of print exposure process words more efficiently and allocate more attention to semantic processing, even when controlling for differences in vocabulary (Payne et al., 2012). In addition, readers with higher levels of print exposure are more attuned to the statistical properties of syntactic structure (Payne et al., 2014). Finally, print exposure has been shown to modulate the well-replicated relationship between working memory (a fluid ability) and text memory, such that at the highest levels of print exposure, text recall is not at all constrained by poor working memory (Payne et al., 2012). Older adults with poorer literacy skills show steeper declines in cognition measured longitudinally (Manly et al., 2004), and there is some evidence that avid readers are more resistant to the effects of late-life cognitive pathology (Wilson et al., 2000).

Perhaps the most striking evidence for the long-term effects of language use and literacy practices on mind and brain comes from natural experiments examining individuals who are deprived of literacy instruction for reasons unrelated to the ability to acquire literacy (Dehaene et al., 2010; Huettig & Mishra, 2014; Petersson, Ingvar, & Reis, 2009). This work suggests that literacy engagement has a number of effects on cognition, including enhanced verbal working memory, semantic fluency, and episodic memory, as well as effects on neural structure and function. Reading engagement may have effects beyond cognition. Consistent with the idea that narrative comprehension affords immersion into worlds with new places with new people, evoking the simulation of social experiences in particular (Gerrig & Jacovina, 2009; Mar & Oatley, 2008; Nell, 1988), adults higher in narrative print exposure score higher on objective measures of empathy (Mar, Oatley, & Peterson, 2009).

Knowledge Gaps and New Frontiers

There has been a great deal of research assessing the influence of the aging process on comprehension, particularly language comprehension, and more particularly, written language comprehension. Moreover, the materials that people are being asked to comprehend are quite limited in scope and importance, as is typical of many laboratory studies. While research using these sorts of materials can illuminate individual mechanisms, comprehension is much broader than this. There have been major advances in extending the range of contexts and paradigms in which aging and comprehension are being explored. The work on conversation is one example of this. That noted, there are still a number of areas that are severely understudied.

A moment's reflection will reveal that the majority of what younger and older adults are comprehending is not covered by traditional laboratory studies. As is the case earlier in the lifespan, many older adults spend a great deal of time reading books, as well as watching television programs and movies. A common element that is found in many of these cases is that there is a need for the comprehender to keep large amounts of complex information available in memory to understand the unfolding events. In the case of books, a reader often puts the book down to do other things. The book is then picked up some time later. This may be hours, days, weeks, or even months later. Often, the reader can continue reading, picking up where they left off without much difficulty, although we do acknowledge that the longer it has been since the person was reading, the harder this will be to do.

Similarly, when people watch television shows, they track various events that occur over an episode, with the need to refer to elements that may have been encountered several minutes earlier, often with interfering and distracting information in commercials. Even more importantly, in many televisions shows, viewers may need to refer back to events from episodes that may have been seen weeks, months, or even years earlier. Along the same lines, when viewers watch narrative feature films, they may need to remember back to events that occurred quite a while earlier in the movie. There may also be cases in which there is reference to earlier films if they are part of a series, which may have been seen years prior. Even more interesting is the ability of readers and viewers to make and appreciate references to other narratives that may not even be part of the current series, again, even if the narrative events had not been read about or viewed in many years or decades.

Despite these obstacles, most comprehenders seem to have no difficulty doing this. Nor do they seem to have difficulty remembering and tracking large numbers of life "narratives" about themselves, family members, friends, co-workers, and so on. More importantly, many of the age-related comprehension and memory complaints that are mentioned by older adults tend to fall along the lines of the kinds of unrelated, less systematic information that is typically studied in the laboratory. Older adults are not known for regularly complaining about not being able to comprehend and remember things that are described in the books that they read, or the television shows and movies that they watch. Thus, there are great swaths of comprehension and memory abilities that are largely preserved during the natural aging process that have not been intensively studied to date. If anything, older adults may be in a better position to comprehend and remember such "real life" narratives because they have a larger base of narrative memories on which to draw.

Technology is radically changing the ecology in which discourse processing occurs, not just in the delivery of conventional texts in electronic formats (e.g., e-books, Internet) but also in creating a culture in which we are deeply embedded in diverse forms of discourse through social media. For the current cohort of older adults, this creates avenues of cognitive

and social enrichment that are unprecedented, but also within a context that is historically novel in terms of discourse forms and the roles of participants. These new forms of discourse are shaping our collective understanding of narrative forms and information exchange, so that future cohorts of older adults are aging into new modes of discourse with knowledge schemas for communication and information transmission that are very different from those of current cohorts. Of interest is how age-graded change in cognition impacts, and is impacted by, participation in these new ecologies.

References

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

Adams, C. (1991). Qualitative age differences in memory for text: A life-span developmental perspective. *Psychology and Aging*, *6*, 323–336.

Adams, C., Labouvie-Vief, G., Hobart, C. J., & Dorosz, M. (1990). Adult age group differences in story recall style. *Journal of Gerontology: Psychological Sciences*, *45*, P17–27.

Adams, C., Smith, M. C., Nyquist, L., & Perlmutter, M. (1997). Adult age-group differences in recall for the literal and interpretive meanings of narrative text. *Journal of Gerontology: Psychological Sciences*, *52B*, P187–P195.

Adams, C., Smith, M. C., Pasupathi, M., & Vitolo, L. (2002). Social context effects on story recall in older and younger women: Does the listener make a difference? *Journal of Gerontology: Psychological Sciences*, *57B*, P28–P40.

Arbuckle, T. Y., & Gold, D. P. (1993). Aging, inhibition, and verbosity. *Journal of Gerontology: Psychological Sciences*, *48*, P225–P232.

Attali, E., & Dalla Barba, G. (2013). Confabulation in healthy aging is related to poor encoding and retrieval of over-learned information. *Aging*, *Neuropsychology*, *and Cognition*, *20*, 339–355.

Avivi-Reich, M., Daneman, M., & Schneider, B. A. (2014). How age and linguistic competence alter the interplay of perceptual and cognitive factors when listening to conversations in a noisy environment. *Front Syst Neurosci*, *8*, Article 21.

Baltes, P. B. (1987). Theoretical propositions of life-span developmental psychology: On the dynamics between growth and decline. *Developmental Psychology*, *23*, 611–626.

Baltes, P. B. (1997). On the incomplete architecture of human ontogeny: Selection, optimization, and compensation as foundation of developmental theory. *American Psychologist*, *52*, 366–380.

Barron, E., Riby, L. M., Greer, J., & Smallwood, J. (2011). Absorbed in thought: The effect of mind wandering on the processing of relevant and irrelevant events. *Psychological Science*, *22*, 596–601.

Bell, L. C., & Perfetti, C. A. (1994). Reading skill: Some adult comparisons. *Journal of Educational Psychology*, *86*, 244–255.

Bluck, S., Alea, N., Baron-Lee, J. M., & Davis, D. K. (2016). Story asides as a useful construct in examining adult story recall. *Psychology and Aging*. doi: http://dx.doi.org/10.1037/a0039990.

Borella, E., Ghisletta, P., & de Ribaupierre, A. (2011). Age differences in text processing: The role of working memory, inhibition, and processing speed. *Journal of Gerontology: Psychological Sciences*, *66B*, 311–320.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network. *Annals of the New York Academy of Sciences*, 1124, 1–38.

Carlson, M. C., Parisi, J. M., Xia, J., Xue, Q.-L., Rebok, G. W., Bandeen-Roche, K., & Fried, L. P. (2011). Lifestyle activities and memory: Variety may be the spice of life: The Women's Health and Aging Study II. *Journal of the International Neuropsychological Society*, *18*, 1–9.

Carstensen, L. L., Mikels, J. A., & Mather, M. (2006). Aging and the intersection of cognition, motivation, and emotion. In J. E. Birren & K. W. Schaie (Eds), *Handbook of the psychology of aging* (6th ed., pp. 343–362). New York, NY: Academic Press.

Cavanaugh, J. C. (1983). Comprehension and retention of television programs by 20- and 60-year olds. *Journal of Gerontology*, *38*, 190–196.

Chapman, S. B., Anand, R., Sparks, G., & Cullum, C. M. (2006). Gist distinctions in healthy cognitive aging versus mild Alzheimer's Disease. *Brain Impairment*, *7*, 223–233.

Chapman, S. B., Zeintz, J., Weiner, M., Rosenberg, R., Frawley, W., & Burns, M. H. (2002). Discourse changes in early Alzheimer Disease, mild cognitive impairment, and normal aging. *Alzheimer Dis Assoc Disord*, *16*, 177–186.

Chin, J., Fu, W.-T., & Kannampallil, T. (2009). Adaptive information search: Age-dependent interactions between cognitive profiles and strategies. *Proceedings of the 27th ACM Conference on Human Factors in Computing Systems CHI'09*, 1683–1692. doi: 10.1145/1518701.1518961.

Chin, J., Madison, A., Gao, X., Graumlich, J. F., Conner-Garcia, T., Murray, M. D., … Morrow, D. G. (2015). Cognition and health literacy in older adults' recall of self-care information. *The Gerontologist*. doi: 10.1093/geront/gnv091.

Christianson, K., Williams, C. C., Zacks, R. T., & Ferreira, F. (2006). Younger and older adults' "good-enough" interpretations of garden-path sentences. *Discourse Processes*, *42*, 205–238.

Cohen, G., & Faulkner, D. (1986). Does "elderspeak" work? The effect of intonation and stress on comprehension and recall of spoken discourse in old age. *Language and Communication*, *6*, 91–98.

Copeland, D. E., & Radvansky, G. A. (2007). Aging and integrating spatial situation models. *Psychology and Aging*, *22*, 569–579.

Dalla Barba, G., Attali, E., & La Corte, V. (2010). Confabulation in healthy aging is related to interference of overlearned, semantically similar information on episodic memory recall. *Journal of Experimental and Experimental Neuropsychology*, *32*, 655–660.

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Filho, G. N., Jobert, A., … Cohen, L. (2010). How learning to read changes the cortical networks for vision and language *Science*, *330*, 1359–1364.

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

Ferstl, E. C. (2006). Text comprehension in middle aged adults: Is there anything wrong? *Aging, Neuropsychology, and Cognition*, *13*, 62–85.

Fraundorf, S. H., Watson, D. G., & Benjamin, A. S. (2012). The effects of age on the strategic use of pitch accent in discourse: A processing-resource account. *Psychology and Aging*, *27*, 88-98.

Gerrig, R. J., & Jacovina, M. E. (2009). Reader participation in the experience of narrative. In B. H. Ross (Ed.), *Psychology of learning and motivation* (Vol. 51, pp. 223–254). New York, NY: Elsevier.

Giambra, L. M. (1995). A laboratory method for investigating influences on switching attention to task-unrelated imagery and thought. *Consciousness and Cognition*, *4*, 1–21.

Giambra, L. M., & Arenberg, D. (1993). Adult age differences in forgetting sentences. *Psychology and Aging*, *8*, 451–462.

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory and Language*, *26*, 69–83.

Glosser, G., & Deser, T. (1992). A comparison of changes in macrolinguistic and microlinguistic aspects of discourse production in normal aging. *Journal of Gerontology: Psychological Sciences*, *47*, P266–P272.

Hambrick, D. Z., & Engle, R. W. (2002). Effects of domain knowledge, working memory capacity, and age on cognitive performance: An investigation of the knowledge-is-power hypothesis. *Cognitive Psychology*, *44*, 339–387.

Hamm, V. P., & Hasher, L. (1992). Age and the availability of inferences. *Psychology and Aging*, *7*, 56–64.

Hartley, J. T., Stojack, C. C., Mushaney, T. J., Annon, T. A. K., & Lee, D. W. (1994). Reading speed and prose memory in older and younger adults. *Psychology and Aging*, *9*, 216–223.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation*, Vol. 22 (pp. 193–225). New York, NY: Academic Press.

Hertzog, C., Kramer, A. F., Wilson, R. S., & Lindenberger, U. (2008). Enrichment effects on adult cognitive development: Can the functional capacity of older adults be preserved and enhanced? *Psychological Science in the Public Interest*, *9*, 1–65.

Hess, T. M. (2014). Selective engagement of cognitive resources: Motivational influences on older adults' cognitive functioning. *Perspectives on Psychological Science*, *9*, 388–407.

Horton, W. S., & Spieler, D. H. (2007). Age-related differences in communication and audience design. *Psychology and Aging*, *22*, 281–290.

Huettig, F., & Mishra, R. K. (2014). How literacy acquisition affects the illiterate mind: A critical examination of theories and evidence. *Language and Linguistics Compass*, *8*, 401–427.

Hupet, M., Chantraine, Y., & Nef, F. (1993). References in conversation between young and old normal adults. *Psychology and Aging*, *8*, 339–346.
Jackson, J. D., & Balota, D. A. (2012). Mind-wandering in younger and older adults: Converging evidence from the sustained attention to response task and reading for comprehension. *Psychology and Aging*, *27*, 106–119.
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.
Johnson, R. E. (2003). Aging and the remembering of text. *Developmental Review*, *23*, 261–346.
Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.
Kemper, S., Greiner, L. H., Marquis, J. G., Prenovost, K., & Mitzner, T. L. (2001). Language decline across the life span: Findings from the Nun Study. *Psychology and Aging*, *16*, 227–239.
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., Thompson, M., & Marquis, J. (2001). Longitudinal change in language production: Effects of aging and dementia on grammatical complexity and propositional content. *Psychology and Aging*, *16*, 600–614.
Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. New York, NY: Cambridge University Press.
Kintsch, W., Welsch, D., Schmalhofer, F., & Zimny, S. (1990). Sentence memory: A theoretical analysis. *Journal of Memory and Language*, *29*, 133–159.
Koustaal, W., & Schacter, D. L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory and Language*, *37*, 555–583.
Krawietz, S. A., Tamplin, A. K., & Radvansky, G. A. (2012). Aging and mind wandering during text comprehension. *Psychology and Aging*, *27*, 951–958.
Kurby, C. A., & Zacks, J. M. (2011). Age differences in the perception of hierarchical structure in events. *Memory & Cognition*, *39*, 75–91.
Kurby, C. A., Asiala, L. K. E., & Mills, S. R. (2014). Aging and the segmentation of narrative film. *Aging*, *Neuropsychology*, *and Cognition*, *21*, 444–463.
Li, S.-C., Lindenberger, U., Hommel, B., Aschersleben, G., Prinz, W., & Baltes, P. B. (2004). Transformations in the couplings among intellectual abilities and constituent cognitive processes across the life span. *Psychological Science*, *15*, 155–163.
Linderberger, U. (2014). Human cognitive aging: Corriger la fortune? *Science*, *346*, 572–578.
Liu, X., Chin, J., Fu, W.-T., Morrow, D. G., & Stine-Morrow, E. A. L. (submitted). Adult age differences in information foraging in an interactive reading environment.
Lysander, K., & Horton, W. S. (2012). Conversational grounding in younger and older adults: The effect of partner visibility and referent abstractness in task-oriented dialogue. *Discourse Processes*, *49*, 29–60.
Magliano, J. P., & Zacks, J. M. (2011). The impact of continuity editing in narrative film on event segmentation. *Cognitive Science*, *35*, 1489–1517.
Magliano, J. P., Miller, & Zwaan, R. A. (2001). Indexing space and time in film under- standing. *Applied Cognitive Psychology*, *15*, 533–545.
Magliano, J., Kopp, K., McNerney, M. W., Radvansky, G. A., & Zacks, J. M. (2012). Aging and perceived event structure as a function of modality. *Aging*, *Neuropsychology*, *and Cognition*, *19*, 264–282.
Manly, J. J., Byrd, D., Touradji, P., Sanchez, D., & Stern, Y. (2004). Literacy and cognitive change among ethnically diverse elders. *International Journal of Psychology*, *39*, 47–60.
Mar, R. A., & Oatley, K. (2008). The function of fiction in the abstraction and simulation of social experience. *Perspectives on Psychological Science*, *3*, 173–192.
Mar, R. A., Oatley, K., & Peterson, J. B. (2009). Exploring the link between reading fiction and empathy: Ruling out individual differences and examining outcomes. *Communications*, *34*, 407–428.
Meyer, B. J. F., & Pollard, C. K. (2006). Applied learning and aging: A closer look at reading. In J. E. Birren & K. W. Schaie (Eds), *Handbook of the psychology of aging* (6th ed., pp. 233–260). New York, NY: Elsevier.
Miller, L. M. S. (2003). The effects of age and domain knowledge on text processing. *Journal of Gerontology: Psychological Sciences*, *58B*, P217–P223.
Miller, L. M. S. (2009). Age differences in the effects of domain knowledge on reading efficiency. *Psychology and Aging*, *24*, 63–74.

Miller, L. M. S., Cohen, J. A., & Wingfield, A. (2006). Contextual knowledge reduces demands on working memory during reading. *Memory & Cognition*, *34*, 1355–1367.
Miller, L. M. S., & Stine-Morrow, E. A. L. (1998). Aging and the effects of knowledge on on-line reading strategies. *Journal of Gerontology: Psychological Sciences*, *53B*, P223–P233.
Miller, L. M. S., Stine-Morrow, E. A. L., Kirkorian, H., & Conroy, M. (2004). Age differences in knowledge-driven reading. *Journal of Educational Psychology*, *96*, 811–821.
Mol, S. E., & Bus, A. G. (2011). To read or not to read: A meta-analysis of print exposure from infancy to early childhood. *Psychological Bulletin*, *137*, 267–296.
Morrow, D. G., Bower, G. H., & Greenspan, S. L. (1989). Updating situation models during comprehension. *Journal of Memory and Language*, *28*, 292–312.
Morrow, D. G., Leirer, V., Altieri, P., & Fitzsimmons, P. (1994). Age differences in updating situation models from narratives. *Language and Cognitive Processes*, *9*, 203–220.
Morrow, D. G., Leirer, V. O., & Altieri, P. A. (1992). Aging, expertise, and narrative processing. *Psychology and Aging*, *7*, 376–388.
Morrow, D. G., Miller, L. M. S., Ridolfo, H. E., Magnor, C., Fischer, U. M., Kokayeff, N. K., & Stine-Morrow, E. A. L. (2009). Expertise and age differences in pilot decision making. *Aging*, *Neuropsychology*, *and Cognition*, *16*, 33–55.
Morrow, D. G., Stine-Morrow, E. A. L., Leirer, V. O., Andrassy, J. M., & Kahn, J. (1997). The role of reader age and focus of attention in creating situation models from narratives. *Journal of Gerontology: Psychological Sciences*, *52B*, P73–P80.
Nell, V. (1988). *Lost in a book: The psychology of reading for pleasure*. New Haven, CT: Yale University Press.
Newtson, D. (1973). Attribution and the unit of perception of ongoing behavior. *Journal of Personality and Social Psychology*, *28*, 28–38.
Newtson, D., & Engquist, G. (1976). The perceptual organization of ongoing behavior. *Journal of Experimental Social Psychology*, *12*, 436–450.
Noh, S. R., & Stine-Morrow, E. A. L. (2009). Age differences in tracking characters during narrative comprehension. *Memory & Cognition*, *37*, 769–778.
Payne, B. R., Gao, X., Noh, S. R., Anderson, C. J., & Stine-Morrow, E. A. L. (2012). The effects of print exposure on sentence processing and memory in older adults: Evidence for efficiency and reserve. *Aging*, *Neuropsychology*, *and Cognition*, *19*, 122–149.
Payne, B. R., Grison, S., Gao, X., Christianson, K., Morrow, D., & Stine-Morrow, E. A. L. (2014). Aging and individual differences in binding during sentence understanding: Evidence from temporary and global syntactic attachment ambiguities. *Cognition*, *130*, 157–173.
Payne, B. R., Gross, A. L., Parisi, J. M., Sisco, S. M., Stine-Morrow, E. A. L., Marsiske, M., & Rebok, G. W. (2014). Modeling longitudinal changes in older adults' memory for spoken discourse: Findings from the ACTIVE cohort. *Memory*, *22*, 990–1001.
Payne, B. R., & Stine-Morrow, E. A. L. (2016). Risk for mild cognitive impairment is associated with semantic integration deficits in sentence comprehension. *Journal of Gerontology: Psychological Sciences*, *71*, 243–253.
Perfetti, C. A., & Hogaboam, T. (1975). Relationship between single word decoding and comprehension skill. *Journal of Educational Psychology*, *67*, 461–469.
Petersson, K. M., Ingvar, M., & Reis, A. (2009). Language and literacy from a cognitive neuroscience perspective. In D. R. Olson & N. Torrance (Eds), *Cambridge handbook of literacy* (pp. 152–181). Cambridge: Cambridge University Press.
Pirolli, P. (2005). Rational analysis of information foraging on the web. *Cognitive Science*, *29*, 343–373.
Price, J. M., & Sanford, A. J. (2012). Reading in healthy aging: The influence of information structuring in sentences. *Psychology and Aging*, *27*, 529–540.
Radvansky, G. A., & Copeland, D. E. (2006). Walking through doorways causes forgetting. *Memory & Cognition*, *34*, 1150–1156.
Radvansky, G. A., & Zacks, J. M. (2014). *Event cognition*. Oxford: Oxford University Press.
Radvansky, G. A., Copeland, D. E., Berish, D. E., & Dijkstra, K. (2003). Aging and situation model updating. *Aging*, *Neuropsychology*, *and Cognition*, *10*, 158–166.
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., & Curiel, J. M. (1998). Narrative comprehension and aging: The fate of completed goal information. *Psychology and Aging*, *13*, 69–79.
Radvansky, G. A., & Dijkstra, K. (2007). Aging and situation model processing. *Psychonomic Bulletin and Review*, *14*, 1027–1042.
Radvansky, G. A., Gerard, L., 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.
Radvansky, G. A., Krawietz, S. A., & Tamplin, A. K. (2011). Walking through doorways causes forgetting: Further explanations. *The Quarterly Journal of Experimental Psychology*, *64*, 1632–1645.
Radvansky, G. A., Pettijohn, K. A., & Kim, J. (2015). Walking through doorways causes forgetting: Younger and older adults. *Psychology and Aging*, *30*, 259–265.
Radvansky, G. A., Tamplin, A. K., & Krawietz, S. A. (2010). Walking through doorways causes forgetting: Environmental integration. *Psychonomic Bulletin & Review*, *17*, 900–904.
Radvansky, G. A., Zwaan, R. A., Curiel, J. M., & Copeland, D. E. (2001). Situation models and aging. *Psychology and Aging*, *16*, 145–160.
Richardson, A. E., Montello, D. R., & Hegarty, M. (1999). Spatial knowledge acquisition from maps and from navigation in real and virtual environments. *Memory & Cognition*, *27*(4), 741–750.
Riecke, B. E., Cunningham, D. W., & Bülthoff, H. H. (2007). Spatial updating in virtual reality: The sufficiency of visual information. *Psychological Research*, *71*(3), 298–313.
Salthouse, T. A. (2010). *Major issues in cognitive aging*. New York, NY: Oxford University Press.
Schacter, D. L., Guerin, S. A., & St. Jacques, P. L. (2011). Memory distortion: An adaptive perspective. *Topics in Cognitive Science*, *15*, 467–474.
Schaie, K. W. (2005). *Developmental influences on adult intelligence: The Seattle Longitudinal Study*. New York, NY: Oxford University Press.
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.
Shake, M. C., Noh, S. R., & Stine-Morrow, E. A. L. (2009). Age differences in learning from text: Evidence for functionally distinct text processing systems. *Applied Cognitive Psychology*, *23*, 561–578.
Shake, M. C., & Stine-Morrow, E. A. L. (2011). Age differences in resolving anaphoric expressions during reading. *Aging*, *Neuropsychology*, *and Cognition*, *18*, 678–707.
Shimamura, A. P., Berry, J. M., Mangels, J. A., Rusting, C. L., & Jurica, P. J. (1995). Memory and cognitive abilities in university professors: Evidence for successful aging. *Psychological Science*, *6*, 271–277.
Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*, 946–958.
Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology*, *66*, 487–518.
Stanovich, K. E., West, R. L., & Harrison, M. R. (1995). Knowledge growth and maintenance across the life span: The role of print exposure. *Developmental Psychology*, *31*, 811–826.
Stine, E. A. L., & Hindman, J. (1994). Age differences in reading time allocation for propositionally dense sentences. *Aging and Cognition*, *1*, 2–16.
Stine, E. A. L., & Wingfield, A. (1988). Memorability functions as an indicator of qualitative age differences in text recall. *Psychology and Aging*, *3*, 179–183.
Stine, E. A. L., & Wingfield, A. (1990a). The assessment of qualitative age differences in discourse processing. In T. M. Hess (Ed.), *Aging and cognition: Knowledge organization and utilization* (pp. 33–92). New York, NY: Elsevier.
Stine, E. A. L., & Wingfield, A. (1990b). How much do working memory deficits contribute to age differences in discourse memory? *European Journal of Cognitive Psychology*, *2*, 289–304.
Stine-Morrow, E. A. L., & Chui, H. (2012). Cognitive resilience in adulthood. In B. Hayslip, Jr. & G. C. Smith (Eds), *Annual Review of Gerontology and Geriatrics* (Vol. 32, pp. 93–114). New York, NY: Springer.
Stine-Morrow, E. A. L., Gagne, D. D., Morrow, D. G., & DeWall, B. H. (2004). Age differences in rereading. *Memory & Cognition*, *32*, 696–710.
Stine-Morrow, E. A. L., Hussey, E. K., & Ng, S. (2015). The potential for literacy to shape lifelong cognitive health. *Policy Insights from the Behavioral and Brain Sciences*, *2*. doi: 10.1177/2372732215600889.

Stine-Morrow, E. A. L., Miller, L. M. S., Gagne, D. D., & Hertzog, C. (2008). Self-regulated reading in adulthood. *Psychology and Aging*, *23*, 131–153.
Stine-Morrow, E. A. L., Miller, L. M. S., & Hertzog, C. (2006). Aging and self-regulated language processing. *Psychological Bulletin*, *132*, 582–606.
Stine-Morrow, E. A. L., Miller, L. M. S., & Leno, R. (2001). Patterns of on-line resource allocation to narrative text by younger and older readers. *Aging*, *Neuropsychology*, *and Cognition*, *8*, 36–53.
Stine-Morrow, E. A. L., Morrow, D. G., & Leno, R. (2002). Aging and the representation of spatial situations in narrative understanding. *Journal of Gerontology: Psychological Sciences*, *57B*, P291–P297.
Stine-Morrow, E. A. L., Payne, B. R., Gao, X., Roberts, B., Kramer, A. F., Morrow, D. G., … Parisi, J. M. (2014). Training versus engagement as paths to cognitive optimization with aging. *Psychology and Aging*, *29*, 891–906.
Thomas, R., & Hasher, L. (2012). Reflections of distraction in memory: Transfer of previous distraction improves recall. *Journal of Experimental Psychology: Learning*, *Memory*, *and Cognition*, *38*, 30–39.
Tolstoy, L. (1869). *War and Peace*. London: Penguin.
Tun, P. A., Wingfield, A., Rosen, M. J., & Blanchard, L. (1998). Response latencies for false memories: Gist-based processes in normal aging. *Psychology and Aging*, *13*, 230–241.
Umanath, S., & Marsh, E. B. (2012). Aging and memorial consequences of catching contradictions with prior knowledge. *Psychology and Aging*, *27*, 1033–1038.
Umanath, S., & Marsh, E. J. (2014). Understanding how prior knowledge influences memory in older adults. *Perspectives on Psychological Science*, *9*, 408–426.
United Nations Department of Economic and Social Affairs Population Division. (2013). *World population ageing 2013*. Retrieved from www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2013.pdf.
van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension.* New York, NY: Academic Press.
Weissman, D. H., Roberts, K. C., Visscher, K. M., & Woldorff, M. G. (2006). The neural bases of momentary lapses in attention. *Nature Neuroscience*, *9*, 971–978.
Wilson, R. S., Bennett, D. A., Gilley, D. W., Beckett, L. A., Barnes, L. L., & Evans, D. A. (2000). Premorbid reading activity and patterns of cognitive decline in Alzheimer Disease. *Archives of Neurology*, *57*, 1718–1723.
Wingfield, A., & Grossman, M. (2006). Language and the aging brain: Patterns of neural compensation revealed by functional brain imaging. *Journal of Neurophysiology*, *96*, 2830–2839.
Wingfield, A., & Lash, A. (in press). Audition and language comprehension in adult aging: Stability in the face of change. In K. W. Schaie & S. L. Willis (Eds), *Handbook of the psychology of aging* (8th ed.). New York, NY: Elsevier.
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: Erlbaum.
Wright, H. H., Capilouto, G. J., Srinivasan, C., & Fergadiotis, G. (2011). Story processing ability in cognitively healthy younger and older adults. *Journal of Speech*, *Language*, *and Hearing Research*, *54*, 900–917.
Wright, H. H., Koutsoftas, A. D., Capilouto, G. J., & Fergadiotis, G. (2014). Global coherence in younger and older adults: Influence of cognitive processes and discourse type. *Aging*, *Neuropsychology*, *and Cognition*, *21*, 174–196.
Zacks, J. M., & Swallow, K. M. (2007). Event segmentation. *Current Directions in Psychological Science*, *16*, 80–84.
Zacks, J. M., Speer, N. K., & Reynolds, J. R. (2009). Segmentation in reading and film comprehension. *Journal of Experimental Psychology: General*, *138*, 307–327.
Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, *123*, 162–185.
Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The construction of situation models in narrative comprehension: An event-indexing model. *Psychological Science*, *6*, 292–297.
Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995). Dimensions of situation model construction in narrative comprehension. *Journal of Experimental Psychology: Learning*, *Memory*, *and Cognition*, *21*, 386–397.