
REVIEW

AGE DIFFERENCES IN LANGUAGE SEGMENTATION

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Reading bears the evolutionary footprint of spoken communication. Prosodic contour in speech helps listeners parse sentences and establish semantic focus. Readers' regulation of input mirrors the segmentation patterns of prosody, such that reading times are longer for words at the ends of syntactic constituents. As reflected in these "micropauses," older readers are often found to segment text into smaller chunks. The mechanisms underlying these micropauses are unclear, with some arguing that they derive from the mental simulation of prosodic contour and others arguing they reflect higher-level language comprehension mechanisms (e.g., conceptual integration, consolidation with existing knowledge, ambiguity resolution) that are common across modality and support the consolidation of the memory representation. The authors review evidence based on reading time and comprehension performance to suggest that (a) age differences in segmentation derive both from age-related declines in working memory, as well as from crystallized ability and knowledge, which have the potential to grow in adulthood, and that (b) shifts in segmentation patterns may be a pathway through which language comprehension is preserved in late life.

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The nature of language comprehension is such that mental representations of meaning and mental simulations of events are constructed from input that unfolds linearly in time. A fundamental problem that theories of language and discourse processing have to solve is how we accomplish this feat in spite of limitations in working memory capacity. Part of the solution to this puzzle is the idea that language is segmented into smaller units for processing (Frazier, Carlson, & Clifton, 2006; Frazier & Fodor, 1978; James, 1890/1950). Listeners use prosodic contour to segment spoken language, which ordinarily provides cues to syntactic units (Watson & Gibson, 2004; Wingfield, 1975). Readers, on the other hand, who self-regulate input by moving the eyes through the text in a series of discrete fixations (Rayner & Pollatsek, 2006), tend to allocate more processing time to words at the ends of syntactic constituents. Interestingly, these timing patterns correspond to the temporal patterning of prosodic contour in speech, such that readers tend to allocate time to points at which a speaker would ordinarily pause.

These micropauses in reading have been interpreted as points for consolidation of the mental representation, leading Just and Carpenter (1980), for example, to coin the term “wrap-up.” According to this Semantic Processing Hypothesis, the time allocated to wrap-up, in part, reflects effort toward computations related to reactivation of prior concepts, conceptual integration, and ambiguity resolution (Daneman & Carpenter, 1983; Haberlandt, Graesser, Schneider, & Kiely, 1986). An alternative view is that the correspondence in temporal patterning between speech and reading merely reflects the reader’s mental simulation of prosody in speech (Hirotani, Frazier, & Rayner, 2006). According to this Dwell Time Hypothesis, then, micropauses may impact interpretation through low-level mechanisms related to parsing, but serve no functional role in higher-order mechanisms related to semantic processing. Note that both views are consistent with the view that these micropauses serve a function in structuring information in memory (Frazier et al., 2006). Importantly, however, the Dwell Time Hypothesis suggests that time allocated to wrap-up does not reflect cognitive workload. This debate is significant for theories of cognitive aging because older adults are often found to produce different temporal patterning in the allocation of reading time across sentences and larger discourses relative to younger adults (Stine-Morrow, Miller, Gagne, & Hertzog, 2008; Stine-Morrow, Miller, & Hertzog, 2006). By the same token, age differences have the potential to inform the theoretical debate on the functional role of wrap-up. In this review, we consider evidence for age differences in segmentation patterns in reading, and the cognitive mechanisms underlying these effects.

FLIGHTS, PERCHINGS, AND REFLECTION

The notion that segmentation is key to understanding how humans make sense of experience dates back at least to James (1890/1950, pp. 243–244). He compared consciousness to the life of a bird, which consisted of “an alternation of flights and perchings.” During the flight, “[t]he rush of thought is . . . headlong”; during the perching, we reflect on the experience of the flight. He viewed the nature of language as emblematic of how we parse experience: “every thought is expressed in a sentence, and every sentence closed by a period. The resting-places are usually occupied by sensorial imaginations of some sort, whose peculiarity is that they can be held before the mind for an indefinite time, and contemplated without changing; the places of flight are filled with thoughts of relations, static or dynamic, that for the most part obtain [when] contemplated in the periods of comparative rest.”

Segmentation in language understanding is among the earliest topics of research in modern psycholinguistics (Fodor & Bever, 1965), and has been studied in both speech comprehension and production (Watson & Gibson, 2004; Wingfield, 1975; Wingfield, Lahar, & Stine, 1989; Wingfield & Stine, 1986; Wingfield, Tun, & Rosen, 1995; Wingfield, Wayland, & Stine, 1992) and reading (Aaronson & Scarborough, 1976, 1977; Green, Mitchell, & Hammond, 1981; Haberlandt & Graesser, 1989a, 1989b; Haberlandt et al., 1986; Stine, 1990). Perhaps in part driven by the development of methodologies that allow for detection of moment-to-moment processes in activation of meaning at ever finer levels of granularity (e.g., eye-tracking, including the visual world paradigm with speech; event-related potentials), the immediacy of incremental change in mental representations as language unfolds is of focal interest in the current zeitgeist of psycholinguistics (Pickering & van Gompel, 2006; Sedivy, Tanenhaus, Chambers, & Carlson, 1999). However, incremental and segmental processes, associated with “flights” and “perchings,” respectively, are not mutually exclusive, and both sorts of processes are needed for the online construction of the mental representation of a text’s meaning. There is considerable evidence not only for the existence of segmental processing, but also for its functional significance in comprehension and memory (consistent with the Semantic Processing Hypothesis), as reflected in offline measures.

For example, the fact that time allocated to wrap-up increases with conceptual load and other sorts of demands that are not inherent to the particular site of the perch (e.g., ambiguity, lack of contextual framing) supports the idea that not all the mental work is completed during the flight in which the representation is incrementally constructed (Stine, 1990; Stine-Morrow et al., 2008). Similar sorts of effects are observed in the

pauses produced in spoken language as well (Watson & Gibson, 2004). Interestingly, there are individual differences in sentence wrap-up that are reliable across time and across different sorts of texts (Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine-Morrow et al., 2008), suggesting that patterns of flights and perches reflect “habits of mind” in reading engagement. Importantly, more time spent in perching, which according to the Semantic Processing Hypothesis, corresponds to more thorough “reflection” on the “flight,” is related to better performance (e.g., memory) based on the text (Miller & Gagne, 2008; Stine-Morrow et al., 2006). The fact that time allocated to wrap-up both increases with conceptual load and is predictive of memory implies that wrap-up reflects, in part, a binding process, in which relationships among concepts are resolved and a cohesive propositional representation of the content in consolidated (Shake, Noh, & Stine-Morrow, 2009).

Older adults most certainly show segmentation in both speech comprehension and reading just as younger adults do, although subtle differences in the nature of the patterns are sometimes observed. Using the spontaneous segmentation paradigm, in which the participant stops the speech stream at liberty for immediate recall, Wingfield et al. (1989) showed that older adults are almost identical to younger adults in segmenting between syntactic constituents, as long as the speech has normal prosodic contour. Without prosody, older adults differentially selected smaller segments and were relatively more likely to segment at inopportune points (and showed relatively poorer recall). When prosodic contour and syntactic structure are put in conflict, older listeners are differentially likely to rely on the prosody for interpretation (Wingfield et al., 1992).

In reading, older adults are often found to be more likely to wrap up at more minor syntactic constituents, suggesting a tendency toward processing language in smaller segments (Miller & Stine-Morrow, 1998; Stine, 1990). Assuming that aging can compromise the ability to bind elements together in memory (Old & Naveh-Benjamin, 2008), one interpretation of this shift in segmentation patterns is that it represents an adaptation toward a more incremental construction of the language representation, so that there are fewer elements to be bound at any one point. Also, although both younger and older readers with larger wrap-up effects show better recall in sentence processing, older readers have to expend more cognitive effort to reach the same levels of recall performance as the young. In other words, when younger and older adults show equivalence in sentence memory (i.e., an offline measure), it is typically preceded by differentially greater allocation of time to wrap-up by the older readers (i.e., online adjustments; e.g., Stine-Morrow et al., 2001). Thus, it appears that older readers can compensate for deficient binding mechanisms to some extent by allocating more effort to this process. On the other hand, older readers can also take

advantage of context to support conceptual binding. For example, the time allocated to wrap-up tends to be reduced in discourse relative to sentence processing and when the context affords a schema for how text elements are related (Sharkey & Sharkey, 1987; Wiley & Rayner, 2000), and (among readers with good memory for what they have read) this effect is larger for older adults than for young (Miller & Stine-Morrow, 1998; also cf. Miller, Cohen, & Wingfield, 2006; Stine-Morrow et al., 2008). Also, for extended discourse, there is a weaker relationship between wrap-up and performance (e.g., Stine-Morrow et al., 2008), consistent with the idea that elaborated discourse affords routes to memory (e.g., schemas, discourse structures, event simulations) that are less dependent on conceptual bindings (cf. Shake et al., 2009).

Collectively, this literature suggests that there is variation in the location of segmentation within the constraints licensed by language structure (i.e., between syntactic constituents) and in the amount of effort allocated to conceptual consolidation at the segmentation site, and that these differences in patterning are related to both individual difference variables and variation in the text. The age differences that have been observed—more frequent segmentation, and differential allocation to segmental processing for good performance—hint at ways in which older readers can maintain excellent comprehension and recall of text in spite of certain declines in processing capacity. In the following section, we consider the mechanisms underlying these effects in more detail.

WHY SEGMENTATION CHANGES WITH AGE

Conceptual Integration Is Resource-Consuming

The idea that older adults segment more often to manage the cognitive load of integration is predicated on the assumption that wrap-up consumes attentional resources and that segmenting more frequently results in a reduction of these demands. This assumption has been directly tested in a couple of different ways. First, consistent with the Dwell Time Hypothesis, it is well known that readers can be induced to segment at particular locations through the manipulation of syntactic structure (Millis & Just, 1994). However, assuming that more frequent wrap-up allows the reader to consolidate the semantic representation in smaller chunks, as argued by the Semantic Processing Hypothesis, manipulations that encourage earlier segmentation (e.g., through prosodic mechanisms) would be expected to produce a savings in effort at segmentation sites downstream, both because there are fewer unbound concepts to integrate and because the

semantic representation would afford a richer context for subsequent integration sites. In two experiments, we (Stine-Morrow, Shake, Miles, Lee, & McConkie, 2010) tested this idea by asking younger and older adults to read short texts of the sort below:

1. After doing her chores Susan wanted the candy her mom had kept hidden in the hall *closet*. Susan looked all over the house for it.
2. After doing her chores Susan wanted the *candy*, but her mom kept it hidden in the closet. Susan looked all over the house for it.
3. After doing her chores Susan wanted the *candy*. Her mom had hidden it in the closet. Susan looked all over the house for it.

Each contains two target words. The later target, T2 (e.g., closet), occurs at a sentence boundary, and is therefore a very typical site for wrap-up. Before that is T1 (e.g., *candy*), which varies in its salience as a point of wrap-up. In (1), T1 is modified by a reduced relative clause and is not marked by punctuation, so that readers are less likely to pause for wrap-up relative to (2) and (3). In (2), T1 is at the end of a subordinate clause, making it a more salient site for wrap-up; and in (3), T1 is at the end of a sentence, an even more salient wrap-up site. Based on reading time measures from both self-paced reading and eye-tracking, both younger and older adults showed systematic increases in reading time at T1 with increases in boundary salience (i.e., (1) < (2) < (3)). Importantly, with increased boundary salience at T1, reading time at T2 decreased for both younger and older adults, thus supporting the idea that early wrap-up can decrease later processing load. Thus, consistent with the Dwell Time Hypothesis, prosodic mechanisms certainly come into play in selection of segmentation sites, but inconsistent with the Dwell Time Hypothesis and as predicted by the Semantic Processing Hypothesis, the mental work that is accomplished at these sites is functionally significant for semantic processing. There would be good reason then for older readers to self-regulate effort to conceptual integration toward more frequent segmentation because it would, in fact, enable them to manage the cognitive load.

Empirical support for wrap-up as a resource-consuming process that is especially taxing for older readers comes from a study making use of the parafoveal preview benefit to index cognitive load (Payne & Stine-Morrow, 2012). When the eyes are fixated on a word, information (mainly abstract orthographic and phonological codes) is available from up to about 15 characters to the right (in languages that are read left to right, as in English). This is called the parafoveal preview, and we typically make use of this information to achieve a fluent reading experience. This can be demonstrated empirically, using an eye-contingent display in which

a target word N is followed by a word $N + 1$ that is masked in the parafovea, but unmasked as soon as the eyes saccade from word N to word $N + 1$. Reading time on word $N + 1$ is slower (by 30–50 ms) when it had been masked in the parafovea relative to when it had not, showing that readers take advantage of this information to start processing words before they are actually fixated. However, this parafoveal preview benefit can be greatly reduced when the word in focus introduces some cognitive demand, such as low-frequency lexical items or syntactic ambiguity (Henderson & Ferreira, 1990). One way to think about this is that as attentional demands of information in the fovea increase, the more narrow attentional focus becomes or the longer it takes to shift covert attention. Using materials similar to those described above, Payne and Stine-Morrow (2012) showed that the parafoveal preview benefit was reduced by sentence wrap-up in (3) and, to a lesser extent, by clause wrap-up in (2), relative to the unmarked boundary in (1). Older readers showed an exaggeration of these effects, such that at sentence boundaries they showed no parafoveal preview benefit at all. These findings support the claim that wrap-up is a cognitively demanding process, especially as language segments contain more semantic content, and particularly so for older readers. The upshot is that there is good reason to believe that the shift toward more frequent segmentation with age is adaptive in reducing integration demands as the reader moves through the text.

The Roles of Working Memory and Crystallized Abilities on Segmental Processes

Recall that another way in which segmentation seems to vary with age is in the amount of time allocated to wrap-up that is required to achieve good memory performance. Older readers who show good sentence memory relative to the young seem to accomplish this by allocating differentially more effort to wrap-up. On the other hand, older adults sometimes show reduced allocation to wrap-up and subsequently show poor memory. This variation in allocation to wrap-up processes is curious. Based on a distributional analysis of reading times, which enables the isolation of differential age effects in wrap-up in central tendency, spread, and the tail of the distribution, we (Payne & Stine-Morrow, 2014) recently showed that age-related differences in both verbal ability and working memory contribute to wrap-up time, but verbal ability impacts the central tendency, whereas working memory had stronger effects on the tail of the distribution, such that lower span adults show a larger proportion of extreme reading times at sentence boundaries (cf. Staub & Benatar, 2013).

Verbal ability and habitual engagement with print (as measured by print exposure) appear to contribute to age differences in conceptual integration, perhaps in ways that are counterintuitive. Relatively small age differences in language comprehension and memory tend to be found among samples with high levels of education and good verbal ability (Hultsch & Dixon, 1984; Johnson, 2003; Meyer & Rice, 1989). Such advantages may be in part due to the way in which education and verbal ability (which are correlated) engender habits of regulating segmental processes. The contrast between reading and speech domains is interesting: although verbal ability moderates longitudinal changes in memory for written text (Lewis & Zelinski, 2010), this is not the case in memory for speech, in which rate of input cannot be controlled (Payne, Gross, Parisi, Sisco, Stine-Morrow, Marsiske, & Rebok, 2014), suggesting that the advantages of verbal ability derive from self-regulation.

Individuals with higher levels of vocabulary tend to allocate less effort to word-level decoding processes (as measured by the effects of word length and word frequency on reading time) and more time to wrap-up (Stine-Morrow et al., 2008). Controlling for vocabulary, print exposure seems to have very similar effects (Payne, Gao, Noh, Anderson, & Stine-Morrow, 2012). Such evidence is consistent with the notion that reading is a procedural skill that is reinforced by practice (Perfetti, 1989), a point to which we will return in a bit. Older adults who habitually engage in literacy practices experience advantages in rapid word recognition and lexical access, as well as in well-developed mental habits of segmentation and allocation to conceptual integration.

The effects of verbal skill versus working memory capacity on segmentation can be dissociated in how readers interpret certain types of ambiguity. Consider the following sentences:

1. The son of the princess who scratched himself in public was embarrassed.
2. The son of the princess who scratched herself in public was embarrassed.
3. The maid of the princess who scratched herself in public was embarrassed.

In (4) and (5), there is a temporary ambiguity that is resolved at the reflexive pronoun, which clarifies whether it was the son who scratched (i.e., a high attachment in which the reflexive pronoun refers to the head noun *son*) or the princess who scratched (i.e., a low attachment in which the reflexive pronoun refers to the modifying phrase *princess*). In (6), on the other hand, the ambiguity is never actually resolved. Generally, readers interpret such sentence without any conscious awareness of the

problem, but in English, we have a slight bias to prefer low attachments, which occur more frequently in the language. This is evidenced in slightly longer reading times at the reflexive pronoun *himself* in (4), and the tendency to interpret (6) as a low attachment (i.e., the princess scratched). Interestingly, individuals with relatively low working memory spans show a greater preference for high attachments (Swets, Desmet, Hambrick, & Ferreira, 2007). The account of this phenomenon is that low-span readers segment the sentence earlier (e.g., after *princess* rather than *public*). This early segmentation strategy, which engenders conceptual consolidation of the phrase, “*the son of the princess*,” increases the prominence of the head noun “*son*” as an attachment site.

Payne, Grison, Gao, Christianson, Morrow, and Stine-Morrow (2014) examined both reading time and comprehension in an age-diverse sample of adults using this paradigm. Even though working memory decreased with age in this sample, age increased the preference for low (not high) attachments, as measured by relatively more time spent on the reflexive pronoun in (4) than in (5), as well as a comprehension advantage for (5) over (4). In other words, contrary to the expectation that age-related declines in working memory would lead to early segmentation and therefore late attachment, older readers were more likely to initially interpret the sentence so as to be consistent with the attachment frequency in the language. A more fine-grained analysis showed that this age-related increase in the preference for low attachments could be accounted for by older adults’ relatively greater print exposure. Thus, the age-related growth of verbal experience trumped the effects of working memory declines (cf. also Payne et al. (2012) for an example of such effects in text memory).¹ On the other hand, controlling for print exposure, older adults with low working memory spans did show evidence of the expected high attachment. Interestingly, individual differences in the interpretation of the globally ambiguous sentences (6) patterned with the preferences for high or low attachments, as measured by comprehension errors for (4) and (5), such that the more errors a reader made for high attachments (4), the greater the probability of interpreting the global ambiguity as a low attachment. This is interesting because this case, in which the language does not license a particular interpretation, implies that readers have habitual segmentation patterns (shaped in part by both working memory and crystallized ability) that impact comprehension.

¹This study illustrates the importance of considering the role of literacy experience in studies of aging and language processing. Given that high attachments introduce long-distance dependencies, one might have easily interpreted older adults’ preference for low attachments as an issue of memory load. With a measure of print exposure, however, we were able to get a more accurate picture of the role of experiential factors in how prosodic phrasing impacts segmentation (cf. Swets et al., 2007).

The Role of Domain Knowledge on Segmental Processing

Another factor that may contribute to segmentation and allocation to conceptual integration is domain-related knowledge. Generally, knowledge increases the time allocated to wrap-up (Miller, 2001, 2003; Miller, Stine-Morrow, Kirkorian, & Conroy, 2004). This is interesting in suggesting that the integration processes at wrap-up do not simply involve consolidating the representation of what is given directly by the text. Rather, when an individual reads a text, existing knowledge structures are accessed, so that there is essentially more information that must be integrated. As a result, knowledge-driven reading produces a representation that is more conceptually rich. Consistent with this idea, even though experts reading new information in their domain of expertise allocate more time to conceptual integration, they are also more efficient in encoding new ideas (Miller, 2009); in other words, they learn more information per unit time invested in wrap-up.

Importantly, there is evidence that domain knowledge and verbal ability (as measured by vocabulary) have independent effects on consolidation. Chin et al. (in press) showed that whereas individuals with relatively higher levels of knowledge about cardiovascular health allocated more time to clausal wrap-up in health texts (but not in domain-general texts), those who were higher in verbal ability showed enhanced conceptual integration for both types of text. Chin et al. argued that such findings support a “procedural-declarative model” of wrap-up, in which verbal skills support the procedural skill of segmentation, whereas domain knowledge promotes higher levels of conceptual integration through knowledge activation.

Evidence for a Causal Relationship Between Segmental Processing and Performance

Largely, the literature showing effects of wrap-up on performance is correlational, raising the concern that it is simply an epiphenomenon and not at all causally related to performance as argued above. A number of studies have introduced manipulations that impact the extent of wrap-up and subsequent performance, supporting the causal claims. For example, our group (Gao, Levinthal, & Stine-Morrow, 2012; Gao, Noh, Eskew, & Stine-Morrow, 2011) has conducted a series of studies, in which younger and older adults read sentences embedded in varying levels of dynamic visual noise to examine the effects of such a challenge in decoding the surface form on semantic processing. Participants self-paced the text presentation as word-by-word reading times were measured. According to the

Effortfulness Hypothesis (Wingfield, Tun, & McCoy, 2005), degradation of the surface form can evoke an attentional cost that reduces the resources available for deeper processes that support memory. Accordingly, it was expected that reading times would be differentially increased with noise for longer and less frequent words, reflecting the challenge of word recognition processes, and that such a distraction would reduce wrap-up. This is exactly the pattern of findings obtained with recall performance patterning with decreased wrap-up. Importantly, the wrap-up of older readers was impacted at relatively lower levels of noise, suggesting that age-related sensory declines may make older adults relatively more sensitive to lack of fidelity in the surface form. The noise manipulation, which decreased wrap-up, which in turn decreased recall, makes a stronger case that wrap-up reflects processes underpinning the consolidation of the language representation.

In contrast to purely correlational evidence for a relationship between wrap-up and offline performance at retrieval are studies that introduce a manipulation to promote conceptual integration, which then results in improved performance. Adult readers who are provided with explicit strategy instruction in conceptual integration have been shown to increase reading time allocation as a function of new concepts relative to an expectancy control group (Stine-Morrow, Noh, & Shake, 2010). Even though the groups of younger, middle-aged, and older adults in this study all showed favorable changes in reading time patterns with training, the age groups varied in the nature of these effects. Younger readers tended to show the strongest effects in increased sentence wrap-up, whereas older readers tended to show the strongest effects in allocating processing time to new concepts as they occurred, and middle-aged adults were somewhat in the middle, responding somewhat at both sites. Although the groups that received conceptual integration training did not show differential improvement in memory performance as a whole, there were significant correlations between changes in conceptual integration and changes in recall. Also, Miller and West (2009) showed that older adults who were provided positive feedback on their performance in reading texts to solve problems showed an increase in wrap-up across trials. This was only among those with initially strong control beliefs, suggesting that feedback may be differentially effective for different types of people. From an applied point of view, these findings suggest that allocation to wrap-up is a malleable factor that is responsive to changes in task conditions. From the point of view of understanding mechanism, these findings also support a causal link between wrap-up as a conceptual integration process and language memory.

Segmentation as a Procedural Skill Versus Effortful Allocation to Integration

Finally, evidence for the distinction between segmentation as a procedural skill (related to prosodic mechanisms) versus a resource-demanding conceptual integration process (operating on residual activation of concepts held in working memory) comes from a recent study examining wrap-up among individuals with psychometrically defined mild cognitive impairment (Payne & Stine-Morrow, in press). In this study, a sample of 439 older adult participants who were administered a comprehensive psychometric battery were categorized into three groups based on neuropsychological performance (Cook et al., 2013). Those in the amnesic mild cognitive impairment (aMCI) group were those who had particular difficulty with episodic memory tasks (scoring at least 1 *SD* below the mean in memory performance). Those in the nonamnesic MCI (nMCI) group were those who showed relative deficits in the nonmemory domain (scoring at least 1 *SD* below the mean in verbal ability, speed, reasoning, and/or visual-spatial processing). Those in the unimpaired controls scored better than 1 *SD* below the mean in all domains. All groups showed at least some evidence of segmentation, with time allocation to words at sentence boundaries significantly greater than to other words in the sentence. Both MCI groups showed less extensive time allocation to wrap-up, but did not differ from each other in this regard. The important difference among the groups was in the extent to which wrap-up was predictive of subsequent memory performance. As seen in Figure 1, the unimpaired individuals in the right panel showed the well-replicated robust relationship between time allocation to sentence wrap-up and recall performance. Even though the nMCI group showed somewhat less allocation to wrap-up, their allocation of effort to this process was effective in improving recall to the same degree as the unimpaired controls. Those in the aMCI group, however, not only allocated less time, but the allocation of this effort was not effective in improving memory. The fact that the aMCI group still showed segmentation (in spite of its lack of effectiveness) is consistent with the idea that segmentation itself is a procedural skill that is resistant to cognitive declines. The computations at sentence wrap-up require that information from the sentence be retained in working memory for consolidation; presumably, when memory declines are significant, this information fades too quickly to be consolidated into a coherent representation that supports retrieval.

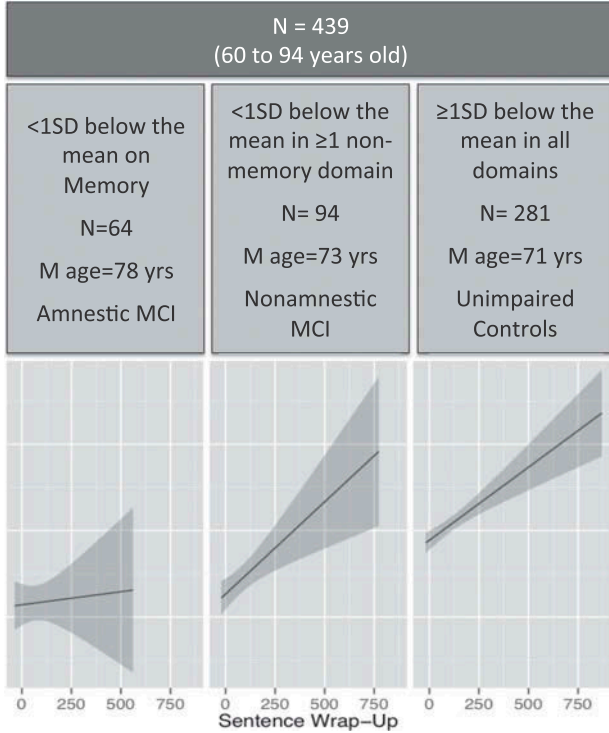


Figure 1. Recall performance as a function of time allocation to sentence wrap-up (in ms, controlling for word length, frequency, and new concepts) for older adults with cognitive profiles for amnesic MCI (left), nonamnesic MCI (middle), or relative cognitive health (right). Adapted from Payne, B. R., & Stine-Morrow, E. A. L. (in press). Risk for mild cognitive impairment is associated with semantic integration deficits in sentence comprehension. *Journal of Gerontology: Psychological Sciences*.

CONCLUSIONS

Reading is a ubiquitous activity that is taken quite for granted by those who can do it effortlessly. However, reading is without a question a highly complex cognitive activity and arguably one of the most complicated skills that an individual can learn. In fractions of a second, the language comprehension system enacts a massive number of computations at multiple levels of representation to ultimately form message-level meaning representations from sensory input. These computations entail not only the immediate and incremental processing of language input in real time, but also elaborative

segmental processing, in which concepts within- and between-sentence constituents are consolidated into an incomplete and ever-evolving semantic representation. Segmentation is a procedural skill that is developed as a consequence of lifelong literacy habits and can be well maintained into late life. To some extent, language structure provides cues for segmentation, but the hierarchical structure of language also allows and/or requires individual self-regulation. Conceptual integration, a set of processes in which concepts from the text and/or the knowledge base are (re)activated and bound into a coherent representation of meaning, may be conducted to varying degrees. In contrast to segmentation itself, conceptual integration is highly demanding of cognitive resources. The extent to which these demands are taken up by the reader can depend on abilities of the reader, the demands of the text environment, and motivational variables. The development of strong literacy skills through adulthood can support segmental processing in late life, so that the qualitative patterns of segmentation show little change with aging in the sense that segmentation strategies honor the constraints given by language structure. However, aging appears to bring variation in how attentional resources are marshaled across these sites. Furthermore, the effectiveness of this allocation in creating mental representations can arise from individual and age-related differences in processing capacity, literacy skill, and knowledge. Such self-regulation can lead to very good comprehension and memory for text into later adulthood.

Important questions about segmentation and its function in language processing remain, especially with respect to its interface with cognitive aging. As a procedural skill, segmentation derives from both spoken language capacities and literacy experience that engenders engagement with print that in some ways that mirror spoken language. Future research should seek to understand mechanisms across these modalities and how they change with age for individuals with varying exposure to print (e.g., analogies between reading and spoken production). Given the opportunity for strategic regulation (“reflection”) offered by differential segmentation patterns, we also need to know the consequences for how memory representations created (e.g., whether conceptual binding and knowledge activation processes are substantially changed with variation in segmentation patterns).

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