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Self-Regulated Reading in Adulthood

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Abstract

Younger and older adults read a series of passages of three different genres for an immediate assessment of text memory (measured by recall and true-false questions). Word-by-word reading times were measured and decomposed into components reflecting resource allocation to particular linguistic processes using regression. Allocation to word and textbase processes showed some consistency across the three text types and was predictive of memory performance. Older adults allocated more time to word and textbase processes than the young did, but showed enhanced contextual facilitation. Structural equation modeling showed that greater resource allocation to word processes was required among readers with relatively low working memory spans and poorer verbal ability, and that greater resource allocation to textbase processes was engendered by higher verbal ability. Results are discussed in terms of a model of self-regulated language processing suggesting that older readers may compensate for processing deficiencies through greater reliance on discourse context and on increases in resource allocation that are enabled through growth in crystallized ability.

Keywords

reading; language processing; text memory; resource allocation; self-regulated cognition

The way in which readers encode text is of long-standing interest in psycholinguistics (e.g., Aaronson & Scarborough, 1976; Claus & Kelter, 2006; Haberlandt, Graesser, Schneider, & Kiely, 1986; Just & Carpenter, 1980; Zwaan, Magliano, & Graesser, 1995). The possibility that aging may bring changes in the way in which text is processed (e.g., Kemper & Liu, 2007; Kemper & McDowd, 2006; Noh et al., 2007; Radvansky, Zwaan, Curiel, & Copeland, 2001; Stine, 1990; Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine-Morrow, Gagne, Morrow, & DeWall, 2004; Stine-Morrow, Shake, Miles, & Noh, 2006) is interesting and important, in part, because reading gives rise to a range of experiences that can contribute to expanding knowledge, altering perspective, and regulating affect (Smith, 1998). This issue is also interesting because relative to their younger counterparts, older readers often show poorer comprehension and memory for text (e.g., Johnson, 2003; Kemper & Liu, 2007; Meyer & Pollard, 2006; Thornton & Light, 2006; Wingfield & Stine-Morrow, 2000). This is surprising

⁷We note that these recall groups did not differ in our composite measure of speed, $F(1,214) < 1$; however, those with relatively higher recall were also higher in verbal ability, $F(1,214) = 13.19$, $p < .001$, and marginally higher in working memory, $F(1,213) = 3.37$, $p < .068$. None of the Age by Recall Group interactions were reliable, $F < 1$

to some because verbal abilities and language-based processes typically show resilience into later life relative to nonverbal tasks (e.g., Baltes, 1997; Baltes, Staudinger, & Lindenberger, 1999). However, unlike the literature on more conventional laboratory tasks of explicit memory, text recall does not consistently generate age deficits (Hultsch & Dixon, 1984), showing considerable heterogeneity in effect size (Johnson, 2003). One source of variability that is often neglected is individual differences in the way in which readers initiate and regulate processing as they engage text. Given the importance of effective language processing to everyday experiences and competencies in adult life, it is important on both a theoretical and a practical level to understand how the cognitive mechanisms underlying language processing change with age and how their operation is moderated by other factors. In fact, text processing is not a monolithic skill, but rather depends upon the coordinated execution of an array of processes that tap into multiple abilities. For individuals to understand and remember what they read, cognitive resources must be allocated to these processes so that the linguistic and pragmatic representation of the text can be constructed (Stine-Morrow, Miller, & Hertzog, 2006). In this paper we report a study examining the nature of this allocation policy, considering the manner in which it is regulated, its contextual sensitivity, its status as an individual difference, its relationship to ability, and its contribution to text memory performance.

What Readers “Have”

The argument that individual differences in language comprehension and memory ultimately reside in individual differences in more basic component abilities has been in the literature for some time (e.g., Hunt, 1975; Daneman & Carpenter, 1980). Effective readers are faster at categorical access, orthographic decoding, and lexical decisions (Bell & Perfetti, 1994; Hunt, 1975). They have better vocabularies (Meyer & Rice, 1989) and greater working memory (WM) spans (Daneman & Merikle, 1996). So the dominant approach to understanding age differences in language performance has been to account for them in terms of age differences in such component abilities. For example, Hultsch, Hertzog, and Dixon (1990) used regression analysis to show that age differences in text memory could be almost completely accounted for in terms of verbal speed and verbal WM (see also Hultsch, Hertzog, Dixon, & Small, 1998). Using structural equation modeling, van der Linden et al. (1999) concluded that the best-fitting model to account for age variance in language performance (a composite of memory and comprehension) was one in which WM mediated the relationship between age and language performance and in which the shared variance between age and WM could in turn be explained by speed and inhibition (see also Kwong See & Ryan, 1995; Hultsch et al., 1998; Norman et al., 1992; Stine & Wingfield, 1987, 1990; Zabracky & Moore, 1994). An even stronger case for the cause of age differences in language performance ultimately residing in underlying abilities comes from longitudinal studies in which individual differences in change in particular abilities are correlated with longitudinal change in language performance (e.g., Hertzog, Dixon, Hultsch, & MacDonald, 2003).

Meyer and Rice (1983) have argued that age differences in text memory are most likely to appear when samples are lower in verbal ability, or when age differences in verbal ability favor the young (see also Johnson's (2003) meta-analysis). A possible implication of these findings is that age-graded increases in vocabulary and crystallized abilities can, to some extent, offset declines in text memory. For example, Stine-Morrow, Loveless, and Soederberg (1996) showed in a sample in which there was age-equivalence in text memory for short expository passages that age became a significant negative predictor of performance when vocabulary was partialled out.

Collectively, the evidence suggests that age differences in text memory are attributable in part to processing mechanisms that contribute to memory deficits more generally. It seems likely that WM deficits (rooted in speed or inhibition) compromise older readers' capacity to

construct a distinctive and elaborated text representation that would guide performance at retrieval. Enhanced verbal ability that may afford an advantage in terms of knowledge about content and discourse structures, may to some extent offset these deficits. Little is known about how these relationships change with movement from early to later old age. Vocabulary may be substantially preserved, but declines in processing speed, episodic memory, and fluency accelerate (Singer, Verhaeghen, Ghisletta, Linderberger, & Baltes, 2003; Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992). Adults over the age of 80 are less responsive to memory training than those less than 80 years of age (Singer, Lindenberger, & Baltes, 2003), suggesting that the biological entailments of senescence may limit plasticity, and so perhaps, the ability to learn from text.

What Readers “Do”

It is generally accepted that the construction of meaning from text depends on an array of computations that transform the orthographic code to representations of the surface form, the textbase, and the discourse (e.g., Graesser, Millis, & Zwaan, 1997; Kintsch, 1988, 1998). At the *surface level*, the meaning(s) of individual words as well as the syntactic form of the text are represented. This level of representation rests on computations to decode printed symbols into lexical units (words), to access word meaning(s), and to parse the discourse into syntactically coherent segments. The *textbase* is a representation of the meaning of the text as given. This is typically conceptualized as an organized set of idea units, or propositions, that define interrelationships of concepts described in the text. Processes that give rise to the textbase include the instantiation of word meanings as particularized concepts in the text and the integration of concepts to yield the semantic representation. At the *discourse level* are represented structural properties of the discourse (e.g., narrative schema; contrastive vs. temporal organization in expositions; Mandler & Johnson, 1977; Britton, 1994), as well as the *situation model*, a representation of the implied perceptual qualities of the situation (Barsalou, 1999; Morrow, Greenspan, & Bower, 1989).

Evidence for this general conceptualization can be found in an array of methodological paradigms that assess memory performance, reading time, and probe accuracy (see Stine-Morrow et al. (2006) for a review). Important for our purposes here is that evidence for many of these component processes can be found in patterns of time allocation for readers engaged in text (e.g., Aaronson & Scarborough, 1976; Daneman & Carpenter, 1983; Haberlandt et al., 1986; Just & Carpenter, 1980; Miller, Stine-Morrow, Kirkorian, & Conroy, 2004; Morrow et al., 1989; Stine-Morrow et al., 2004; Stine-Morrow, Miller, & Leno, 2001; Stine-Morrow, Morrow, & Leno, 2002). Readers spend more time on longer words and low-frequency words, for orthographic decoding and lexical access, respectively. Controlling for these factors, they spend extra time on words that introduce new concepts into the text to instantiate these concepts in the discourse context, and to texts that express more ideas, for propositional encoding and organization. Evidence for conceptual integration during reading is well replicated with the phenomenon of “wrap-up,” an increase in reading time at the ends of syntactic constituents, the magnitude of which increases with the processing demands of the segment as a whole (e.g., more new information concepts, ambiguity). Readers increase their reading speed through a text, facilitated by the representations of the situation and discourse structures constructed early in the text, and decrease their reading speed when a new topic is introduced. When events or objects are mentioned in the text that are spatially or temporally distant from the here-now point of the protagonist, readers slow down to update the situation model.

This array of computational demands is measured collectively in the “resource allocation” approach (e.g., Graesser, 1981), in which reading time for naturalistic or loosely constrained text is measured. Regression analysis of text variables onto unit reading time (e.g., for the word or sentence) is used to partition reading times into attentional resources allocated to a

corresponding array of computations. Doing this for each individual enables the researcher to model how individual readers engage resources for the simultaneous demands of text processing (Lorch & Myers, 1990). While allocation is to some extent stimulus-driven, shifts in time allocation in response to task demands (e.g., instructions or reader goals (Aaronson & Ferres, 1984; Stine-Morrow & Miller, 1999; Stine-Morrow, Shake et al., 2006), rereading (Millis et al., 1998; Stine-Morrow et al., 2004), memory load (Carpenter & Just, 1989; Smiler, Gagne, & Stine-Morrow, 2003), the availability of domain knowledge (Miller, 2001, 2003)) suggests that readers regulate processing so that linguistic computations may be conducted in a more or less complete manner, depending on task conditions. The pattern of coefficients representing the way in which readers allocate their attention during reading shows considerable interindividual variability and (under comparable task demands) reliability across time (Stine-Morrow, Milinder et al., 2001), and is related to reading outcomes (e.g., Miller & Stine-Morrow, 1998; Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997; Stine, 1990; Stine-Morrow, Milinder et al., 2001; Stine-Morrow, Miller et al., 2001; Stine-Morrow, Morrow et al., 2002).

Older readers are sometimes found to show reduced levels of resource allocation and deficits in text memory (Stine, 1990; Stine et al., 1995). When older readers show comparable or superior memory performance to the young, they often appear to have accomplished this feat by exaggerated allocation to textbase features or differential allocation to discourse level features (e.g., Stine-Morrow et al., 2004; Stine-Morrow, Milinder et al., 2001; Stine-Morrow, Miller et al., 2001), suggesting that age differences in language processing may well depend on how reading is self-regulated.

A Model of Self-Regulated Language Processing

There is growing recognition that there is variability in how thoroughly linguistic computations are completed. For example, Ferreira, Christianson, and colleagues (Christianson, Hollingsworth, Halliwell, & Ferreira, 2001; Ferreira, Bailey, & Ferraro, 2002) have argued that syntactic parsing may not yield a single veridical representation of sentence structure, but rather may produce a “good enough” representation that suffices in the ordinary course of communication. Another variation on this idea is the “standard of coherence” described by van den Broek and colleagues (e.g., van den Broek, Lorch, Linderhold, & Gustafson, 2001; van den Broek, Rapp, & Kendeou, 2005). For example, van den Broek et al. (2001) showed that adults reading under instructions to study for a subsequent test generated more explanatory and predictive inferences in think-aloud protocols than when reading for pleasure (and not surprisingly, also showed better recall). Van den Broek and colleagues account for these findings in terms of the different “standards of coherence” engendered by the instructional conditions, which act to shift the criterion for what is “good enough.” In other words, as Sanford and Garrod (1994) have suggested, “coherence does not seem to be a property of text; rather, ... coherence occurs in the mind of the reader” (p. 701). We amend this assertion by adding that the reader makes an implicit choice about how thoroughly to establish that coherence.

Recognition of the variability in the way the text representation is constructed leads to questions such as, what is the architecture of the system that defines how processing tasks are distinguished, and what are the heuristics by which resources are distributed to different processing components? We have developed a model of Self-Regulated Language Processing (SRLP) in an attempt to address these issues (Stine-Morrow et al., 2006). In this model, self-regulation of how effort is distributed to various linguistic computations is conceptualized as a discrepancy reduction process governed by a set of three negative feedback loops (Carver & Scheier, 2000) that regulate construction of word-level, textbase, and discourse-level representations. Resource allocation to these computations contributes to an elaborated and distinctive representation that, in turn, gives rise to a range of phenomenological experiences

in reading, as well as to performance. The fidelity of the current representation within each domain of function (word, textbase, discourse) is monitored relative to a standard of completeness or coherence. If the comparison process reveals that the representation does not meet the standard, more effort is allocated to the computations needed to sharpen the representation at that level. Note that rather than a unitary “standard of coherence” (e.g., van den Broek et al., 2001), the model suggests that there is a set of reference values that can vary independently.

The SRLP model suggests that while this architecture is fundamentally preserved with aging, there are subtle changes arising from age-graded declines in processing capacity, as well as age-related growth in knowledge and crystallized abilities. The model makes four claims about age-related change in language processing (p. 591). First, computational efficiency declines with age (as a consequence of declines in speed of processing, WM, and/or inhibitory function) so that more effort (measured as time allocation) is required to achieve the same ends (e.g., Hartley et al., 1994; Stine & Hindman, 1994; Stine-Morrow, Milinder et al., 2001). Second, because the equivalent amount of effort allocated is likely to produce a slower rate of learning among older readers, this reduction in processing efficiency (i.e., the rate of information uptake) is likely to reduce perseverance (see Metcalfe & Kornell, 2005), especially for the textbase representation, which is highly demanding of cognitive resources for construction relative to the other two (e.g., Jefferies, Lambon Ralph, & Baddeley, 2004). Third, the potential for expanded knowledge provides an alternative route for constructing the language representation (Stine-Morrow et al., 2004). These changes collectively make it more likely that older readers will rely on knowledge-based processing and contextual constraints in interpreting text (e.g., Beier & Ackerman, 2005; Miller, Cohen, & Wingfield, 2006; Miller & Stine-Morrow, 1998; Miller, Stine-Morrow et al., 2004). Finally, there is a regulatory shift toward a relatively heightened value for discourse-level coherence, in part, afforded by the affective experience engendered at this level (Isaacowitz, Charles, & Carstensen, 2000; Carstensen & Turk-Charles, 1994).

The Focus of the Current Study

At the broadest level, our goals in the current study were to explore certain implications of this SRLP model, in particular, the consistency and contextual sensitivity of the allocation policy, as well as its relationship to individual differences in relevant cognitive abilities (e.g., WM, verbal ability) and to performance. We examined the allocation policy across different sorts of texts (individual sentences, narratives, expository passages) in the same individuals for whom we had a comprehensive battery of ability measures. Our sample of adults was drawn from a wide age range to allow us to examine cross-sectional differences in resource allocation and its consequences for performance within the older group (in addition to the more conventional young-old comparison). We, in fact, know very little about how language processing develops through later adulthood. The acceleration of declines in later old age may well impact how readers approach text. For example, McGinnis and colleagues (McGinnis, submitted; McGinnis, Goss, Tessner, & Zelinski, submitted) have suggested that inferences generated in encountering novel words are more generalized among the oldest old, so that the semantic representation created from the text may be impoverished. In the study reported here, a wide age range within the elderly sample allowed us to examine age differences in patterns of resource allocation within the older group, which as far as we know, has not been done before.

Our analytic approach was to decompose reading times for each individual (Lorch & Myers, 1990) using the variables in Table 1. Details of this coding system are presented in the Method section, but at this point, suffice it to say that this array of variables allowed us to operationalize time allocation to the word and textbase computations that were common to all three types of

text, as well as selected processes associated with construction of the discourse level representation for narratives and expository texts. We analyzed the resulting coefficients in a way so as to target selected theoretical questions (as described below).¹

(a) Is resource allocation to lexical and textbase processing reduced by discourse context, and is this facilitation enhanced for older readers?

Even though we can conceptualize the array of individual computations as distinct from one another in giving rise to the experience of meaning from print, they work interactively. The best demonstrations of this principle are the effects of sentence context on lexical processing, in which facilitation has been shown in latency for lexical decisions (e.g., Simpson, 1981), gaze duration in reading time (e.g., Rayner & Well, 1996; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006), and word recognition accuracy (e.g., Speranza et al., 2000). One might expect that the availability of discourse context would facilitate the construction of the textbase (just as the availability of a textbase representation facilitates surface processing). Evidence for discourse-based facilitation would be seen in reduced coefficients associated with textbase processing in discourse processing relative to those in sentence processing. There has been surprisingly little research on such discourse-textbase interactions (Sharkey & Sharkey, 1987; Miller & Stine-Morrow, 1998; Wiley & Rayner, 2000), prompting us in the current study to examine the sensitivity of textbase allocation to discourse context and to assess whether these effects might be exaggerated with age (Wingfield & Stine-Morrow, 2000; Stine-Morrow et al., 2006).

(b) Does the allocation policy show consistency across type of text?

Rank-order stability in word and textbase allocation has been demonstrated for sentence processing across a one-month interval (Stine-Morrow, Milinder et al., 2001), but the novel question here was whether individual differences in the allocation to word and textbase computations are stable as readers move from one genre of text to another. If this were the case, it would provide evidence that the allocation policy represents a “habit of mind” that may engender individual differences in the text representation that is constructed.

(c) Does self-regulation of the allocation policy operate at the level of the particular language computation, or is there a simpler heuristic that honors the distinctions among word, textbase, and discourse-level processing?

At one extreme, we might speculate that the outcome of every single computation is monitored and resources are allocated until it is complete (or “good enough” relative to the reference value). If that were the case, computations would be conducted independently of one another such that there should be little or no correlation among allocation coefficients. How one allocates time to orthographic decoding, for example, would be completely unrelated to how one allocates time to lexical access or conceptual instantiation or construction of an expository structure. At the other extreme, a unitary standard of coherence model (van den Broek et al., 2001) would suggest that the array of computations is monitored and regulated as a whole, so that individual differences will reside in how much time is allocated to the array of computations as a whole – so that all allocation coefficients will be highly intercorrelated. In a factor analysis, for example, allocation coefficients would load on a single general factor. Such a pattern would indicate that individuals who process text more thoroughly simply put more resources into a holistic compiled “language processing” module. This monolithic model

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has some appeal. Under the assumption that monitoring and self-regulation is resource-consuming (e.g., Thiede & Dunlosky, 1999), the system would gain some efficiency by allocating resources uniformly to all computations until the criterion for understanding is met. The disadvantage with such an algorithm, of course, is that if there is intraindividual variability in efficiency among particular computations, the allocation of resources would not be targeted to where they are needed the most.

There are two intermediate possibilities. One is that allocation could be peculiar to a genre so that some readers allocate more effort to narratives, others to expository, and so forth. If this were the case, allocation factors would align with different types of text. The final possibility, proposed by the SRLP model (p. 588), is that language is monitored and regulated according to functions defined by level of analysis (word, textbase, discourse). There are numerous examples in the literature of conditions that dissociate these different levels of processing (e.g., Millis et al., 1998; Schmalhofer & Glavanov, 1986; Radvansky et al., 2001; Stine-Morrow et al., 2004) suggesting that these sets of computations are psychologically distinct.² In the current study, we empirically examined the dissociation among these processing domains in terms of regulatory control. The SRLP model would suggest that allocation coefficients for word-level processes (regardless of genre) should load on one factor; coefficients for textbase allocation, on another; and allocation to discourse features on another.

(d) Do individual differences in abilities contribute to the development of an allocation policy, and if so, how do ability and allocation policy jointly contribute to text performance?

The larger question here is how the allocation policy is situated within the cognitive system as a whole. Given that both abilities (Meyer & Rice, 1989; Daneman & Merikle, 1996) and the allocation policy (Stine, 1990; Stine-Morrow et al., 2001; Stine-Morrow, Shake et al., 2006) are related to language performance, one might wonder whether the ability-performance relationship is mediated (or partially mediated) by the allocation policy, though one could conceptualize two very different scenarios. The efficiency assumption of the SRLP model suggests that the allocation policy would be compensatory in nature so that those with relatively lower levels of abilities over-allocate to achieve the same ends as those with relatively good abilities (suggesting a negative correlation between abilities and resource allocation). On the other hand, resource allocation may be “fueled” by endogenous abilities such that it is those with higher levels of abilities who recruit and manage cognitive resources effectively (suggesting a positive relationship between abilities and allocation). Interestingly, at this point there is little evidence at all that the allocation policy (“what readers do”) is related to ability (“what readers have”) (Smiler et al., 2003; Stine-Morrow et al., 1996). However, to the extent this has been tested, it has been with single indicators of ability, which may not have the reliability to detect subtle effects. The more extensive battery of individual differences used in this study provided greater sensitivity to examine this question, which we addressed first by considering bivariate correlations between indicators of ability (“what you have”) and allocation (“what you do”), following up with structural equation modeling.

Collectively, then, this study examined four sets of assumptions of the SRLP model, the knowledge-driven assumption, the “habit of mind” assumption, the tripartite model of regulatory control, and the efficiency assumption.

¹An alternative approach with such data is to use multilevel modeling to simultaneously model variation in reading time as function of properties of the individual reader and the individual texts (Kliegl, in press; Quené & van den Bergh, 2004). Our preference was to work with the regression coefficients as individual difference variables, collapsing as suggested by our theoretical model and analyzing with repeated measures (Lorch & Myers, 1990; Kliegl, Nuthmann, & Engbert, 2006). As we will show, this allowed us to directly test selected ideas about resource allocation on a theoretical level.

METHOD

Participants

Participants were 128 university students participating for course credit or payment (18 to 39 yrs, $M = 20.0$, $SD = 3.0$), as well as 117 community-dwelling elders from the New Hampshire seacoast, who participated for a small honorarium. Elderly participants were clustered into young-old (YO; $n = 59$; 58 to 70 yrs, $M = 64.7$, $SD = 3.8$) and old-old (OO; $n = 58$; 71 to 87 yrs, $M = 76.4$, $SD = 4.2$) groups for analysis. All participants had attained at least a high school diploma. The younger adults had completed a range of 12 yrs to 18 yrs (master's degree) of formal education (5.6% post-baccalaureate). For both of the older groups the range of educational attainment was 12 yrs to 20 yrs (doctorate or professional degree) (for the YO group, 49.2% post-baccalaureate and 19.6% post-master's; for the OO group, 39.7% post-baccalaureate and 12.1% post-master's). Generally then, the sample was well educated. Given that the University of New Hampshire has approximately a 70% graduation rate, the younger sample is generally comparable in ability to the older groups as gauged by their projected educational attainment.

Descriptive statistics of ability measures (described below) for the three age groups are presented in Table 2. Samples were typical of other age-comparative samples in cognitive aging research in showing an older adult advantage in verbal ability and an older disadvantage in measures WM and speed of processing. While differences across age were generally monotonic across age, there was some variation in whether the young-old group was relatively closer to the younger group or the old-old group in level of performance. Both older groups showed lower levels of performance on WM tasks, but did not significantly differ from one another. Measures of speed of processing, however, showed age differences between the two older groups. Reading interference, a slowing in reading speed by distracting material as a measure of inhibitory function, did not show reliable change from youth to early old age, but showed significant deterioration in later old age. Phonological interference (relatively slow lexical decision time for nonwords with phonology corresponding to real words), however, was greatest for the YO group. Finally, it was the youngest group that showed a relative disadvantage in speed of naming low-frequency words, suggesting an older adult advantage in speed of lexical access.

Ability Measures

Vocabulary—The Extended Range and Advanced Vocabulary subtests of the ETS Kit of Factor-Referenced Tests (Harmon, Ekstrom, French, & Dermen, 1976) were used to measure verbal ability. Instructions and scoring procedures were used such that guessing was not encouraged and there was a penalty for incorrect answers.

Working Memory (WM) Span—The reading and listening span measures described by Stine and Hindman (1994) were used to measure verbal WM. Given the concern that such sentence span measures may predict language memory because they themselves are language memory measures, computation span (Salthouse & Babcock, 1991) was assessed to get a more comprehensive representation of the WM construct so as to alleviate this concern.

Speed of Processing—The Letter and Pattern Comparison Tasks (Salthouse & Babcock, 1991) were used to measure perceptual motor speed. On these tasks, participants complete as many same-different judgments on strings of letters (letter comparison) or abstract patterns (pattern comparison) as possible in 90 sec. Scoring is based on performance so that a higher score represents more speeded performance.

Naming—In this task (Hartley, 1988) subjects named 60 words as quickly as possible. These words were drawn from the Thorndike-Lorge (1952) word norms such that all words were the names of objects and one or two syllables long; half the words were high in frequency (50 or greater) and half were low in frequency (5 or less). Naming time was taken as the interval between word presentation and voice onset, as measured by a voice relay. Mean naming time was taken as the measure of verbal speed. In addition, access time for low-frequency words was taken as proportionately greater time needed to name low-frequency words relative to high-frequency words (i.e., (L-H)/H).

Lexical Decision—In this task, participants made speeded decisions about the lexical status of letter strings (i.e., word vs. nonword). Nonwords were matched with words in number of characters. Half of the nonwords were phonologically identical to words (i.e., pseudohomophones, e.g., nerse). Measures derived were (a) verbal speed, as the time to correctly detect words (hits) and (b) phonological interference as the proportionately greater time to verify phonological nonwords as nonwords (i.e., (PNW-NW)/NW).

Reading Interference—Older readers have been found to be disproportionately slowed by interspersed text or letters (Connelly, Hasher, & Zacks, 1991). We used the task developed by Earles and colleagues (Earles et al., 1997) to measure interference in reading by interfering material. Reading interference was measured as the proportionate extra time taken to read the experimental passages in which italicized words were interspersed with the target text, relative to different control texts matched in length and complexity to the experimental texts (i.e., (E-C)/C).

Text Materials

Participants read three types of text: expository, narrative, and single sentences matched on Flesch-Kincaid readability with mean grade levels of 9.2, 8.6, and 9.6, respectively. The four expository passages (“Fossils,” “Mexican Jumping Beans,” “Japanese Sword-Making,” and “Wine-Making in Ancient Egypt”), adapted from Stine-Morrow et al. (1996), each contained between 191 and 236 words (total words: 844). The two narrative passages (“Lute Player” and “The Woodcutter”), adapted from Stine-Morrow, Miller et al. (2001), contained 450 and 523 words (total words: 973). The 48 single sentences (describing facts from nature, science, or history) were borrowed from Stine-Morrow, Milinder et al. (2001); each contained 18 words (total words: 864) and was followed by a filler sentence to ensure that reading time on the sentence-final word of the target sentence would reflect encoding and comprehension processes (as in the two discourse conditions) rather than retrieval planning.

Each of the 2,681 words was coded for a set of text characteristics that would be used to decompose reading times for the analysis of resource allocation (Table 1). Descriptive statistics for each of these variables are provided for each type of text in Table 3. All texts were analyzed using the Kintsch system of propositional analysis (Kintsch, 1988, 1998; Kintsch & van Dijk, 1978) to describe features related to textbase processing. In addition, expository texts were analyzed according to Britton's (1994) system from which were derived measures unique to expository discourse above and beyond the textbase (cf. Miller, Stine-Morrow et al., 2004). Narrative texts were analyzed according to both Zwaan's event-indexing model (Zwaan, Langston, & Graesser, 1995) and also within a story grammar framework (Mandler & Johnson, 1977). A number of indicators were derived from each of these systems; the final subset of variables used to model the allocation policies of individual readers (shown in Table 1) were selected so as to represent unique facets of processing within the three different levels of processing (word, textbase, discourse). Variables that were ultimately selected were those that showed the highest correlations with median word reading times, but did not correlate highly with other text variables (so as to avoid problems of multicollinearity).

Variables reflecting word-level processes were the number of syllables (SYLL) and the log word frequency (WF; Kucera & Kucera, 1982). Variables reflecting demands for textbase construction included whether or not a word introduced a new concept into the discourse (NC), whether the word was at the end of a clause, complex noun phrase, or other major syntactic constituent within the sentence (INTSB), and whether the word fell at a sentence boundary (SNTB); each of these was dummy-coded (0/1). These five variables were coded for all texts.

The story grammar analysis (Mandler & Johnson, 1977) involved constructing a tree-structure for narrative events reflecting the story structure (e.g., a story is composed of a setting and a set of episodes, each of which can be divided into a beginning, a development, and an ending). We coded the breadth of an event as the position of its branch of this tree (going from left to right, or beginning to end of the story) and its depth as its position along a branch (e.g., an event that was part of a subgoal used to achieve a goal would be relatively deeper in the tree). Both depth and breadth were negative predictors of reading time, but their product, which on an intuitive level seemed to reflect “depth into the narrative plot” (with the index rising as an episode developed and decreasing with the beginning of a new episode) was the single best predictor of median reading time, so we used that to reflect sensitivity to the narrative structure (N_PLOT). Of the features of the narrative situation (Zwaan, Langston et al., 1995) that we coded, only temporal discontinuity (N_TEMP; e.g., “The next day...”) reliably predicted reading time. For narratives, each word in the event was assigned the value for which the event was coded.

Britton’s (1994) system for coding expository text assumes that topics or lines of argument are established and then developed. For example, in the Japanese Sword Making passage, the topic switched from technical information about making the blade to several sentences about intergenerational transmission of the craft. We coded the first statement of this topic switch as a new line of argument (E_NEWARG) and then the serial position for each statement about the transmission (E_SP; 1 for a description of blades passed down from father to son, 2 for a statement about an apprentice learning the craft if an heir was not available, 3 for a statement that this assured this process would not be lost). A unitizing statement in Britton’s system is one that summarizes or wraps up the argument (often signaled phrases such as, “Thus,...,” “All of this suggests...,” e.g., in this case, a concluding statement about how many features of a sword’s history and construction contributed to its value); we dummy-coded such sentences (E_UNIT). As with narratives, each word was assigned the value for which the sentence was coded.

These materials, as well as coding schemes and coded texts, are available on request.

Procedure

For the younger participants, all measures were completed in one session requiring about two and a half hours. For the older participants, the experimental protocol was completed in two sessions, each about an hour and a half in duration; the two sessions were conducted on separate days less than a week apart.

Participants read the texts on the computer screen of a Macintosh G3 computer using PowerLaboratory software (Chute, Westall, & Barisa, 1996). Texts were presented word-by-word using the moving window method, which produces patterns of reading time very similar to eye-tracking (Just, Carpenter, & Wooley, 1982). Each text began with a Ready signal at which a press of the space bar produced a screen of dashed lines (the lengths of which corresponded to the lengths of the words that would appear on the screen) as well as punctuation. The next button press produced the first word of text, while the underscores and punctuation for the rest of the text remained on the screen. Each successive button press produced a single word of the text while simultaneously erasing the previous word. Practice

texts were presented before the target texts to give participants experience reading in this manner.

A signal was presented after each passage to indicate that the participant should recall the passage. Participants were asked to recall as much as they could from each passage (“both the main points and the details”), but were reminded that they should not try to remember the passages word for word. Oral recall was recorded for later transcription and scoring. After this free recall, true/false probes were presented on the screen (with half of these probes in each condition expressing information consistent with the passage and the other half information that was inconsistent). These probes were designed to broadly sample understanding and memory of the text. For the sentences, these were single questions probing either a proposition given directly by the sentence or an inference. For each of the longer passages, 6 probes were presented, 2 of which probed inferences reflecting macropropositions or themes, 2 of which probed propositions of central importance to the passage, and 2 of which probed minor ideas.

RESULTS

Memory Performance

Recall protocols were scored for the proportion of propositions from the textbase contained in the recall using a gist criterion (Turner & Greene, 1978). Scoring of a subset of the protocols among independent raters produced correlations over .90. Performance on T/F questions was measured as the proportion of correct responses. Descriptive statistics (and F-values for the age effect) for memory measures are presented in Table 4. While there is some variation in the pattern of age differences, the data generally showed a curvilinear pattern, with the young-old participants outperforming the youngest participants, and the oldest participants performing at levels lower than or equivalent to the young-old group. Neither of the older groups showed performance lower than the youngest group.

Relative to the larger literature on text memory and aging, the lack of an age deficit is somewhat unusual, but not completely surprising (Hultsch & Dixon, 1984), especially given that self-pacing and age-related growth in verbal ability are each thought to reduce age differences (cf. Johnson, 2003). A covariate analysis in which vocabulary was controlled showed that for sentences, there were reliable age deficits in both recall, $F(2, 205) = 6.99, p < .001$, and accuracy to T/F probes, $F(2, 239) = 8.20, p < .001$ ($Y > YO > OO$, for both). This was also true for expository texts, in both recall ($Y = YO > OO$), $F(2, 190) = 4.64, p < .01$, and probe accuracy ($Y > YO > OO$), $F(2, 234) = 6.91, p < .001$. For narratives, with the effects of vocabulary partialled out, age differences in neither recall, $F(2, 234) = 2.06, p = .13$, nor probe accuracy, $F(2, 234) = 1.83, p = .16$, reached significance.

Resource Allocation during Reading

Calculation of the Allocation Coefficients—Prior to regression analysis to derive allocation coefficients, raw reading times for each participant within each text condition were trimmed. Word reading times greater than 5 standard deviations above the mean were replaced with the value corresponding to the mean plus 5 standard deviations for that word, resulting in .01% of the times being replaced for the younger group; and .02%, for the older groups. Three regression analyses were performed for each subject, one for each type of text. Trimmed reading times were regressed onto the text variables in Table 1 that were appropriate for each type of text (cf. Lorch & Myers, 1990). Note that the inherent differences among genres entail that resource allocation be measured with somewhat different yardsticks. While word processing and textbase processing are common to the three text types, there are qualitatively unique processing requirements for narratives and expository texts. Regression models for all three text types included the five variables reflecting word and textbase characteristics, as well

as two dummy codes to control for nuisance effects associated with right-to-left scan to start a new line of text, as well as the first word of each sentence (a total of seven variables). Models for narrative reading times included the two additional variables reflecting story grammar processing and temporal shifts (a total of nine variables). Models for expository reading times also included the three variables reflecting the processing of expository structures (a total of ten variables).

Mean allocation coefficients collapsed across age are presented in Table 5. All of the parameters reflecting textbase processing, as well as the constants, were significantly different from zero, $p < .001$ for all, as were the discourse-level variables, $p < .01$. Generally speaking, readers allocated time for orthographic decoding (i.e., extra time as a function of word length), lexical access (i.e., extra time for low frequency words; producing negative coefficients in Table 5 reflecting less processing time for familiar words), instantiation of new concepts (i.e., extra time for the first occurrence of new noun concepts), and time for conceptual integration at the ends of sentences (“wrap up,” i.e., extra time at the ends of sentences). For sentences and narrative texts, readers also allocated time to conceptual integration at clause boundaries, though there appeared to be significant suppression effects for intrasentence boundaries in expository texts. These models accounted for an average of 22.2% of the variance in reading times ($se = .8$; ranging from 0 to 55.0%) for sentences; an average of 14.7% ($se = .6$; 0 to 52.2%) for expository texts; and 12.8% ($se = .6$; 0 to 40.0%) for narratives; for each text type, these means were significantly different from the null, $p < .001$ for each. These means were somewhat lower than what we have found in the past (e.g., Stine-Morrow et al., 2001); the more expanded protocol may have been more taxing for subjects, thus adding noise to the reading times. Intercepts, reflecting sensorimotor slowing as well as linguistic computations not represented by our list of predictors, increased monotonically with age group ($M_Y = 370$, $se = 11$; $M_{YO} = 497$, $se = 16$; $M_{OO} = 589$, $se = 16$), $F(1,236) = 67.24$, $p < .001$. Intercepts were greater for sentences than for either discourse condition and were greater for narratives than for expository texts, $F(2,472) = 90.78$, $p < .001$. The Age X Genre interaction was not significant, $F(4,472) = 1.18$.

Contextual Facilitation for Resource Allocation to Word and Textbase

Processing—Our first question dealt with the effects of age and genre on resource allocation to encoding text content (i.e., word and textbase processing). Specifically, we wanted to test the hypothesis that conceptual processing was especially taxing for older adults when contextual support was weak, as in the case of single sentences relative to the extended discourse context provided by narratives and expository texts. In other words, if we assume that construction of the textbase requires the reader to represent connections among concepts in memory (e.g., Kintsch, 1998), we expected that the time needed to achieve these representations would be reduced by a discourse context that provided a schema for integrating this information (e.g., Miller & Stine-Morrow, 1998).

To simplify the analysis, we computed composite indices of resource allocation to word and conceptual (textbase) processing as average z-scores of the appropriate allocation coefficients as defined in Table 1 (cf. Stine-Morrow et al., 2004). These indices, plotted in Figure 1, were analyzed in a 3 (Age: Y vs. YO vs. OO) $\times$ 3 (Level: Textbase, Word) $\times$ 3 (Genre: Sentence, Expository, Narrative) repeated measures ANOVA. Consistent with our expectations, genre had a strong effect on resource allocation, $F(2,236) = 248.98$, $p < .001$, such that sentence processing engendered more attention to word and textbase features than did discourse processing. Resource allocation also increased monotonically with age, $F(2,236) = 24.22$, $p < .001$. The older groups showed enhanced contextual facilitation as indicated by an Age $\times$ Genre interaction, $F(4, 472) = 9.83$, $p < .001$.

The three-way interaction, shown in Figure 1, was reliable, $F(4,472) = 6.81, p < .001$.³ This interaction reflects the fact that age differences in the contextual facilitation effect were somewhat different for word and textbase processes. Both discourse conditions reduced the age difference in textbase allocation (right panel), whereas only the narrative condition reduced the age difference in allocation to word-level processing (left panel). Context, of course, reduced resource allocation to lexical analysis of expository text, but not differentially so for older readers. This is interesting because some of these passages were scientific passages with technical vocabulary. Older adults may have difficulty deriving the meanings of unfamiliar words from context (McGinnis & Zelinski, 2003), an effect that may have limited contextual facilitation in this case. In spite of this, older adults reading these scientific texts did show a level of contextual facilitation similar to that of the young.⁴

This shift in allocation with discourse constraints provides clear evidence that the allocation policy is contextually sensitive. Other examples include the decrease in time needed for word processing under strong semantic constraints (e.g., Rayner & Well, 1996) and the exaggeration of wrap-up when reading is done for recall relative to when it is done for comprehension (e.g., Aaronson & Ferres, 1984; Stine-Morrow & Miller, 1999). Furthermore, these data show that older readers take particular advantage of discourse context to support and facilitate encoding of textbase content.

Resource Allocation to the Discourse Level—As was done with word and textbase processing, a composite score reflecting sensitivity to expository structure was computed by averaging the z-scores of the allocation coefficients reflecting time to instantiate a new line of argument, to assemble supporting nodes, and to unitize the argument. In fact, allocations to these three processes were moderately interrelated (Cronbach's $\alpha = .55$). The two older groups ($M_{YO} = .17, se = .11$; $M_{OO} = .21, se = .14$) were more attentive to expository structure than the younger group ($M_Y = -.18, se = .05$), $F(2,239) = 6.70, p < .001$. When vocabulary was entered as a covariate, the age effect was no longer reliable, $F(2,236) = 2.16, p = .12$, though specific contrasts showed that the oldest old group showed stronger allocation to expository structure than the young group, $p < .05$, even when vocabulary was controlled.

The two allocation coefficients associated with narrative processing were not correlated, $r = .03$. This is perhaps not surprising since one variable operationalized responsiveness to the story grammar, and the other, the extra time taken to process a temporal shift, operationalized the extent to which readers track the protagonist through the timeline of the narrative. This independence suggests that attention to the narrative structure and the narrative situation model may not be linked. Therefore, no common index was computed, and these variables were analyzed separately. Younger adults and the young-old group showed stronger responsiveness to plot engagement than the oldest group ($M_Y = .16, se = .07$; $M_{YO} = .17, se = .14$; $M_{OO} = -.53, se = .16$), $F(2,239) = 11.45, p < .001$, suggesting that the oldest group may not have been following the story line as completely as the other two age groups; this relationship held when vocabulary was entered as a covariate, $F(2,236) = 7.76, p < .001$. Responsiveness to temporal shifts showed a somewhat different pattern, with both older groups showing greater responsiveness than the younger adults ($M_Y = -.37, se = .08$; $M_{YO} = .38, se = .11$; $M_{OO} = .$

²There is most likely fractionation within the discourse level, in terms of both the situation model (e.g., Friedman & Miyake, 2000) and discourse structure (Graesser et al., 1987), but we start with the simplest idea in which the discourse level is monitored and regulated as a whole. We will show in our data, that this idea is too simple.

³This pattern of results did not substantively change if vocabulary level was entered as a covariate; e.g., $F(4,470) = 3.57, p < .05$, for the three-way interaction. Also, these age differences were not simply a by-product of general slowing (Salthouse, 1996). When a composite measure of perceptual speed (the average z-score of the letter and pattern comparison tasks) was entered as a covariate, the three-way interaction also remained significant, $F(4,470) = 4.41, p < .01$. An analysis of raw reading times showed that the contextual facilitation effect was more clearly evident in the analysis of coefficients. Median RTs for each individual replicated the effect of Genre, $F(2,466) = 71.06, p < .001$, and Age, $F(2,233) = 75.10, p < .001$, but not the interaction, $F(4,466) < 1$. Similarly, mean RTs showed the effect of Genre, $F(2,466) = 200.68, p < .001$, and Age, $F(2,233) = 70.32, p < .001$, but a marginal interaction, $F(4,466) = 2.48, p = .062$.

42, $se = .15$), $F(2,239) = 17.78$, $p < .001$; this pattern did not change when vocabulary was entered as a covariate, $F(2,236) = 5.91$, $p < .01$.

Recapitulation—Collectively, these data suggest that resource allocation increased monotonically with age to all processing components with the exception of plot engagement, with the oldest old showing markedly less responsiveness. This general pattern of increase suggests that the computations that give rise to text understanding are more resource-consuming for older adults. However, age effects on word and textbase processes were diminished by the presence of discourse context, suggesting the older readers may rely relatively more on the structural properties of discourse to support lexical access and conceptual processing. This conclusion was bolstered somewhat by the finding that older readers appeared to allocate more attention to tracking the line of argument in expository text (cf. Miller, Stine-Morrow et al., 2004) and to construction of the situation model (cf. Radvansky et al., 2001; Stine-Morrow et al., 2004).

The pattern of monotonic increases in resource allocation to word and textbase processes as a function of age stands in contrast to the curvilinear effects of age in memory performance. It appears that the higher levels of resource allocation among the young-old paid off in terms of enhancing the fidelity of the text representation. The oldest group achieved performance levels comparable to the young, but at a much greater cost in terms of effort. In terms of the SRLP model, these divergent patterns suggest that older adults maintain good monitoring ability, and increase resource allocation in the face of processing capacity declines. This was relatively more effective for the young-old group, producing comparable gains in performance, so that they actually showed better performance than the younger group. It cannot be said that the oldest old showed text memory deficits, at least not when considered relative to the performance of the young, however, they required higher levels of resource allocation to reach the same level of performance, and their increased allocation relative to the young-old did not pay off to the same extent on performance.

Consistency of Word and Textbase Processing Across Text Types

As noted earlier, the allocation policy to word and textbase computations in sentence processing shows some consistency across time (Stine-Morrow, Miller et al., 2001). Here we ask whether these computations are consistently implemented across different types of text as well. We have already demonstrated that the allocation policy is contextually sensitive, but even if readers generally allocate less time to word and textbase processing in discourse context, it may still be that readers who allocate relatively more time to construct the textbase for sentences may also do so for discourse. That is, the question here is whether there is rank-order stability in allocation among readers as they moved among different texts (even though readers generally allocate more effort to word representations and textbase construction in reading single sentences). The correlations in Table 6 showed that there was indeed some stability, with the most reliable coefficients relating to sentence wrap-up and word processing. Separate values are reported within younger and older groups as well. (Note that for this and subsequent correlational analyses, the two older groups are collapsed.) Notable exceptions are the coefficients reflecting immediacy in conceptual processing and intrasentence wrap-up among the younger readers. We (Stine-Morrow, Milinder et al., 2001) have found that intrasentence wrap-up shows poor test-retest reliability. This is probably because there are a number of options for readers to opportunistically consolidate representations before sentence boundaries. While readers may generally wrap-up within a sentence, it is difficult a priori to specify exactly where this will be; this is especially so for younger readers with greater processing capacity, who may opt to forego integration until the sentence boundary (Miller & Stine-Morrow, 1998). Interestingly, these processes did show consistency within the older group. Collectively, the stability of word and wrap-up processing suggests that the allocation policy used to

construct lexical and propositional representations is a reliable individual difference, a "habit of mind" with which the reader engages different texts at different times.

How is the Allocation Policy Regulated?

A general assumption of the SRLP model is that the learner allocates effort until the fidelity of the mental representation meets some standard of coherence (i.e., a discrepancy reduction process). As noted earlier, what is unclear is the level at which the representation is monitored and effort is recruited to shore up the representation. We used factor analysis to assess the extent to which coefficients hang together within readers. Allocation coefficients were submitted to factor analysis using unweighted least squares as the method of extraction and oblimin rotation ($\delta = 0$). Thus, factors were allowed to be correlated. To facilitate interpretation, allocation coefficients tending in the negative direction were multiplied by -1 . Thus, positive factor loadings for allocation coefficients related to word frequency (lexical access) could be interpreted as relatively more time to low-frequency words. Similarly, positive factor loadings for the parameter associated with story grammar processing could be interpreted as facilitation by depth into the narrative structure (i.e., plot engagement).

The factor structure converged in six iterations. Five factors were extracted accounting for 66% of the variance in the array of allocation coefficients. The factor loadings for the pattern matrix (correlations between scores and factors, with variance from other factors partialled out) are shown in Table 7, with the loadings that would be predicted by the SRLP model included in shaded cells (factors are arranged in the order of percent variance accounted for). This structure is remarkably simple, but not unitary, and largely consistent with the SRLP model. The first factor is marked by high loadings on parameters related to the processing of new concepts and to processing at clause and sentence boundaries for all three types of text, reflecting textbase construction. The parameters with the highest loadings on the third factor are those related to orthographic decoding and lexical access, processes needed for word-level representation (again for all three types of text). The second factor includes high loadings for the three variables characterizing processing of expository structure. There appears to be some overlap between conceptual processing and word processing (i.e., the computations used to derive a representation of content), but these two factors appear to be cleanly separated from the factor representing the processing of expository structure. The fourth factor, another related to expository processing, is marked by relative inattention to lexical processing and immediate conceptual processing but relatively greater attention to clausal processing for this genre, suggesting a strategy of "buffering" over "immediacy" (e.g., Haberlandt et al., 1986) in reading expository text. Thus, we have labeled this an "expository chunking" factor. The fifth factor is characterized by attention to narrative structure and conceptual integration in narratives as well as conceptual processing (immediate and clausal processing of new concepts) in sentences.

This factor solution is largely consistent with our SRLP model, suggesting that individual differences in allocation coefficients respect the expected distinctions between word and textbase processing, on the one hand, and discourse-level processing, on the other hand. Rather than a unitary discourse factor, however, the data are more consistent with the idea that the particular types of discourse may demand unique computations that overlay word and textbase processing. Expository processing separated out from word and textbase analysis. We did not find coherent loading for narrative processes, which may not be surprising given that one reflected sensitivity to narrative schema (Mandler & Johnson, 1977) and the other to situation model construction (Zwaan Langston et al., 1995). Correlations among factors was generally low, with the highest between first and third factors ($r = .36$), suggesting that word and textbase allocation may show some overlap. One might speculate that these factors may well be more

tightly integrated among mature readers, but might show greater separation among children learning to read for whom orthographic decoding is as yet fragile.

Collectively, this factor solution suggests that the algorithm for allocating effort in text processing is neither monolithic nor conducted on a per computation basis nor unique to genre. The level of monitoring and adjustment of resource allocation to construct the text representation roughly aligns with the SRLP model, with regulation governed at an intermediate level, specifically word recognition, conceptual instantiation and integration, and structural schemas for particular discourse forms. At the same time, we found little evidence for a unitary discourse factor. Rather, regulation at the discourse level appears to be multidimensional.

The Relationship Between Allocation Policy and Ability and How Both Contribute to Performance

Our final goal was to situate the allocation policy with respect to its relationships to intellectual and cognitive abilities and to what is remembered from text. As noted earlier, we wanted to know whether the stability in the allocation policy derived in part from abilities. Also, while there has been considerable work regarding ability predictors of text recall, there has yet been little evaluation of the mediating mechanisms for these relationships. We wanted to determine the extent to which the allocation policy for self-regulated reading mediated or complemented the predictive power of abilities like WM and vocabulary for text recall.

First, we replicated the core phenomenon that high levels of memory performance are preceded by higher levels of resource allocation. Composites were created for performance by averaging the z-scores for probe-response accuracy and for recall across the three types of text. Recall scores formed a more cohesive scale ($\alpha = .84$) than did probe scores ($\alpha = .50$), and so were used as our measure of performance.⁵ The indices of word and textbase allocation used in our analysis of contextual facilitation (Figure 1) were analyzed in an Age $\times$ Recall Group (High vs. Low, based on a median split of the average z-scores for the whole sample) $\times$ Level (Word, Textbase) repeated measures ANOVA. Aside from replicating the effects and interactions already obtained in the analysis of contextual facilitation, this analysis showed that those who were above-average in recall showed greater resource allocation while reading, $F(1,213) = 22.41, p < .001$. There was a trend for this effect to be exaggerated for older adults, $F(2,213) = 2.76, p = .065$. This two-way interaction between Age and Recall Group became reliable when age differences in vocabulary were covaried out, $F(2, 212) = 3.63, p = .028$.⁶ Shown in Figure 2 for word processing (left panel) and textbase processing (right panel), this interaction did not vary as a function of process type, $F < 1$. This analysis demonstrates that older readers had to allocate relatively more processing time than the young to linguistic analysis in order to achieve high levels of memory performance.⁷

⁴For illustrative purposes, we conceptually replicated aspects of these findings with raw reading times to show age differences in contextual sensitivity without the derived scores. First, we divided the words into high- and low-frequency groups (an example of word-level demands) based on a median split ($\log wf = 2.5$), calculating medians for individuals in each condition collapsing across words, as well as for words in each condition collapsing individuals (Clark, 1982). We performed a comparable analysis for words as a function of whether they were at a sentence boundary (an example of textbase demands). In both cases, we replicated the three-way interaction, for word frequency, $F(1,4,458) = 4.15, p < .01$, $F(2,2,614) = 21.15, p < .001$, and for sentence wrap-up, $F(1,4,458) = 4.15, p < .01$, $F(2,2,675) = 208.17, p < .001$. So for example, younger adults allocated an average of 388 ms per word on nonboundary words in reading sentences, but 734 ms per word at sentence boundaries, a wrap-up effect of 346 ms, but when reading narratives, this effect was reduced to $(445 - 331) = 114$ ms, and when reading expository texts, to $(440 - 315) = 125$ ms. The oldest group, on the other hand, showed a sentence wrap-up effect of $(1518 - 574) = 943$ ms, which was reduced to $(901 - 514) = 387$ ms for narratives and $(956 - 503) = 453$ ms when reading expository texts.

⁵Recall and probe-accuracy scores were related, $r = .49$, but the latter were not related to the allocation coefficients.

⁶The Age by Recall Group interaction was not evident in the raw reading times, either in the analysis of medians, $F(2,207) = 1.21, p = .30$, or means, $F(2,207) = 1.76, p = .17$.

Correlations among Ability, Resource Allocation, and Memory Performance—

To examine interrelationships among the allocation policy, ability, and performance, we began by examining bivariate correlations among composites representing our key constructs. One way to do this would have been to use factor scores to represent components of the allocation policy. However, even though generally supportive of the SRLP model, the five factors were not uniformly interpretable in terms of our theory, so we elected to construct theory-based composites by averaging z-scores of the allocation parameters representing our constructs of interest (cf. Stine-Morrow et al., 2004). Word processing was operationalized as the mean z-score for allocation parameters related to syllables and word frequency (again, with the sign reversed for word frequency) (6 parameters, $\alpha = .84$). Textbase processing was operationalized as the mean z-score of allocation parameters associated with conceptual processing (9 parameters, $\alpha = .84$). Processing of expository text was measured as the mean z-scores for the three parameters related to expository structure ($\alpha = .74$). The composites for word and text processing were significantly correlated, $r = .63$, $p < .001$, but neither of these was correlated with the composite for expository processing. As noted earlier, the two variables associated with narrative processing were not correlated, $r = .03$, and so were treated as separate constructs in our analysis.

Similarly, composite variables of core abilities were created by averaging z-scores for the component measures. Verbal ability was operationalized as the Extended Range and Advanced Vocabulary tasks ($\alpha = .93$). Speed was measured in terms of letter and pattern comparison tasks ($\alpha = .69$). Verbal response time was based on the two measures taken from naming time (high and low frequency words) and the three measures taken from the lexical decision task (words, nonwords, and phonological nonwords) ($\alpha = .80$). WM capacity was measured in terms of the listening, reading, and computation span tasks ($\alpha = .73$). Finally, our measures of inhibitory function did not form a scale (cf. Park et al., 1996), and so were excluded from analysis.

Ability and Resource Allocation: Table 8 shows modest relationships between "what you have" (i.e., ability) and "what you do" (i.e., allocation policy). This contrasts with null findings on this point in earlier research (Smiler et al. 2003; Stine-Morrow et al., 1996; Stine-Morrow, Milinder et al., 2001). These are certainly not large correlations and our more extensive battery of ability measures no doubt allowed us to detect these subtle relationships. Most importantly, negative relationships between indices of mental mechanics (i.e., WM and speed) and allocation to word, textbase, expository processing, and temporal updating suggested a compensatory account of ability-allocation relationships. Verbal ability, on the other hand, was a positive predictor of textbase allocation, expository structure processing, and temporal updating, suggesting that crystallized abilities may support the regulation of effort to constructing the text representation. Verbal ability was not related to word processing in the sample as a whole (as shown in Table 8), but it was within the younger ($r = -.24$, $p < .01$) and older ($r = -.29$, $p < .01$) samples separately, such that higher vocabulary was related to relatively less allocation to word processing. Thus, verbal ability may facilitate lexical processing, thus freeing resources for more elaborative encoding of the textbase and discourse-level features.

Resource Allocation and Memory: Table 9 shows the relationships between components of the allocation policy and recall performance. The most reliable relationships between the allocation policy and recall were found for word and textbase processes, suggesting that an allocation policy in which attention was devoted to lexical elaboration and conceptual processing engendered good memory performance. This is consistent with the argument that accurate recall depends on the availability of a coherent textbase representation (e.g., Kintsch, 1994). However, while these patterns held for both younger and older readers, these relationships tended to be somewhat less consistent in the older group reading longer discourse passages, a point to which we will return in a bit. We were generally less successful in predicting

recall from allocation to discourse-level features. Although the relationship between plot engagement and narrative recall did not reach significance in the sample as a whole, it is interesting to note that older readers, but not younger readers, showed better recall for narratives when they were attentive to narrative structure. This is consistent with arguments that older adults take better advantage of the holistic character of narratives (Adams et al., 1990; Stine-Morrow, Miller et al., 2001). At the same time, advanced old age seemed to bring less responsiveness to plot engagement (cf. Table 8), calling to mind earlier arguments in the literature that the cognitive demands of tracking narrative plot may be especially difficult for older adults (Hartley, 1986; Zelinski & Gilewski, 1988). It appears that even though older readers may be less likely to track the narrative plot, when they do, they benefit from it.

So far, we have shown that resource allocation generally increased monotonically with age (cf. Figure 1, Table 8). This was most reliably found for conceptual / textbase processing, and the clear exception to this rule was plot engagement, which showed somewhat of a decline with age. The correlational analysis suggests that the increase in word and textbase processing, which was most strongly predictive of recall (Figure 2, Table 9), was driven in part by a need to compensate for age-related declines in speed, but was also enabled by good verbal ability. Ironically, even though older readers allocated more time to word and textbase processing, they may have derived less benefit, at least for extended discourse. Structural equation modeling (SEM) allowed us to directly test these ideas.

Structural Equation Modeling: How Ability and Resource Allocation Contribute to Performance

—We used two-group SEM to examine the extent to which individual differences in the allocation policy could account for the well-replicated relationship between ability and text memory performance. There are problems associated with estimating regression effects in extreme-groups designs (e.g., Preacher & MacCallum, 2005) and with distorting process-specific correlations due to influences of similar or dissimilar cross-sectional mean age trends (Hofer, Flaherty, & Hoffman, 2006). Thus, we estimated the relationships of cognitive constructs within the two age groups rather than in the aggregated sample and focused on influences other than chronological age (specifically, relationships between abilities, allocation parameters, and text recall). Given that both samples varied in age over periods of the life span suspected to show change, we included age within each group as a predictor variable. The standardized age-related effects reported here, consequently, do not reflect age differences across the life span. First, because the coefficient representing age effects does not encompass the full age range, any linear effects of age are underestimated (see also Hertzog et al., 2003; Hofer et al., 2006; Hofer & Sliwinski, 2001; and Lindenberger & Pötter, 1998, regarding concerns about age-related effects in cross-sectional SEM). At the same time, there were nonlinear age effects evident in our data, which we could effectively model with this two-group approach. For example, even though the young group as a whole showed much better performance on the speed measures than the older adults, speed showed improvement within the young group. Also, verbal ability was generally much higher for the older participants, but within age groups, age only had an effect within the young group. Because the older participants in the young group (in their 20s and 30s) were more likely to be enrolled in graduate or professional programs, this positive effect is likely a selection effect (as well as perhaps a positive effect of the educational experience itself).

The conceptual model that guided our analyses is presented in Figure 3. It assumes that age-graded effects on basic abilities engender an allocation policy that is the proximal cause of memory performance. Our measurement model was fairly well aligned with the factor analysis in defining indicators of resource allocation to word and textbase processes and with the scales of speed (letter and pattern comparison), WM (listening, reading, and computation spans), and verbal ability (ETS Extended Range and Advanced Vocabulary) already described, so we do not present it here. Although we evaluated a number of preliminary models, we present a subset

of structural regression models that test principled hypotheses regarding whether resource allocation could account for ability-recall relationships. We were able to eliminate certain possibilities early on. For example, all models we report include age as a predictor for text memory because our preliminary results suggested that age effects were not completely mediated by ability and resource allocation. Also, speed did not independently contribute to resource allocation or text memory, so that models in which speed effects were mediated through WM provided the best fit (cf. van der Linden et al., 1999). In addition, age effects on WM were mediated entirely through speed (Salthouse & Babcock, 1991). We considered models in which resource allocation to both word-level and textbase processing independently contributed to text memory, however, these two constructs (although independent in our measurement model) were highly correlated and created suppression effects when both were included as predictors of text memory. Therefore, the models we report embody the assumption that it is the construction of the textbase representation (rather than lexical representations) that is the more important determining factor of text recall (e.g., Kintsch, 1998). Finally, we tested models that constrained the unstandardized structural regression coefficients to be equal in all cases, and found this assumption to be viable, with the exception of the paths from age. Hence, the models we report estimated invariant regression coefficients (constrained to be equal) across age groups for all paths except those from age, which were allowed to vary. (There was one other case in which we relaxed the equality constraint that we will discuss in a moment.) Model parameters were estimated in LISREL 8.53 (Jöreskog & Sörbom, 1996) using full-information maximum likelihood. This method uses all available data to fit the raw data likelihood under missing-at-random assumptions, which is advantageous with a small-to-moderate sample size.

The path coefficients and fit statistics for viable alternative models for discourse processing are presented in Table 10; corresponding results for sentences are presented in Table 11. In both cases, Model 1 is a completely mediated model, in which we tested whether ability effects could be entirely mediated by resource allocation. That is, effects of the WM and Verbal Ability latent variables on Text Recall were fixed to zero, forcing all effects to be funneled indirectly through resource allocation to Word and Textbase processing. This produced a relatively good fit for both discourse (narrative and expository) memory and for sentence memory, with Root Mean Square Error of Approximation (RMSEA; Steiger, 1990) of about .07 (a fit of .05 is considered a benchmark for excellent fit). Consistent with the correlational analyses, these models suggest three sources of influence of ability on resource allocation. (a) As might be expected, Word processing was facilitated by good Verbal Ability. (b) The negative path from WM to Word processing suggests that a larger WM capacity also leads to faster lexical processing. (c) Finally, the positive path from Verbal Ability to Textbase processing shows that high verbal ability engendered stronger attentional control to textbase construction.

We next considered the possibility that WM and Verbal Ability might each exert effects on Text Memory other than those mediated by resource allocation. Model 2 is this partially mediated model, retaining the allocation effects but adding the ability-recall relationships. This model provided a somewhat better fit than the completely mediated model for sentence processing, although the change in RMSEA was modest; for discourse processing, the fit was indistinguishable from Model 1. Model 2 results suggested that the weak path from WM to Textbase processing could be removed. This effect was trimmed for both text types in Model 3, our compromise model.

For Model 3 of discourse processing, we also removed the marginally significant path from WM to Text Memory. This created a somewhat better fit. Finally, in Model 3a we relaxed the equality constraint for the Textbase to Text Memory path to test the idea that resource allocation to textbase processing was less effective for older readers than for the young. In fact, relaxing this constraint significantly improved the fit, $\chi^2(2) = 6.76$, $p < .05$. Model 3a represents our

accepted model for discourse processing (Figure 4). Resource allocation partially mediated the effects of ability, with WM facilitating lexical processing and verbal ability both creating efficiency in lexical processing and enhancing allocation to textbase construction. Nevertheless, resource allocation was not similarly effective in promoting recall in young and old. Young and old alike increased propositional recall as a function of their attentional allocation to textbase construction, but it appears that older adults got “less bang for their buck,” showing a reduced effect of resource allocation on recall performance (e.g., Hartley et al., 1994; Stine-Morrow, Shake, Miles, & Noh, 2006).

Model 3 of sentence processing differed from that of discourse in that WM was retained as a significant independent predictor of text memory. This is consistent with earlier findings that sentence processing is more demanding of WM resources than discourse processing (Stine & Wingfield, 1990; Jefferies et al., 2004). The Age to Text Memory path was not significant in this model, so this was eliminated in Model 3a, however, this did not improve the fit. Model 3 is our accepted model for sentence processing (Figure 5).

Recapitulation—Collectively, these analyses suggest that intraindividual consistency in the allocation policy derives in part from abilities. Older readers tend to allocate more time to lexical processing to compensate for age-related declines in mental mechanics (speed/WM). Age-related growth in verbal ability enhance text processing by reducing the demands on lexical processing and engendering regulatory control in the construction of the semantic representation.

DISCUSSION

The Self-Regulated Language Processing (SRLP) Model (Stine-Morrow et al., 2006) suggests that language processing depends on the coordinated allocation of attention to multiple levels of linguistic and pragmatic features of language. The data presented here provide some support for this conceptualization and clarify certain architectural and developmental features of this model.

Three Principles of Self-Regulated Reading through the Life Span

Our study elucidated three principles of how reading is self-regulated. Resource allocation (a) is regulated with some economy, (b) reflects a “habit of mind” that serves both a compensatory function, as well as a constructive function arising from crystallized knowledge, and (c) is contextually sensitive.

First, the heuristic governing the allocation policy appears to operate with some economy among both younger and older readers. Although there are independent and measurable effects of microlevel processes (e.g., allocation to orthographic decoding, lexical access, conceptual instantiation, wrap-up), these appear to be monitored and regulated neither at the level of individual process nor in a unitary fashion. Rather, we found evidence for a dissociation among word processing, textbase processing, and certain facets of discourse structure and situation construction. For example, allocation coefficients to word-level features and to textbase features each formed reliable scales, loaded on separate factors in factor analysis, and were differentially related to endogenous abilities. However, these facets of the allocation policy were not entirely independent: these factors were correlated and the structural equation models with the best fit contained a path linking these two constructs. Thus, although the dissociation between the word and textbase has psychological validity, it appears that the allocation policies governing the construction of these two levels operate in concert. Allocation to structural properties associated with particular genres and situation updating are clearly distinct from word and textbase processing, but we were not able to develop a cogent model for the architecture at the discourse level. This is arguably the most important facet of language

understanding for older adults (e.g., Radvansky et al., 2001; Stine-Morrow et al., 2004), and deserves further attention.

Second, the self-regulatory heuristics for word-level and textbase processing appear to represent reliable dimensions of individual differences that are engaged independently of the particular type of text encountered. For example, readers who allocated relatively more time to textbase processing in sentences also allocated relatively more time to these computations in extended discourse. This builds on earlier work showing a consistency in the allocation policy for sentence processing across a one-month interval (Stine-Morrow, Milinder et al., 2001). To some extent, such habits of mental engagement may be a consequence of component abilities, so that age-related differences in the allocation policy (e.g., Stine-Morrow, Milinder et al., 2001; Stine-Morrow, Miller et al., 2001; Stine-Morrow et al., 2004) can compensate for declines, as well as reflect knowledge-based text construction strategies. Speed and WM capacity were inversely related to time allocation to lexical processes (as well as to allocation to expository structure and encoding temporal discontinuities in narratives), so that those with larger/faster WM capacities who could presumably conduct component operations more efficiently, apparently did so. Likewise, greater allocation among low-span readers apparently enabled a comparable construction of the language representation.

One question raised by these findings is whether age changes in resource allocation are simply a manifestation of general slowing (e.g., data from Kliegl et al. (2006) suggest that slower reading time (because of age or reduced contrast) can increase sensitivity of current fixation time to word frequency). While our accepted structural model certainly suggests that age-related changes in resource allocation are in part engendered as a response slowing, we do not believe that this is the whole story. First, older readers do not always show larger allocation coefficients even though their reading times may be longer (e.g., Stine et al., 1995). Second, there are data that show that there can be selective change in allocation in response to experimental conditions (e.g., Smiler et al., 2003). Also, in the current data set, individual differences in allocation did not always align with what would be predicted by a slowing explanation. For example, those with high recall showed exaggerated resource allocation (Figure 2), but did not differ in the composite speed measure from those with lower recall. Also, exaggerated patterns of resource allocation to sentence processing among older readers (Figure 1) could not be accounted for with our speed measure. We, therefore, conclude that age-related changes in resource allocation in reading, in part, encompass adaptations to slowing, and are not simply entailed by slowing.

Verbal ability conferred a number of benefits. Age-related increases in verbal ability enabled more efficient lexical processing, which may have freed resources for the construction of higher order semantic representations. In fact, high verbal ability engendered attentional allocation to conceptual processing for textbase construction, as well as to expository structure and the temporal situation. The growth of crystallized ability is a key strength in cognitive aging, and our SEM suggested it can promote productive processing. These effects may have been underestimated, however, since the effects of verbal ability were only modeled within each age group and did not capture its effects across the full age range.

Interestingly, this relationship between verbal ability and attentional engagement to semantic processes in text is likely reciprocal. For example, findings from Stanovich, West, and Harrison (1995) suggest that reading is a self-enhancing strategy that can account in part for age-related growth in crystallized ability. Our findings are complementary in suggesting that crystallized ability (e.g., vocabulary) enables productive reading as well. Increased crystallized ability may contribute to a more knowledge-driven approach to reading (cf. Miller et al. 2004) such that conceptual integration is more effortful in engendering greater integration with existing knowledge stores (cf. Graesser, Haberlandt, & Koizumi, 1987).

We note that generally there were not strong relationships between abilities and indices of the allocation policy, suggesting that consistency in allocation policy is not simply a manifestation of ability. Rather, habits of mental engagement presumably arise not only as a consequence of ability, but also from a lifetime of (implicit or explicit) choices about how and where to allocate effort to cognitive challenges (Stine-Morrow, accepted pending revision). For example, in a recent study, Stine-Morrow, Shake et al. (2006) showed that individual differences in shifting reading time allocation with stringency of recall goal could be accounted for, in part, by an independent estimate of memory self-efficacy.

Third, even though the allocation policy is consistent across time and text, this heuristic is sensitive to context. Less attention is required for lexical and conceptual / propositional analysis in extended discourse relative to sentence processing. This is consistent with earlier literature showing the advantage of knowledge-based processing in reading (Miller & Stine-Morrow, 1998; Rayner & Well, 1996; Wiley & Rayner, 2000). These findings were also consistent with arguments in the literature that older readers take differential advantage of context in lexical processing (e.g., Stine & Wingfield, 1994) and differential advantage of the availability of a situation model in integrating concepts in text (Miller & Stine-Morrow, 1998; Miller et al., 2006).

Self-Regulated Cognition and Aging

Individual differences in allocation to textbase construction predicted memory performance. This is consistent with other findings showing that good text memory is engendered by attentional allocation to propositional and conceptual analysis (Haberlandt et al., 1986; Miller & Stine-Morrow, 1998; Stine-Morrow, Milinder et al., 2001). Importantly, older adults allocated differentially more effort to achieve good text memory performance. With declines in WM capacity and speed of processing, older readers allocated more attention to word and textbase processing relative to their younger counterparts, and this paid off in terms of good performance. Interestingly, this shift in allocation policy was less effective in increasing memory performance for the older old than it was for the younger old readers. This represents a puzzle. Perhaps, as argued by Baltes and colleagues (e.g., Baltes et al., 1999; Singer et al., 2003), a qualitative difference in the oldest-old is that compensatory behaviors yield increasingly meager benefits, i.e., less effective compensation, as age-related losses in required processing resources become too severe to overcome. Be that as it may, allocation of resources as measured here certainly had a diminished effect in our oldest sample (see Hartley et al., 1994). In terms of the SRLP model, among the oldest old, the monitoring function appeared to be accurately gauging the status of memory, recognizing the incompleteness of the representation and enabling the “appropriate” response of increased allocation to linguistic computations. Perhaps, this represents a “breaking point,” at which the system continues to respond in a way that has been adaptive through the life course, but is no longer so because of greater declines in mental mechanics. Alternatively, it may be that the representation is adequately constructed, but is more fragile over time such that retrieval deficits play more of a role among the oldest old. Whatever the reason, it appears that the oldest old use a heuristic in allocating effort to textbase processing that would be expected to be effective (given the level of allocation relative to processing capacity) but that this does not result in the same level of memory performance.

Finally, we note that resource allocation to textbase processing in extended discourse was relatively less effective in improving text memory among the older adults. This may, in part, reflect the diminished effect of resources on performance – but also the fact that older readers’ reliance on discourse structures may have made textbase processing genuinely less important for performance (Stine-Morrow et al., 2004). Interestingly, there was age-equivalence in the

resource allocation - text memory path for sentences, in which there is minimal opportunity to take advantage of discourse context. In this latter case, however, WM had a strong direct effect.

Conclusion

Self-regulation of reading entails the allocation of effort to construct lexical, semantic, situational, and structural representations, which are independently monitored and regulated. Results from the current study suggest that heuristics for resource allocation to lexical and semantic processes are sources of reliable individual differences that are contextually sensitive, arise in part from component abilities, and contribute to text memory. Effectiveness in reading through the adult life span may be relatively immune from the effects of age-related changes in mental mechanics, in part due to both the direct compensatory effects of resource allocation, as well as the indirect effects of growth in crystallized ability, which facilitates surface decoding and augments meaning-construction processes.

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Figure 1. Resource allocation to word (left panel) and conceptual (right panel) processing as a function of age and genre.

Figure 2. Resource allocation to word (left panel) and conceptual (right panel) processing as a function of age and recall level.

Figure 3. Structural equation models for interrelationships among ability, resource allocation, and memory performance.

Figure 4.

Best-fit structural equation model for discourse processing (unless otherwise noted coefficients were the same for young and old; differences are indicated as young/old).

Figure 5.

Best-fit structural equation model for sentence processing (unless otherwise noted coefficients were the same for young and old; differences are indicated as young/old).

Table 1

Text Characteristics Used to Isolate Time Allocation to Processing Components

TEXT FEATURE	THEORETICAL PROCESS	ABBREVIATION
WORD-LEVEL PROCESSING		
Number of syllables	Orthographic decoding	SYLL
Log word frequency	Lexical access	WF
TEXTBASE PROCESSING		
New concept	Instantiation of new element into the textbase	NC
Intrasentence (clause) boundary	Conceptual organization for the clause (end of input cycle)	INTSB
Sentence boundary	Conceptual integration for the sentence; ambiguity resolution	SNTB
NARRATIVE PROCESSING		
Breadth × depth in story grammar	Immersion into the narrative plot	N_PLOT
Presence of temporal shift	Instantiation of situation model into a new time frame	N_TEMP
EXPOSITORY PROCESSING		
New line of argument	Initiate new thread in expository structure	E_NEWARG
Serial position within line of argument	Assemble supporting nodes (evidence, counterevidence, examples)	E_SP
Unitizing statement	Consolidate current line of argument; integrate with other lines of argument and world knowledge)	E_UNIT

Table 2

Sample Characteristics

	YOUNG		YOUNG-OLD		OLD-OLD		Age Differences		p
	M	se	M	se	M	se	F		
Extended Range Vocabulary	15.42 ^a	(0.60)	32.33 ^b	(0.91)	32.43 ^b	(1.27)	150.94		.001
Advanced Vocabulary	11.99 ^a	(0.37)	24.92 ^b	(0.80)	25.59 ^b	(0.91)	183.43		.001
Listening Span	5.27 ^a	(0.10)	4.12 ^b	(0.13)	3.71 ^b	(0.12)	50.20		.001
Reading Span	4.73 ^a	(0.12)	4.22 ^b	(0.17)	3.69 ^b	(0.16)	13.39		.001
Computation Span	6.44 ^a	(0.10)	5.01 ^b	(0.26)	4.35 ^b	(0.29)	37.99		.001
Letter Comparison	23.07 ^a	(0.43)	19.69 ^b	(0.52)	17.14 ^b	(0.57)	36.56		.001
Pattern Comparison	42.30 ^a	(0.69)	32.75 ^b	(0.75)	29.04 ^c	(0.66)	91.30		.001
Naming Time	628.96 ^a	(22.65)	730.83 ^{ab}	(43.48)	831.72 ^b	(48.52)	8.95		.001
Relative Access Time	0.08 ^a	(0.01)	0.06 ^{ab}	(0.01)	0.05 ^b	(0.01)	4.87		.010
Lexical Decision Time	640.69 ^a	(11.41)	788.41 ^b	(21.52)	865.65 ^c	(33.01)	37.87		.001
Phonological Interference	0.09 ^a	(0.02)	0.20 ^b	(0.03)	0.07 ^a	(0.03)	5.46		.005
Reading Interference	1.66 ^a	(0.05)	1.60 ^a	(0.08)	2.04 ^b	(0.12)	7.85		.001

^{a b c} Means within a row without a common superscript are significantly different.

Table 3

Text Characteristics for Each Type of Text

TEXT VARIABLE	Sentences			Expository texts			Narratives		
	Min	Max	M	SD	Min	Max	M	SD	SD
SYLL	1.00	6.00	1.57	0.82	1.00	6.00	1.52	0.88	0.68
WF	0.00	4.84	2.32	1.54	0.00	4.84	2.69	1.48	1.44
NC	0.00	1.00	0.35	0.48	0.00	1.00	0.16	0.37	0.32
INTSB	0.00	1.00	0.24	0.43	0.00	1.00	0.31	0.46	0.45
SNITB	0.00	1.00	0.06	0.23	0.00	1.00	0.06	0.24	0.21
N_PLOT									99.85
N_TEMP									0.47
E_NEWARG					0.00	1.00	0.13	0.34	
E_SP					1.00	12.00	2.85	2.51	
E_UNIT					0.00	1.00	0.15	0.35	

Table 4

Text Memory Performance

Text Type	YOUNG		YOUNG-OLD		OLD-OLD		Age Effect	
	M	se	M	se	M	se	F	p
PROBE ACCURACY (proportion correct)								
Sentences	0.850 ^a	(.008)	0.901 ^b	(.007)	0.867 ^a	(.011)	7.42	.001
Expository texts	0.843 ^a	(.008)	0.892 ^b	(.009)	0.848 ^a	(.010)	6.92	.001
Narrative texts	0.851 ^a	(.009)	0.868 ^a	(.010)	0.846 ^a	(.014)	0.87	ns
ALL TEXTS	0.849 ^a	(.006)	0.887 ^b	(.005)	0.853 ^a	(.008)	8.07	.001
RECALL (proportion propositions recalled)								
Sentences	0.476 ^a	(.013)	0.538 ^b	(.017)	0.493 ^a	(.022)	3.73	.026
Expository texts	0.230 ^a	(.009)	0.286 ^b	(.014)	0.235 ^a	(.012)	6.69	.002
Narrative texts	0.256 ^a	(.011)	0.301 ^b	(.014)	0.257 ^a	(.015)	3.16	.045
ALL TEXTS	0.328 ^a	(.011)	0.391 ^b	(.013)	0.350 ^a	(.018)	5.67	.004

^a ^b Means within a row without a common superscript are significantly different.

Table 5
Mean Allocation Parameters as a Function of Type of Text

	SENTENCES		EXPOSITORY TEXTS		NARRATIVE TEXTS	
	M	se	M	se	M	se
SYLL	44	(2)	18	(2)	18	(1)
WF	-26	(1)	-15	(1)	-9	(1)
NC	13	(3)	30	(3)	26	(3)
INTSB	82	(8)	-8	(2)	15	(2)
SNTB	435	(25)	292	(19)	218	(14)
E_NEWARG			26	(4)		
E_UNIT			8	(3)		
E_SP			7	(1)		
N_PLOT					-0.11	(.02)
N_TEMP					5	(1)
Y-Intercept	518	(11)	402	(12)	435	(10)

Table 6
Correlations between Allocation Parameters for Each Type of Text

ALL SUBJECTS			
	Snt-Narr	Snt-Exp	Narr-Exp
SYLL	.50 **	.49 **	.52 **
WF	.54 **	.61 **	.69 **
NC	.34 **	.35 **	.42 **
INTSB	.45 **	.12 †	.32 **
SNTB	.65 **	.65 **	.83 **
YOUNG			
	Snt-Narr	Snt-Exp	Narr-Exp
SYLL	.56 **	.41 **	.47 **
WF	.54 **	.58 **	.53 **
NC	.14	.03	.22 *
INTSB	.13	.03	.33 **
SNTB	.54 **	.51 **	.75 **
OLD			
	Snt-Narr	Snt-Exp	Narr-Exp
SYLL	.51 **	.53 **	.58 **
WF	.48 **	.56 **	.71 **
NC	.34 **	.38 **	.39 **
INTSB	.42 **	.20 *	.37 **
SNTB	.58 **	.59 **	.79 **

NOTE: Snt=sentences; Narr= narratives; Exp=expository texts

†
p<.1

*
p<.05

**
p<.001

Table 7
Factor Pattern Matrix for Factor Analysis of Allocation Parameters

Allocation Parameter	Factor 1: Conceptual Processing	Factor 2: Expository Structure	Factor 3: Word Processing	Factor 4: Expository Chunking	Factor 5
S_SNTB	0.66				
N_SNTB	0.82				
E_SNTB	0.78		0.23		0.35
S_INTSB	0.42		0.33		
N_INTSB	0.73			0.65	
E_INTSB	0.22				0.47
S_NC	0.37				0.47
N_NC	0.42		0.36	-0.42	
E_NC	0.21				
S_SYLL			0.63		
N_SYLL			0.85		
E_SYLL			0.66		
NEG S_WF			0.61	-0.21	
NEG N_WF			0.60		
NEG E_WF			0.53	-0.50	
E_SP	0.29	1.01			
E_NEWARG		0.59			-0.28
E_UNIT		0.53			
N_TEMP	0.28			-0.21	0.47
NEG N_PLOT	-0.24				
% variance	32.31	12.31	8.61	7.20	5.48

Table 8
Correlations Between Ability Measures and Indices of Allocation Policy

	Verbal Ability	Speed	Verbal RT	Working Memory	Age
Word	.02	-.20 **	.08	-.24 ***	.25 ***
Textbase	.36 ***	-.28 **	.12	-.23 ***	.49 ***
Expository Structure	.19 **	-.25 *	.02	-.20 **	.23 ***
Plot Engagement	-.19 **	.16 *	-.06	.07	-.21 ***
Temporal Updating	.33 ***	-.27 ***	.13	-.15 *	.39 ***
Age	.78 ***	-.63 ***	.41 ***	-.55 ***	

* p < .05
 ** p < .01
 *** p < .001

Table 9
Correlations between Indices of Allocation Policy and Recall Performance

ALL SUBJECTS				
	Sentences	Expository	Narrative	OVERALL
Word	.20 **	.24 ***	.31 ***	.20 **
Textbase	.36 ***	.26 ***	.31 ***	.29 ***
Expository Structure	-.05	.13	-.05	-.11
Plot Engagement	.04	-.01	.13	.04
Temporal Updating	.06	.16 *	.04	.07
Age	.12	.13	.08	.16 *
YOUNG				
	Sentences	Expository	Narrative	OVERALL
Word	.16	.29 **	.28 **	.23 *
Textbase	.32 ***	.40 ***	.41 ***	.31 ***
Expository Structure	-.10	-.10	-.15	-.26 **
Plot Engagement	.02	.01	.02	-.02
Temporal Updating	.14	.11	.10	.14
Age	.04	-.12	-.15	.03
OLD				
	Sentences	Expository	Narrative	OVERALL
Word	.10	.16	.32 **	.13
Textbase	.38 ***	.16	.28 **	.24 *
Expository Structure	-.09	-.08	-.03	-.10
Plot Engagement	.10	.03	.27 **	.12
Temporal Updating	.14	.09	-.10	-.14
Age	-.19	-.24 *	-.16	-.20 *

*
p < .05

**
p < .01

p < .001

Table 10
Path Coefficients for Structural Equation Models to Predict Memory for Discourse (Narrative and Expository Passages)

Path	Model 1		Model 2		Model 3		Model 3a	
	Young	Old	Young	Old	Young	Old	Young	Old
<i>a</i> Age --> Speed	.41 *	-.36 *	.41 *	-.36 *	.40 *	-.36 *	.40 *	-.36 *
<i>b</i> Age --> Verbal Ability	.60 *	.07	.60 *	.07	.60 *	.03	.60 *	.03
<i>c</i> Speed --> Working Memory	.52 *	.52 *	.53 *	.53 *	.53 *	.53 *	.53 *	.53 *
<i>d</i> WM --> Verbal Ability	.27	.27	.27	.27	.28	.28	.28	.28
<i>e</i> WM --> Textbase	.11	.11	.09	.09				
<i>f</i> WM --> Word	-.18 *	-.18 *	-.18 *	-.18 *	-.16 *	-.16 *	-.16 *	-.16 *
<i>g</i> Verbal Ability --> Textbase	.31 *	.31 *	.28 *	.28 *	.30 *	.30 *	.30 *	.30 *
<i>h</i> Verbal Ability --> Word	-.21 *	-.21 *	-.20 *	-.20 *	-.21 *	-.21 *	-.20 *	-.20 *
<i>i</i> Word --> Textbase	.86 *	.86 *	.86 *	.86 *	.84 *	.84 *	.84 *	.84 *
<i>j</i> Textbase --> Text Memory	.51	.51	.48 *	.48 *	.47	.47	.62 *	.36 *
<i>k</i> WM --> Text Memory	—	—	.15 †	.15 †				
<i>l</i> Verbal Ability --> Text Memory	—	—	.19 *	.19 *	.23 *	.23 *	.49 *	.16 *
<i>m</i> Age --> Text Memory	-.32 *	-.20 *	-.45 *	-.17	-.48 *	-.20 *	-.67 *	-.19 *
RMSEA	0.0696		0.0697		0.0685		0.0679	
PCLOSE	0.530		0.534		0.579		0.603	
CHI-SQ	598.96		601.07		591.91		585.15	
df	377		375		377		375	

* $p < .05$ ~ $p < .06$ † $p < .1$

Table 11
Path Coefficients for Structural Equation Models to Predict Memory for Sentences

Path	Model 1		Model 2		Model 3		Model 3a	
	Young	Old	Young	Old	Young	Old	Young	Old
<i>a</i> Age --> Speed	.41 *	-.36 *	.40 *	-.36 *	.40 *	-.36 *	.39 *	-.36 *
<i>b</i> Age --> Verbal Ability	.60 *	.07	.60 *	.07	.60 *	.07	.59 *	.07
<i>c</i> Speed --> Working Memory	.52 *	.52 *	.52 *	.52 *	.52 *	.52 *	.53 *	.53 *
<i>d</i> WM --> Verbal Ability	.27	.27	.28	.28	.28	.28	.28	.28
<i>e</i> WM --> Textbase	.13	.13	.07	.07				
<i>f</i> WM --> Word	-.18 *	-.18 *	-.18 *	-.18 *	.16 ~	.16 ~	-.16 ~	-.16 ~
<i>g</i> Verbal Ability --> Textbase	.33 *	.33 *	.28 *	.28 *	.30 *	.30 *	.30 *	.30 *
<i>h</i> Verbal Ability --> Word	-.21 *	-.21 *	-.21 *	-.21 *	-.21 *	-.21 *	-.21 *	-.21 *
<i>i</i> Word --> Textbase	.85 *	.85 *	.85 *	.85 *	.83 *	.83 *	.83 *	.83 *
<i>j</i> Textbase --> Text Memory	.40 *	.40 *	.38 *	.38 *	.38 *	.38 *	.28 *	.28 *
<i>k</i> WM --> Text Memory	—	—	.30 *	.30 *	.32 *	.32 *	.35 *	.35 *
<i>l</i> Verbal Ability --> Text Memory	—	—	.32 *	.32 *	.32 *	.32 *	.38 *	.38 *
<i>m</i> Age --> Text Memory	.03	-.17 *	-.21	-.11 †	-.21	-.11 †	—	—
RMSEA	0.0774		0.0692		0.0690		0.0693	
PCLOSE	0.218		0.545		0.558		0.546	
CHI-SQ	585.93		532.89		533.75		538.60	
df	339		337		338		340	

* $p < .05$

~ $p < .06$

† $p < .1$