NIH Public Access
Author Manuscript
Psychol Bull. Author manuscript; available in PMC 2008 February 18.

Published in final edited form as:
Psychol Bull. 2006 July ; 132(4): 582–606.

Aging and Self-Regulated Language Processing

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Abstract

This paper introduces an adult developmental model of self-regulated language processing (SRLP), in which the allocation policy with which a reader engages text is driven by declines in processing capacity, growth in knowledge-based processes, and age-related shifts in reading goals. Evidence is presented to show that the individual reader's allocation policy is consistent across time and across different types of text, can serve a compensatory function in relation to abilities, and is predictive of subsequent memory performance. As such, it is an important facet of language understanding and learning from text through the adult life span.

Keywords

reading; language processing; comprehension; text memory; strategies; cognitive aging; adult development and aging; self-regulation; compensation

Conventional notions of human development place education and learning at the front end of the life span where they serve to create a repository of knowledge upon which one may draw in the course of adult pursuits (Riley & Riley, 1994). However, with longer life spans and a shifting demographic toward an older population, it is becoming increasingly obvious that the ability to learn new things is critical to maintaining vitality throughout the life span. Text serves as a primary conduit for learning, even in later adulthood. Yet there is considerable controversy with respect to the nature of language processing, in general, and the way in which age-related changes in cognition impact language functions, including comprehension and production. Contemporary models of discourse processing conceptualize language understanding as arising from a coordinated array of processes that operate on the orthographic (or acoustic) signal to produce a multifaceted representation of the meaning of a text (e.g., Caplan & Waters, 1999; Graesser, Millis, & Zwaan, 1997; Just & Carpenter, 1992; Kintsch, 1998). Our goal in this paper is to offer a model of how these processes are coordinated in concert and consider how this coordination may change through the adult life span. By way of introduction to this

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Self-Regulated Language Processing (SRLP) Framework, we consider the nature of language processing, the nature of cognitive aging, and the principles through which cognition is self-regulated. After outlining the basic tenets of our model, we consider the landscape of adult developmental change and stability in language processing through the lens of the SRLP Framework.

In a nutshell, we argue that the heuristics for self-regulation in language processing show dynamic change through the life span. These changes reflect adaptation to age-related changes in relevant cognitive and affective processes. Moreover, the goals of older readers may evolve in ways that influence how text is comprehended and used. These life-span developmental changes have important implications for reading during adulthood. Reading requires resource-consuming computations (in addition to those that are relatively automatic) to construct a representation of text content (Just & Carpenter, 1992) and is affected in terms of both process and product by the availability of knowledge (Britton & Tesser, 1982; Chiesi, Spilich, & Voss, 1979; Moravcsik & Kintsch, 1993). Furthermore, reading is both guided by and gives rise to affective responses (Hacker, 1998; Smith, 1998). Developmental changes in all of these features of text processing provide reasons to believe that the processes and outcomes of reading may change throughout adult life.

The Nature of Language Understanding from Written Text

In reading, written configurations are decoded so as to activate lexical representations of words; the meanings of individual words are activated and a particular meaning is selected and instantiated in context. Based on the syntactic organization of discourse, interrelationships among concepts are constructed so as to produce a representation of the ideas, or propositions, in the text. These ideas are organized and prioritized to represent the meaning of the content given by the text (a “textbase”). Limitations in memory capacity to some extent constrain the way this is accomplished. A text’s meaning is constructed across a series of “input cycles,” equivalent to a sentence, clause, or more minor syntactic constituent, depending on the individual capacity of the reader. As such, the propositional representation at any point in the discourse is constructed so as to be coherent with the residual representation of the meaning of the text constructed to that point. At the same time, this representation is constructed in light of and integrated with the existing knowledge of the reader. Three important sources of knowledge that the reader brings to bear are (a) cultural and socioemotional knowledge, (b) domain knowledge relevant to the content of the text, and (c) structural knowledge of how certain types of discourse are constructed (e.g., a sequence of narrative episodes or lines of argument in an exposition). Ultimately, a reader’s understanding of a text encompasses a representation of the situation described by the discourse that derives from textbase content, knowledge-based inferences, and the structure of the text.

This exposition of language understanding may be characterized as a fairly uncontroversial, consensus perspective of language processing (see Kintsch’s (1988, 1998) construction-integration model; also, Graesser et al. (1997) for a review). This conceptual frame, nevertheless, sets the stage for many points of disagreement on the particulars. Issues that are particularly controversial include (a) the processing mechanisms underlying lexical access and the instantiation of word meanings in particular contexts (Kambe, Rayner, & Duffy, 2001; Swinney, 1979), (b) the extent to which inferences are driven by attention to local or global coherence (Graesser, Singer, & Trabasso, 1994; McKoon & Ratcliff, 1992) (c) whether the availability of inferences reflect the automatic spread of activation or strategic integration (e.g., Long & Lea, 2005; van den Broek, Rapp, & Kendeou, 2005), and (d) more generally, the exact nature of the cognitive resources used to fuel computations (Caplan & Waters, 1999; DeDe, Caplan, Kemtes, & Waters, 2004; Just & Carpenter, 1992; Kemper, Crow, & Kemtes, 2004).

Readers are finely attuned to the moment-to-moment demands of text at the surface, textbase, and discourse levels; hence, reading time is exquisitely sensitive to the processing used to meet these demands. Research in text processing often relies on the measurement of online reading time in response to experimental manipulations of text demands to demonstrate the existence of particular computations. For example, longer reading times associated with low-frequency words provide evidence for a lexical access process (Rayner, Liversedge, White, & Vergilino-Perez, 2003); readers' systematic increase in time allocation as a function of propositional density is evidence for the psychological reality of the textbase (e.g., Kintsch & Keenan, 1973); and differences in reading time as a function of different syntactic structures independent of semantic constraints provide evidence for parsing algorithms (Ferreira & Clifton, 1986). Relatively long reading times at the ends of clauses (Haberlandt & Graesser, 1989b) and sentences (Haberlandt, Graesser, Schneider, & Kiely, 1986) provide evidence for the psychological reality of the input cycle. The increase in these boundary times as function of clausal and sentence complexity (Aaronson & Scarborough, 1976, 1977) has been taken as evidence that readers consolidate the conceptual representation at these discrete points in the course of text processing. The increase in boundary times following the clarification of a lexical ambiguity provides evidence that ambiguity resolution is achieved only at the end of an input cycle (Daneman & Carpenter, 1983).

Similar arguments have been used to justify models of higher-level information in texts. The increase in reading times in the face of information inconsistent with the discourse situation (O'Brien, 1995) and the increase in verification times for backgrounded entities (Glenberg, Meyer, & Lindem, 1987) provide evidence that a representation of the larger network of circumstances and relationships among entities and actions, termed a situation model, has been constructed (Zwaan & Radvansky, 1998). This sort of reasoning is pervasive in the literature (the studies cited are only a small subset of examples), and suggests a paradigmatic understanding of language processing as a collection of computations that are conducted on an "as needed" basis. In the extreme case, the nature of language understanding is articulated as "dumb" (Gerrig & McKoon, 2001), driven by the automatic waxing and waning of activation.

This general conceptualization has been important in articulating the sorts of computations needed to construct meaning. However, there are individual differences in the meaning that readers glean from text, suggesting that these computations are not always completed successfully. In fact, it is virtually impossible for anyone to fully construct meaning from any text of substance. As readers, we cannot access and instantiate the meaning of every concept, appreciate every lexical nuance, represent every conceptual relationship, invariably track a protagonist through the spatiotemporal context with precision, follow every nook and cranny of argumentation, engage every emotional subtly, and so on. Rather, readers make both explicit and implicit choices about the selective allocation of resources to construct meaning, choices that are constrained by individual differences in ability, knowledge, interest, and motivation, as well as by context and task demands.

Recent research suggests that even at the level of syntactic analysis, which is often taken as the exemplar of automatic and obligatory computation (Fodor, 1983; Caplan & Waters, 1999), parsing heuristics may not yield a single veridical representation of sentence structure. Rather, the parser may produce a "good enough" representation that suffices in the ordinary course of communication (Christianson, Hollingsworth, Halliwell, & Ferreira, 2001; Ferreira, Bailey, & Ferraro, 2002). For example, in reading a garden path sentence like "While Anna dressed the baby spit up on the bed," readers revise their syntactic analysis to achieve the correct interpretation that baby is the subject of the second clause, but also do not completely inhibit the (incorrect) interpretation that Anna was dressing the baby (Christianson et al., 2001). Ferreira, Christianson, and their colleagues argue that syntactic parsing is not an all-or-none affair, and that readers simultaneously hold the representation that Anna is dressing herself and the baby; it is "good enough" just to understand that Anna dressed herself (regardless of the other interpretations activated). Similarly, van den Broek, Lorch, Linderhold, and Gustafson (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; not surprisingly, readers with a test goal also showed better recall of the text. 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."

At the same time, there is a vibrant literature examining how individual differences in relevant cognitive abilities, such as verbal ability or working memory, contribute to variability in language performance (Daneman & Merikle, 1996; Meyer, 1989). It is well known that individual differences in reading comprehension and memory for text are correlated with associational fluency, working memory, and reasoning ability (e.g., Carroll 1993; Frederiksen 1981; Hultsch, Hertzog, Dixon, & Small, 1998; Just & Carpenter, 1992). What is often overlooked is the extent to which individual differences in readers' allocation policies, i.e., the manner in which attentional resources are distributed among linguistic computations, contribute to variation in the quality of the mental representation created from text. The focus of this paper is to fill that gap, considering how individual differences in self-regulatory function contribute to language understanding and memory.

The Nature of Cognitive Aging

Cognitive aging is multidimensional and multidirectional (Baltes, 1997). While "mental mechanics," or "fluid" abilities, peak in mid-life and show decline as a byproduct of biological aging, "pragmatics," "crystallized" abilities, and knowledge continue to grow (Beier & Ackerman, 2005; Baltes, Staudinger, & Lindenberger, 1999). Of course this is a broad generalization, and there are some notable exceptions (e.g., mechanisms of selective attention are slowed but otherwise do not appear to be impaired in adulthood; Kramer & Weber, 1999). Nevertheless, the relative preservation of knowledge and well-learned procedural skills (Ericsson & Charness 1994) is essentially undisputed.

Age-related decreases in mental mechanics have been conceptualized in a number of different ways in cognitive aging, for example, as declining speed of processing (Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1996), declining capacity of working memory (Carpenter, Miyake, & Just, 1994; Park et al., 1996), and as a functional decline in working memory capacity rooted in lowered efficiency of inhibitory mechanisms (Hasher & Zacks, 1988, Zacks, Hasher, & May, 1999). Age-related growth in pragmatics and knowledge-based systems is evident in verbal intellectual functions, as well as in world knowledge and acculturation, and particularized knowledge systems that grow as a function of one's choice of engagement (Ackerman & Rolfhus, 1999; Hoyer, Rybash, & Rooodin, 1989; Schaie, 1994; Stanovich, West, & Harrison, 1995). There appears to be a reciprocal relationship between ability and discourse processing. On the one hand, age-graded declines in mental mechanics can limit language processing (van der Linden et al., 1999) and growth in verbal ability can augment language processing (Meyer & Rice, 1983, 1989; Stine-Morrow, Loveless, & Soederberg, 1996), indicating effects of ability on discourse processing. On the other hand, habitual engagement with text during adulthood, along with other forms of intellectual engagement, may also increase crystallized knowledge (Stanovich et al., 1995), and more broadly, provide cognitive reserves that can buffer against the effects of late-life pathology (Hultsch, Hertzog, Small, & Dixon, 1999; Manly, Byrd, Touradji, & Stern, 2004; Ostrosky-Solis, 2004; Wilson et al., 2000; Wilson & Bennett, 2003; C. Schooler & Mulatu, 2001; C. Schooler, Mulatu, & Oates, 2001). Furthermore, this cognitive system is embedded in a broader psychological system in which the nature of intellectual goals may show a developmental shift (Adams, 1991; Labouvie-Vief, 1985; Labouvie-Vief & Diehl, 2000). For example, socio-emotional motives may take precedence over information-based cognitive goals (Carstensen, 1995; Isaacowitz et al., 2000). While evidence is relatively sparse on this latter point, a bidirectional relationship is again plausible: to the extent that reading, as well as broader participation in the discourse world, contributes to affect regulation (Smith, 1998), this might be expected to play a more central role with movement through the adult life span. By the same token, the selection of and manner of engagement with text would be expected to shift with the increasing centrality of emotion. In any case, these three core principles of adult development and aging, (a) later life decline in mental mechanics, (b) preservation or increase in pragmatics, and (c) increased centrality of emotional concerns have, in our view, important potential implications for the organization of reading at the process level.

Self-Regulation of Cognition and Learning

Explicitly or implicitly, self-regulatory effectiveness has featured prominently in discussions of cognitive aging for some time. This is perhaps most clearly seen in Craik's (e.g., Craik & Jennings, 1992; Craik & Anderson, 1999) notion that age-related change in cognition is characterized as a failure to self-initiate the processing required for effective encoding. Self-regulatory failure is implicated in a number of other theories as well. For example, Hasher and Zacks' (1988; Hasher, Zacks, & May, 1999) inhibition deficit hypothesis holds that the source of age-related deficits in cognition is an inability to restrain the activation of irrelevant information. At its essence, the heart of this hypothesis is a failure in cognitive regulation. Social psychological and metacognitive views of self-regulation (e.g., Muraven & Baumeister, 2000; Carver & Scheier, 1998; Nelson & Narens, 1990) derive from a conception of the person as managing goals in cognitively demanding situations (Miller, Galanter, & Pribram, 1960). Life-span developmental theories of self-regulation follow suit with the assertion that primary (or direct) control potential decreases from mid- into late-life, in part, because cognitive mechanics can constrain the effectiveness of cognitive self-regulation using means to achieve goals that had once been effective (Heckhausen, 1999). At the same time, the argument is frequently made that maintaining regulatory control via mechanisms of selection and compensation is key to successful aging (e.g., Bäckman & Dixon, 1995; Baltes, 1997; Baltes & Baltes, 1990; Fernandez-Ballesteros, 2005).

The Role of Resources in Cognitive Self-Regulation

Over the last decade, self-regulation has been assigned a more explicit role in cognition, memory, learning and skilled performance (Gopher & Koriat, 1999; Kanfer & Ackerman, 1996; Schunn & Reder, 2001), and more generally goal attainment (Carver & Scheier, 1998, 2000; Heckhausen, 1999; Heckhausen & Schulz, 1995). Cognitive self-regulation is often studied under the rubric of metacognition, which encompasses the ability to monitor and control one's own cognitive processes (e.g., Nelson, 1996). Sometimes thought of as a procedural skill, such regulation includes decisions about allocation of effort, selection of processing strategies, emitting or withholding responses, and the speed at which the task should be completed (e.g., Hacker, 1998; Koriat, Goldsmith, & Pansky, 2000; Metcalfe & Kornell, 2003; Thiede & Dunlosky, 1999). It is important to note that such monitoring and control may not always be available to conscious awareness (Reder & Schunn, 1996; J. Schooler, 2002), such that readers may shift allocation policy in response to changing demands without an awareness or ability to articulate the change (Howard & Howard, 2001). In the present context, the development of an allocation policy may be an example of implicit learning, in which behavior exhibits changes in response to experience without being available to conscious awareness. At the same time, self-regulation is often conceptualized as being resource-consuming (e.g., regulation of task coordination can be disrupted by an increased load; Baddeley & Logie, 1999). Assuming that working memory regulates the allocation of resources to task demands (e.g., the working memory "central executive" in Baddeley's (1986) model) and that working memory capacity is diminished with age (Carpenter, Miyake, & Just, 1994), one might expect that an age-related decrease in resources available for central executive functioning would produce an age-related decrease in the self-regulation of cognition, thereby impacting language processing (cf. Gathercole & Baddeley, 1993).

In this vein, Kanfer and Ackerman (1996) have argued that self-regulatory processes are among the task demands that are resource-consuming, such that they can either improve or depress performance depending on on-task demands and skill level. For example, goal-setting is more effective once task performance is automatized, but can depress performance in the early stages of learning. They argue that heavy allocation of resources to self-regulation (e.g., goal-setting, goal-monitoring) can direct resources away from where they are needed the most, managing task performance. Similarly, Muraven and Baumeister (2000) have noted that self-regulatory control in one arena can subsequently diminish control in another. Such arguments have been made to explain the effects of trait anxiety on working memory-demanding tasks (i.e., diversion of resources to monitoring affective state, at the expense of task management; Eysenck, 1997).

Recent work by Beilock, Carr and colleagues (Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Carr, MacMahon, & Starkes, 2002) suggests that conscious self-regulation (defined as skill-focused attention) may be more advantageous to novices than to experts. In a series of experiments, they have shown that novice performance is supported by attentional allocation to component skills in complex performance, but that expert performance is depressed by such an allocation policy. The argument is that skilled performance is characterized by proceduralized control in which component skills act in concert (Schneider & Chein, 2003). Whereas novices, who are still "compiling" component skills into procedures (Anderson, 1982), benefit from control at the microlevel level of component processes, expert performance is disrupted by skill-focused attention because it disrupts proceduralized control. An important advantage of proceduralized control is that, in fact, skill can operate without attention, so that performance is substantially immune to the effects of distraction (provided, of course, that the interference is not structural in nature, e.g., operating in the same modality).

Recent research, therefore, suggests that cognitive self-regulation encompasses selective allocation of attention both to the operation of the components of cognitive processes as well as to metacognitive control (see also Thiede & Dunlosky, 1999). Control at the micro- and macrolevels appears to compete for attentional resources, and optimization of performance at different levels of proficiency appears to depend on the allocation policy with respect to these different levels.

Heuristics of Self-Regulated Learning

Carver and Scheier (1998; 2000) have offered a relatively broad-based conceptualization of the self-regulation of behavior that is easily adapted to a cognitive paradigm (e.g., incorporating notions of mental representation and process). In this model, behavior (and processing that gives rise to mental representations) are regulated on the basis of a system of integrated negative feedback loops, the core notion being that behavior change arises when the current state (of the organism or system) is perceived to differ from the desired state (also see T.D. Nelson (1993) and Powers (1973)). A negative feedback loop (as shown in Figure 1) has four elements: (1) an input function (i.e., a sensor, or perception of the current state of the system), (2) a reference value (which sets the standard for the system), (3) a comparator (which compares the reference value and information from the input function), and (4) an output function (a behavior, or a cognitive process), which has some effect on the environment or current mental representation (which in turn is sensed by the input function). Similar conceptions, deriving from general concepts of homeostasis, form the basis for models of self-regulation in many disciplines, and have roots in early information processing models of cognitive and neural functioning (e.g., Miller et al., 1960).

The basic assumption is that the output function is stable in its operation unless the comparator detects a discrepancy between the reference value and the input function. The action of the output function is designed to eliminate the discrepancy (i.e., change the input so that it is not discriminable from the reference value). These systems are called "self-regulatory" because they are regulated by means of the system's own internal organization. For example, the regulator on an air conditioning unit relies on such a mechanism. The inhabitant sets the thermostat at a certain temperature (the reference value). When the thermostat detects that the temperature is higher than the reference value, it turns on the compressor; once the comparator no longer detects a difference, it no longer signals for action from the compressor. Such systems can vary in interesting ways, for example, whether the reference value is a steady state (as in the thermostat example) or a pattern of values (e.g., a set of driving directions); the sensitivity of the input function; the degree of discrepancy tolerated by the comparator; the lag between changes in the output function and its detection by the input function; the addition of "disturbances," which may make a previously effective behavior ineffective.

Negative feedback loops can be integrated into hierarchies such that the output from one system can feed into yet another system. For example, we implement motor programs (e.g., blend brown sugar and butter) to meet "do" goals (e.g., to make fudge nut bars for a potluck), which in turn meet "be" goals (e.g., to be a contributor to a community). Also, the input functions of higher-order systems can feed into the reference values for the lower-order systems (e.g., the inhabitant (who is the higher-order system) can reset the thermostat (the lower-order one)). Through such extensions, Carver and Scheier have applied this approach to a range of psychological phenomena, making the important point, that there are affective consequences to discrepancy. In a series of experiments in which they manipulated the match between expectations and behavior over trials, they showed that while discrepancy can generate negative affect, positive affect arises when discrepancy is reduced.

There is some evidence that self-regulation in learning can be characterized as a discrepancy reduction process. This has been demonstrated in the judgment-of-learning (JOL) paradigm, used to study the self-regulation of learning. For example, Nelson, Dunlosky, Graf, and Narens (1994) asked college students to study Swahili-English word pairs over a series of trials in which they also estimated the probability with which they would later be able to recall the item (the "JOL"). The subjects were randomly assigned to one of four groups that differed in the particular items selected for restudy on each trial: worst learned items (WL), self-chosen items (SC), normatively most difficult items (ND), and best learned items (BL). Across trials, the SC group showed equivalent performance to the WL group, with both of these groups showing better performance than the other two, suggesting that the algorithm for regulation of study time was functionally equivalent to selecting worst-learned items, and that there is a monitoring process that is more effective than a heuristic based on normative difficulty (SC>ND). These data are consistent with the idea that young adult learners self-regulate so as to allocate resources selectively to items perceived to be unlearned, and that this is relatively effective (cf. Dunlosky & Thiede, 2004; Thiede & Dunlosky, 1999). Nevertheless, there are boundary conditions under which this simple relationship breaks down. Instructions to increase accuracy may increase study time without an additional gain in accuracy, a phenomenon known as the "labor-in-vain" effect (Nelson & Leonesio, 1988). Learners may increase study time sufficiently to completely accommodate difficulty only with considerable support (Glenberg, Sanocki, Epstein, & Morris, 1987; Pelgrina & Bajo, 2000).

In paired-associate learning, the accuracy of JOLs is often rather low, and can be dissociated from factors that impact learning itself (e.g., Schwartz, Benjamin, & Bjork, 1997; Hertzog, Dunlosky, Kidder, & Robinson, 2003; Mazzoni & Nelson, 1995). Consequently, one interest in this paradigm is what sorts of "evidence" are used by the input function. In metacognitive models, this information is made available to control processes through mechanisms of monitoring (e.g., Nelson, 1996). Whereas early models held that perceived learning was based on direct monitoring of the representation (or strength of the trace) (cf. Hacker, 1998), this hypothesis has not withstood empirical scrutiny. JOL accuracy is enhanced when there is a brief delay between study and JOL, suggesting that monitoring may be based in part on ease of retrieval from memory, rather than on the direct monitoring of encoding or the contents of memory itself (Cull & Zechmeister, 1994; T. O. Nelson & Dunlosky, 1991).

Koriat (1997) has proposed a cue-utilization model for JOLs in which perceived learning is based on information from three different sources (or cues): intrinsic factors (characteristics of the studied items, e.g., concreteness), extrinsic factors (conditions of learning, e.g., number of study trials), and mnemonic factors ("indicators that may signal for the participant the extent to which an item has been learned and will be recalled in the future," "phenomenological experiences that accompany information processing," p. 351). He argues that intrinsic and extrinsic cues can affect perceived learning directly or indirectly through mnemonic cues, and that the relative weight of these three factors may change with the conditions of learning. For example, after repeated study of the same items, subjects may rely more on mnemonic cues (Connor, Dunlosky, & Hertzog, 1997; Koriat, 1997; Koriat & Bjork, 2004). So in terms of the Carver-Scheier (C-S) conceptualization of the negative feedback loop (cf. Figure 1), the input function (i.e., the perceived degree of learning) may receive information not only from the "effect" (i.e., mnemonic cues with respect to the strength of representation), but also from the output function (i.e., mnemonic cues with respect to the nature of processing), as well as from intrinsic and extrinsic cues of the text and learning context.

Another concern in this paradigm is what principles govern how effort is allocated (i.e., how the output function is engaged) as a consequence of monitoring. Discrepancy reduction may be a resource-consuming heuristic for allocating effort, and may be abandoned entirely under certain conditions. For example, Thiede and Dunlosky (1999) demonstrated that when the learning goal was relaxed or when study time was limited, the relationship between JOLs and the probability of item selection was reversed, such that learners were more likely to pick the easier items for study (Dunlosky & Theide, 2004). Another self-regulatory heuristic that learners may use is to allocate effort within a "region of proximal learning" (Metcalfe & Kornell, 2003, 2005). For example, Metcalfe (2002) asked college students to learn English-Spanish word translations in a situation in which allocation choices were well-structured in terms of difficulty, and showed that learners allocated the most study to items of intermediate difficulty. However, students who were proficient in Spanish selectively allocated study to the most difficult items, showing that this region is relative to the current abilities of the learner.

Models of discrepancy reduction and a region of proximal learning may not be mutually exclusive. Discrepancy reduction is often taken to be synonymous with a strategy of allocating effort to the most difficult elements (Thiede & Dunlosky, 1999) in an effort to reduce the discrepancy between the current state of learning and perfect learning of the whole array (i.e., "complete compensation"). The more generic meaning of discrepancy reduction from the C-S/Powers self-regulatory framework is the reduction of discrepancy between current learning and the goal (thus, not assuming that the goal is perfect learning of the whole array; see Dunlosky & Thiede, 2004). This approach allows one to consider how discrepancy reduction might work relative to the scope of elements within the array as a function of how close the level of learning is to the goal (e.g., unlearned vs. partially learned elements) as well as to the level of the goal itself (e.g. perfect learning vs. 80%). So for example, learners may adopt a discrepancy reduction heuristic with the goal of perfect learning for a subset of elements for which the allocation of effort is most likely to reach the goal. Such a heuristic would be tantamount to a region-of-proximal-learning strategy. As knowledge (i.e., learned elements) and resources available increase, more difficult elements are selected but as resources are constrained, easier elements are targeted for discrepancy reduction. Such a distinction is important in the application of these models to text processing because of the inherent impossibility of "perfect learning" from any text of substance. (See also Kintsch's (1994) notion of "zones of learnability" suggesting that the relationship between knowledge and text difficulty should be moderate in order to promote the most learning; and see Wolfe et al. (1998) for empirical support based on latent semantic analysis). Depending on context, ability, and knowledge, readers will allocate their attention to different levels of analysis in the discourse with goals that vary in the need for fidelity of representation.

Self-Regulation of Cognition with Aging—To the extent that the self-regulatory processes of goal setting and monitoring behavior relative to the goal are resource-consuming, one might expect such processes to be less effective with age. There is some evidence for this (Paas, Camp, & Rikers, 2001; West, Welch, & Thorn, 2001). Also, some have suggested that aging brings diminished capacity to benefit from feedback (Baron & Surdy, 1990), which may, in part, be due to lowered levels of self-efficacy if goals are set so as to be unattainable (West et al., 2005).

There is a growing literature examining the role of self-regulatory failure specifically in age-related memory deficits (Hertzog & Hultsch, 2000; Dunlosky & Hertzog, 1998). Generally speaking, older adults are more likely to overestimate their global memory performance than younger adults are, but are as accurate as the young in monitoring their level of learning for specific instances (e.g., Connor et al., 1997; Hertzog, Kidder, Powell-Moman, & Dunlosky, 2002). Furthermore, in at least some aspects of self-regulation, older adults appear to be similar to younger adults. Dunlosky and Hertzog, (1997) showed that older adults, like the younger adults studied by Nelson et al. (1994), selected items for restudy in accord with a discrepancy-reduction decision rule; they picked items for restudy they had not previously learned. However, older learners may not allocate resources as effectively to studying the unlearned material or in regulating readiness for recall (Murphy, Schmitt, Caruso, & Sanders, 1987). For example, using the JOL paradigm, Dunlosky and Connor (1997) suggested that a failure in self-regulation contributes to age-related deficits in paired-associate learning. Older adults showed both lower levels of recall and lower JOLs and were similar to the young in their JOL accuracy, suggesting that (in terms of the C-S conceptualization) although the output function (i.e., memory processes) was not functioning well in the older sample, the input function (i.e., monitoring the level of functioning) was intact. However, whereas both young and old showed a negative correlation between JOLs and study time (i.e., more time allocated to less well learned items), this relationship was considerably weaker for the older group. Thus, age differences in memory performance could be in part attributed to a regulatory failure. In terms of the C-S framework, there was a breakdown in either the comparator or the responsiveness of the output function (i.e., ability or willingness to adjust the allocation policy) to information from the comparator. While there are a number of other empirical demonstrations of encoding behavior being related to age-related differences in memory (Craik, 2002), it is not always the case that monitoring has been empirically isolated from adjustment of allocation policy, and age differences in self-regulation have not been shown to completely account for age differences in memory performance. However, the Dunlosky and Connor (1997) study suggests that it may be an important contributing factor.

In a direct application of the JOL paradigm to sentence memory, Miles and Stine-Morrow (2004) asked younger and older participants to learn information from sentences that varied in terms of difficulty (informational density) across two trials. Older readers allocated disproportionately less effort to the most difficult sentences and showed disproportionately lower recall of the content, suggesting that their poorer performance was, in part attributable to a failure to allocate resources to these difficult sentences. Interestingly, both younger and older readers appeared to use a discrepancy reduction heuristic in learning (i.e., allocation of effort in rereading to unlearned sentences). However, for the older readers, discrepancy reduction was differentially enhanced for sentences of intermediate complexity. In other words, it appeared that the older readers used a different allocation policy in creating their textbase representation: to maximize the allocation of effort to where it would most likely create a change in the state of the memory representation; that is, they were relatively more likely to allocate effort within their region of proximal learning.

Implications for Language Processing—This abbreviated literature review of self-regulated cognition offers a different lens through which to view language processing. The fact that processing time increases with computational demands suggests that language comprehension may generally operate via a discrepancy reduction process (i.e., time allocated until computations yield comprehension – though we will argue that the role of references values becomes especially important in this extension). A discrepancy reduction heuristic would be evident in language processing when greater effort is allocated to a representation that is relatively more fragmented, and when less effort is allocated as the representation is strengthened, as in the case of the rereading benefit (Levy, Di Persio, & Hollingshead, 1992; Levy & Kirsner, 1989; Levy, Newell, Snyder, & Timmins, 1986). However, an alternative to a discrepancy reduction heuristic (in which one monitors the status of memory and allocates effort to bolster relatively more fragmented representations) is a heuristic in which effort is allocated to that which is on the verge of being learned (i.e., within the region of proximal learning, in which the learning state is relatively close to the reference value).

Furthermore, this overview suggests that the monitoring and selective allocation of effort to mental activity can be resource-consuming, so that aging may bring a change in how cognition is regulated. Contributing factors include the strain on working memory resources for monitoring and processes associated with implementing a discrepancy reduction heuristic, as well as resource-consumption of inhibitory processes. To the extent that reading is a medium through which information is encoded into the memory system, it would be expected to be vulnerable to these effects (e.g., an increased likelihood of dysregulation of language input as demands are increased or resources are otherwise strained, as in aging). However, in learning generally, and in learning from text, older adults might appear to be dysregulated, when they may, in fact, may be allocating effort according to a heuristic that is more likely to garner success (e.g., according to principles of selective optimization and/or a region-of-proximal-learning strategy).

Finally, it is important to keep in mind that reading is often a well-learned skill among adults in a literate society. Consequently, attention explicitly directed to monitoring and self-regulatory control of components may be genuinely detrimental.

An Adult Developmental Model of Self-Regulated Language Processing

Drawing on these three literatures (psycholinguistics, cognitive aging, and self-regulated cognition), we conceptualize self-regulation of language processing in terms of the heuristics that appear to govern learning more generally. Readers (and listeners) allocate effort to the computations that give rise to comprehension so as to create a representation that is "good enough" (Ferreira et al., 2002) for their current processing goals. Self-regulatory control operates at multiple levels of analysis, ensuring effective goal pursuit, subject to constraints created by each person's profile of cognitive resources and other relevant variables. The key functions of the Self-Regulated Language Processing (SRLP) Model are illustrated in Figure 2.

Cognitive Architecture

The core of the SRLP model is a set of negative feedback loops, each regulating the construction of the language representation at the levels of the word, the textbase, and the discourse. These feedback loops operate in the context of both the knowledge and goals of the reader. In terms of cognitive architecture, we assume that (a) the key components of the negative feedback loops (i.e., input and output functions, comparator, reference value, and current representation) are products and processes that must be active in working memory to be executed, (b) that goals and knowledge are available in long-term memory, although specific aspects of both constructs can be maintained in an activated or primed state by conceptual processing (see Ericsson & Kintsch, 1995; Kintsch, 1998), and (c) as needed, goals and knowledge are activated in working memory as part of constructing and integrating meaning (Kintsch, 1998).

Output Functions and Meaning Representation—Reading processes at each of these levels are assumed to be separate but coordinated output functions, each with their own comparators and reference values. In this model, the reader's "allocation policy" (i.e., the manner of engagement with a text) is defined by the coordinated operations of these output functions. So for example, processes that give rise to orthographic decoding and lexical access constitute the output function at the word level. Processes that underlie the construction of a coherent textbase (e.g., conceptual instantiation and organization, anaphoric integration, ambiguity resolution) constitute the output function at the textbase level. Situation model processes (e.g., monitoring and updating the status of the protagonist with respect to spatiotemporal location, emotional state, and goal state) are in the province of the output function at the discourse level, as are processes that construct and monitor structural representations for particular genres of discourse (e.g., story grammars, different expository forms). Although these different levels of analysis are conceptually distinct, they work interactively to give rise to the seamless understanding of discourse. The output functions at the word and at the textbase level each operate holistically, but what is represented as a single output function at the discourse level may well be a collection of output functions, corresponding to discourse structures of different genres and different aspects of the situation model (e.g., Friedman & Miyake, 2000). Finally, for word and textbase processes, output functions are assumed to operate in a relatively consistent manner of allocation (e.g., with respect to efficiency and persistence) within an individual across time and across different types of texts. Because the operation of the output functions involve procedural skills that derive from habitual use (Perfetti 1989) so that allocation can become routinized, if not automatic, an allocation policy may be thought of as reflecting a "habit of mind."

Input Functions and Monitoring—The model assumes that language comprehension is potentially monitored via input functions along the three dimensions corresponding to those of the output functions, though relative levels of attention to these different input functions will vary as a function of the array of reference values. For example, in proofreading a manuscript for which one has little knowledge of content, the word-level reference value might be set to a very stringent level relative to the discourse reference value (see discussion below), so that word comprehension and local coherence would be monitored rather closely, while gaps in the situation model might be entirely ignored.

As noted earlier, the issue of what cues feed into these input functions is complex. It may be that for text understanding, mnemonic cues (e.g., information deriving from the memory representation; Koriat, 1997) figure more prominently in this assessment than is the case in judgments about verbal learning. Maki (1998) showed the delayed-JOL effect (better monitoring accuracy with a delay between study and JOL) did not obtain for reading, and that readers were most accurate with an immediate JOL and immediate test. Assuming that the representation that is constructed while reading is an integrated network of concepts (Kintsch, 1998) grounded in perceptual symbols (Barsalou, 1999), there is greater potential for complexity (compared to that derived in stimulus-response learning), so that the fidelity of this representation is relatively diagnostic of what will actually be remembered (see also Rawson, Dunlosky, & Thiede, 2000).

The individual is assumed to maintain an allocation policy until monitoring processes indicate that reading goals are not being met (e.g., if there is a comprehension failure, or more generally, discrepancies between the desired and current states of the language representation in one or more dimensions). Attentional resources are differentially allocated to the output functions so as to achieve a discourse representation at the fidelity defined by the reference values.

J. Schooler (2002) provides evidence that the act of reading may continue even when comprehension has failed (what he has termed a “zoning out” effect). One might ask, what does it mean “to read” in such a state in which the eyes move across the page without giving rise to the construction of meaning and without meta-awareness that comprehension has failed? In the current framework, such phenomena supports the inference that monitoring of the reference values and the operations of the comparators are imperfect, perhaps in part as a consequence of the resource cost of self-regulatory control (Muraven & Baumseister, 2000). “Zoning out” then might be conceptualized as a temporary breakdown in the input functions and comparators, such that continuation through the text depends primarily on motor programming (Yang & McConkie, 2001). Alternatively, it may be that progression through the text depends on satisfying the reference values for the relatively low-level features of text alone (e.g., word level analysis such as orthographic decoding) (the implication of this latter proposal that “zoning out” would amplify the relative contributions of word-level effects on reading time remains to be tested). In any case, depending upon (a) the reader’s experience with the particular type of text, and (b) the vigilance of the reader in monitoring ongoing comprehension, there may be some variability in how long it takes the reader to stabilize an effective allocation policy.

Reference Values and Goals—As alluded to earlier, an important contrast between the sort of verbal learning tasks (e.g., paired associates) most often used to investigate self-regulated learning and reading concerns the reference values for monitoring processes. Retrieval of each element in an associative memory task is virtually all or none (i.e., a target item is either reported or not, with low base rates of intrusion errors; e.g., Dunlosky & Hertzog, 2000). In contrast, the reference values for text processing (colloquially, “what a reader wants to get out of a text”) are almost certainly more graded. In text understanding, we can never fully represent the textbase content, situation model, procedural implications, and the emotional tone of a text in an absolute sense, such that a perfect reference value can never be satisfied. In everyday discourse processing, the array of reference value changes from situation to situation as a function of input from the higher order systems, influenced by cognitive goals (e.g., information seeking, acquisition of procedures), social goals (e.g., to tell a story to someone else), and emotional goals (e.g., the delight of entering the discourse world).

In other words, rather than a unitary “standard of coherence” (e.g., van den Broek et al., 2001), we conceptualize a set of reference values that can vary independently depending on the weighting conferred by the higher-order goals. For example, the relative weight given to the textbase versus the situation model level of representations may depend on retrieval goals (Kintsch, 1994), with relatively greater attention allocated to the textbase for recall, but to the situation model for understanding and learning (Schmalhofer & Glavanov, 1986; Zwaan et al., 1995). Similarly, the setting and monitoring of reference values may vary as a function of text genre, with relatively greater accuracy in monitoring details (i.e., textbase) for expository texts, but better monitoring of thematic information (i.e., situation model) for narratives (Weaver & Bryant, 1995). The use of reading for expanding the knowledge base versus emotion regulation may vary with phase in the life span (Carstensen & Turk-Charles, 1994). Moreover, the phenomenological experience of being satisfied with what one has accomplished in reading most certainly depends on individual difference and contextual variables. Self-referent memory beliefs, such as perceived control and self-efficacy, likely play a role in goal setting and commitment (e.g., A. Bandura, 1989a, 1989b, Lachman, M. Bandura, Weaver, & Elliott, 1995; Welch & West, 1995; West et al., 2001; West, Thorn, & Bagwell, 2003; West et al., 2005), thereby influencing the level and monitoring of reference values.

In a research context, we try to “reset” reference values with respect to either textbase or situational understanding via instructions (e.g., “please recall as many of the main points and details as possible” vs. “recall the gist” vs. “be ready to answer a question”), but such individual and contextual constraints may limit the capacity or desire to adjust these parameters. Of course, by virtue of the representations it creates, reading has the capacity to, in turn, influence the nature of and commitment to different classes of goals as well.

Disturbances—Even though the manner of engagement of the output functions (i.e., the reading strategy) is reliable, their effectiveness, can be disrupted by disturbances (e.g., unfamiliar vocabulary, noisy reading environment, complicated syntax out of the normal range, sleep deprivation). To the extent that the reader perceives degradation in the representations of the textbase and/or situation model (i.e., the input function is working properly) and the comparator detects a discrepancy between the desired level of comprehension and the perceived one, resources may be redirected (i.e., the allocation policy may be revised) so that the desired level of comprehension is again achieved. Disturbances can be any endogenous or exogenous factors that reduce the effectiveness of the current allocation policy of the output function. Disturbances in the system that are either acute (e.g., illegibility of text, change in conceptual complexity, requirement to shift retrieval goal) or chronic (e.g., age-related change in the basic processes underlying the output function, shift in job demands) might come into play to cause a particular allocation policy to be diminished in its effectiveness. Chronic disturbances in a system in which the discrepancy is monitored and compensated for with adjustments in the allocation policy can gently shape the allocation policy over time. Such a process may underlie some of the age differences in the allocation policy that we will discuss below (e.g., Stine-Morrow, Milinder et al., 2001; Stine-Morrow, Miller, & Leno, 2001). Acute disturbances may cause the reader to regress to earlier portions of the text (e.g., Rayner, 1998), though regressions themselves do not always reflect acute disturbances in that readers may vary in the extent to which they use regressions as an ordinary part of their allocation policies (e.g., Hyona, Lorch, & Kaakinen, 2002).

Output Functions and Executive Control—The output functions are assumed to vary in the extent to which their computations require automatic and controlled processing (e.g., Caplan & Waters, 1999; Fodor, 1983). Computations in the province of any of the output functions may be resource-consuming or be conducted with relative ease depending on the task demands relative to skills of the reader (Fredericksen, 1981), however, it is generally the case that in the natural ecology of reading, word processes are conducted relatively free of attentional control, whereas textbase construction is resource-consuming. For example, Smiler, Gagne, and Stine-Morrow (2003) asked younger and older participants to read a series of sentences for comprehension either with or without a concurrent memory load (thus, introducing a disturbance). Whereas the time that younger adults allocated for sentence processing was not changed by the additional memory load, older adults in the load condition allocated more time to sentence wrap-up but not to word-level processes, suggesting that the requirements for conceptual integration were particularly resource-consuming. Similarly, Jefferies, Ralph, and Baddeley (2004) showed that the introduction of a choice reaction time task (in the visual domain) depressed recall of (auditorially presented) sentences more than it did random word lists. As participants studied the word lists over trials and began to create organizational chunks, the word list learning was disrupted as well by the concurrent task. Jefferies et al. argued that it is the integration of unrelated concepts required in sentence processing that is particularly effortful. Interestingly, when sentences were connected into coherent discourse, the disruption by the concurrent task was reduced, suggesting that the meaningfulness inherent in discourse structures may reduce the requirements for attentional control.

Even though there is relative independence in the operation of the output functions, it may well be that attentional demands at one level of analysis can consume attentional resources needed at other levels. An important case in point is a "disturbance" created by sensory challenge, which can be overcome through more effortful analysis of the signal, but at a cost of less attention to the meaning-making facets of language understanding, that is, the effortfulness hypothesis, articulated by Wingfield, Tun, and McCoy (2005). An interesting example of this principle comes from a study by Dickinson and Rabbitt (1991), who asked normally sighted younger adults (18–35 yrs of age) to read texts aloud either with their normal correction or with correction that created a distorted blur. Subjects uniformly read texts correctly, but in the distorted condition, they read texts more slowly and showed poorer free recall and sentence recognition, demonstrating that the source of distortion effects on memory were not due to a failure to decode the orthography. Additionally, the distortion effect was exaggerated when the text was more conceptually difficult, further suggesting that the effects of distortion played a role beyond the sensory level. Also, in the auditory domain, Pichora-Fuller, Schneider, and Daneman (1995) showed that correlations between working memory and memory performance were higher when the to-be-remembered speech was embedded in noise. Collectively, these findings provide support for the hypothesis that perceptual challenge requires attentional resources, thus drawing attention away from propositional and discourse analysis (see Li et al. (2001) for a analogous argument in the domain of motor control).

Contextual Influences—The operations of the three output functions are proximal and independent causes of the representations at each level, but the construction of the representation at each level is influenced by the representation at the adjacent level (represented by bidirectional arrows). In spite of some controversy over the exact time course of these interactions, context effects on lexical processes have been well documented (e.g., Simpson, 1981; Rayner & Well, 1996). These effects can be explored by examining lexical decision times for ambiguous words (Simpson, 1981). For example, given an unbiased context (*The men decided to wait by the bank*), participants activate the dominant meaning of a homograph (in this case, the *bank* meaning a financial institution); however, if the context has a strong bias (*I pulled the fish up onto the bank*), the contextually appropriate meaning is activated (i.e., edge of a river).

Extended discourse also provides various sources of support for word and textbase processing, such as information needed to create elaborate situation models, story structures, grammars of exposition and other types of macro-level support (Graesser et al., 1997; Kintsch 1998). Memory for the content of longer texts shows lower correlations with working memory than when texts are shorter suggesting that the expanded context reduces the cognitive load for encoding content (Stine & Wingfield, 1990). Script- or schema-based knowledge facilitates conceptual integration (Sharkey & Sharkey, 1987).

Content knowledge relevant to the text, as well as knowledge about the structures of particular text genres, influence the construction of the representations at different levels directly, e.g., facilitate access to arcane vocabulary or enable conceptual integration. Knowledge can also influence how attention is allocated among the different levels. For example, expertise may engender relatively greater attentional allocation to situation model processes. Knowledge may influence regulatory functions in a number of other ways, for example, by stimulating allocation to elaboration on text content with concepts from the existing knowledge base (Graesser, Haberlandt, & Koizumi, 1987) or constraining meaning more efficiently (McNamara & McDaniel, 2004; Kintsch, 1988).

Developmental Architecture

We overlay this cognitive model with developmental theory. First, we assume that age-related slowing in rates of basic information processing steps create processing constraints with age (e.g., Salthouse, 1996). Age-related declines in processing capacity reduce the effectiveness of the output functions for performing particular computations during reading (e.g., Hartley Stojack, Mushaney, Annon, & Lee, 1994). In turn, this decrease in the probability of effective processing has temporal processing consequences (e.g., Byrne, 1998), limiting the time available to be allocated to the computations that give rise to language understanding. Thus, if older individuals persist in implementing the same allocation patterns as they did when they were younger, the products of computations will be insufficiently completed, thereby creating an impoverished representation due to limited processing time (Salthouse, 1996). At every input cycle in discourse processing, understanding depends on an ability to integrate the output of the current cycle with the memory representation computed from earlier cycles (see Kintsch, 1998). The reduced effectiveness of the output functions, therefore, can create problems for both online comprehension and for subsequent memory for discourse.

Second, it is assumed that older readers are less likely in general to spontaneously allocate resources for the construction of language representations when they require more effortful computations (Craik & Jennings, 1992), especially at the textbase level, but perhaps also for more complex aspects of the situation model (Stine, 1990; Stine-Morrow et al., 2004; Zabrucky & Moore, 1994). It is this combination of reduced computational efficiency and a failure to optimally engage resources to compensate for reduced efficiency that is the source of age-related declines in language performance. Age-related declines in language performance, then, may be viewed as a self-regulatory failure in which resources are not allocated in a way that takes into account age-graded change in processing capacity at both the perceptual and cognitive levels (Dixon & Bäckman, 1995).

A third tenet is that aging increases the potential for an expanded knowledge base, so that information stored in long-term memory may be more tightly integrated and more particularized as a consequence of individual experiences (Ackerman, 1998; Beier & Ackerman, 2005). Because of this, older readers may rely more on their extant knowledge and knowledge-based processing in interpreting text (e.g., Miller & Stine-Morrow, 1998).

Finally, we assume that aging brings a shift in regulatory priority from information-seeking goals to social and emotional goals (Adams, 1991; Adams et al., 2002; Carstensen, 1995; Isaacowitz et al., 2001), and propose that this shift influences the reference values for judging the adequacy of comprehension. Such a perspective would suggest, for example, that the representation of textbase content (information) might be neglected unless it was germane to social and/or emotional goals (e.g., a person who needed the information explained; the topic was of long-standing interest), or was imbued with affect through signaling (e.g. Meyer et al, 1998). At the same time, assuming that (a) it is the situation model that gives rise to perceptual simulation (Barsalou, 1999; Glenberg et al., 1987; Zwaan & Radvansky, 1998) leading to the phenomenological experience of entering another world in reading (e.g., Gerrig, 1993; Pavel, 1986), and hence, the affective experiences associated with language understanding, and that (b) aging brings increased centrality to affect, it might be expected that older readers would be relatively more oriented to situation model construction.

Even though older adults are at risk for deficits in language comprehension and memory, they may be capable of achieving high levels of language performance via adaptive shifts in their allocation patterns. While this compensatory shift (Bäckman & Dixon, 1992) may be qualitative such that certain computations would be given relatively higher priority so as to reduce the collective computational burden, allocation shifts may be quantitative as well, that is, by simply allocating more time for the same qualitative array of computations engaged by younger readers. In either case, compensatory allocation depends on sensitivity of the input function to the encoding failure combined with a shift in the operation of the output functions.

The SRLP Model as a Framework for Understanding Age Differences in Language Processing

The SRLP model provides a useful framework for considering age differences in language processing. The selective review of this literature that follows is divided into two sections. We begin by summarizing what is known about age differences in textbase, word, and discourse processing (Thornton & Light, 2006; reflecting the tripartite structure of the SRLP model). We highlight decreases in processing capacity, enhancement of knowledge-based processes, and priority to emotional systems to demonstrate how the model can account for developmental change in late life. We then consider evidence for the SRLP model based on the resource allocation approach.

Our review is focused primarily on comprehension, memory, and learning from written text. Although speech can to some extent be regulated in everyday discourse (e.g., with signals of noncomprehension to a speaker, or by replaying media), reading is the more apt domain because the comprehender has more regulatory control. However, we reference certain research on oral language processing as appropriate, for example in laboratory paradigms in which concepts of self-regulatory control can be applied (e.g., the spontaneous segmentation paradigm, Wingfield & Butterworth, 1984; or the auditory moving window method, Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996).

Age Differences in Textbase, Word, and Discourse Processing

Textbase Processing—The text processing literature on aging features studies that measure memory for content (i.e., the textbase). Although there are certainly exceptions to the rule, the dominant finding is that older adults remember less of the content from what they read or listen to relative to the young (Johnson, 2003; Zelinski & Gilewski, 1988). There is now considerable evidence that this age difference is, at least in part, attributable to age-graded declines in cognitive mechanics, which place limits on the fidelity of the textbase that is constructed during comprehension (see Kemper and Mitzner (2001) and Wingfield and Stine-Morrow (2000) for reviews). Older adults show particular deficits (i.e., poorer memory or slowed processing), for example, when text is syntactically complex (Kemper, 1988) or propositionally dense (Stine & Wingfield, 1990). Older readers require more time than younger adults for propositional encoding (Hartley, 1988; Hartley et al., 1994; Stine & Hindman, 1994). Older readers may have difficulty achieving pronominal coherence when antecedent-pronoun distance is increased (Light & Capps, 1986). Relative to those of the young, the recall protocols of older adults show less discrimination between more and less memorable ideas when text is more propositionally dense, presented at a faster rate, or is less familiar (Hartley, 1993; Stine & Wingfield, 1988). Evidence that language processing deficits arise from capacity deficits is found in (a) studies showing that age differences are exaggerated when task demands are increased (e.g., Kemper, 1986; Light & Capps, 1986; Stine & Wingfield, 1990; Stine-Morrow, Shake et al., submitted), as well as in (b) correlational studies showing that age deficits can be accounted for with independent estimates of working memory (Norman, Kemper, & Kynette, 1992; van der Linden et al., 1999) or processing speed and inhibitory efficiency (Kwong See & Ryan, 1995).

An important exception to the rule of age-related deficits in textbase processing is when there is greater involvement of the socioemotional system, as when the content is emotionally evocative or when the context for retrieval is social grounded (see Hess (2005) for a more general discussion of contextual effects on memory and aging). For example, Carstensen and Turk-Charles (1994) found that age deficits in recall of excerpts from Agatha Christie stories were restricted to propositional content that was emotionally neutral; by contrast, there were no age differences in recall of content with affective value. Another example is when there is a functional social context for memory, as in the case of telling stories to children. Adams, Smith, Pasupathi, and Vitolo (2002) replicated the typical finding of age deficits in text memory when younger and older adults were asked to recall Sufi tales that they had read to an experimenter, whereas age deficits were eliminated when the participants were asked to retell these stories to children (who presumably did not already know the story and would enjoy hearing it).

Collectively, this literature shows that age-related declines in mental mechanics disrupts textbase processing, and that in the context of highly weighted cognitive goals (the typical laboratory scenario), older adults are likely to produce a somewhat more fragmented and undifferentiated representation of propositional content, relative to younger adults. However, social and emotional context may be differentially effective for older readers in incrementing reference values for textbase fidelity.

Word-level Processing—In contrast to textbase processing, word recognition and semantic activation processes appear to show relatively little adult developmental change, with preservation of semantic priming and instantiation of word meaning (Burke & Harrold, 1988; Light, Valencia-Laver, & Zavis, 1991). This, in part, may be due to the fact that these are procedural skills that reach a high level of automaticity among adults living in a literate culture. Of course, development that occurs in the absence of support for literacy practices would not be expected to yield such preservation (e.g., Petersson et al., 2001).

Among literate adults, sensory declines may have some impact on decoding orthography of isolated words in text, but semantic processing remains intact for normal aging (Wingfield & Stine-Morrow, 2000). For example, Balota and Duchek (1988) found that older adults benefited more from a cue delay at short intervals in a pronunciation task, suggesting that they were slower in decoding orthography. Consistent with the idea that semantic processing is preserved, priming was age-invariant. Allen et al. (1993) independently manipulated the difficulty of decoding (through spacing and alternating case) and the difficulty of lexical access (word frequency) and showed that lexical decision speed was similarly affected by word frequency for young and old, but that age differences were increased by decoding difficulty. Based on these findings, they argued that any age differences in lexical processing reside in “peripheral” input processes as opposed to “central” semantic processes.

Nevertheless, older readers may rely on their “lexical expertise” to enhance efficiency in word processing. Spieler and Balota (2000) presented data suggesting that older readers may have more unitized representations of words (at the peripheral level) because their more extensive reading experience enables them to access the word with less allocation of attention to sublexical features. They found that younger adults’ naming times were more affected by neighborhood density (i.e., the similarity between the lexical features of the target word and other words; a “sublexical” feature) than were older adults. Also (and in contrast to the Allen et al. findings), Spieler and Balota found that older adults’ naming times were more affected by frequency (a “lexical” feature), which is also consistent with the notion that older adults are differentially faster at recognizing familiar words. Thus, studies of the recognition of isolated words produce somewhat mixed results, but are generally consistent with the notion that older readers take advantage of their more extensive experience to process individual words efficiently, but may be disrupted by unfamiliar fonts or unusual lexical features.

In fluent reading, word length has similar (Stine, 1990; Stine, Cheung, & Henderson, 1995) or slightly greater (Stine-Morrow, Miller, & Leno, 2001) effects on reading speed for older adults, relative to their younger counterparts. Reading speed among older adults may be particularly hindered when font size is either reduced or enlarged from the optimum value (Akutsu, Legge, Ross, & Schuebel, 1991).

There is some evidence in both speech (Cohen & Faulkner, 1983; Stine & Wingfield, 1994; Stine-Morrow, Miller, & Nevin, 1999) and reading (Madden, 1988; Speranza, Daneman, & Schneider, 2000) that older readers take differential advantage of context to decode phonology and orthography, respectively. For example, older adults shower poorer performance relative to the young in identifying isolated words, age differences that can be exacerbated by auditory or visual noise or other signal distortions (Cohen & Faulkner, 1983; Speranza et al., 2000). However, when these same words are embedded in context that provides semantic constraint, age differences can be greatly reduced if not eliminated (Cohen & Faulkner, 1983; Madden, 1988; Speranza et al., 2000; Stine-Morrow et al., 1999; Stine & Wingfield, 1994). Older adults may also develop compensatory strategies for reading that offset effects of slowed rates of information processing on reading speed (e.g., older typists look farther ahead during text transcription to maintain typing speed; Bosman, 1993; Salthouse, 1984).

Interestingly, even though differential contextual facilitation with age on word identification is fairly replicable, data from cognitive neuroscience appear to show the opposite effect (Federmeier & Kutas, 2005; Federmeier, Van Petten, Schwarz, & Kutas, 2003). The N400 component of event-related potentials (ERPs, the measurement of electrical brain activity time-locked to a particular stimulus, in this case a word) is highly sensitive to contextual constraint, showing greater negativity for words that are semantically anomalous. The work of Federmeier, Kutas, and colleagues has demonstrated that the N400s of younger adults show robust differences for words in weak relatively to highly constraining context (i.e., the brain treats less predictive words as akin to anomalous ones). Older adults, however, show a later and much smaller effect of context. Because there were minimal age differences in the shape of the N400 in weak contexts, Federmeier and colleagues argue that age differences cannot be accounted for simply by speed of processing and that it is older adults' less effective processing of the sentence-level context compromises the predictive utility of context. These data suggest that to the extent that a contextual advantage for older adults is observed at the behavioral level, it may depend on the availability of time and resources to effectively process that context. In fact, even on the behavioral level, older adults can lose the context advantage when memory limitations constrain access to contextual information (e.g., when sentential context follows the word; Wingfield, Alexander, & Cavigelli, 1994).

In addition to the difficulty of deriving message level context, there are two arenas in which older readers demonstrate difficulty in lexical processing in context using behavioral measures. First, older readers may not effectively suppress activation of inappropriate word meanings. Using the Gernsbacher and Faust (1991) paradigm, Faust et al. (1997) showed that in reading sentences (e.g., "He dug in the garden with the spade") older readers had less reliable suppression of strong but irrelevant associations (e.g., ace) (relative to the young in the Gernsbacher and Faust study). Also, declines in fluid ability may disrupt elders in their efforts to derive the meanings of novel words from context. McGinnis and Zelinksi (2000, 2003) presented younger and older adults with brief texts that included an unfamiliar word that was not explicitly defined, although the meaning could be reasonably inferred from the passage (e.g., a story about a teacher who is fired for *dippoldism* after his disciplinary tactics results in welts on some of the children). Younger adults were more likely to give precise definitions that fully capitalized on the contextual constraints for the word (e.g., the beating of school children), while older adults were more likely to define the words in more general terms (e.g., doing something bad). When given a multiple-choice option, older adults still selected the more general definition over the more precise (and correct) definition, suggesting that this difference was not simply due to a stylistic preference of expression. Furthermore, age differences in the ability to select more precise definitions were in part accounted for by age differences in working memory capacity, providing support for the conclusion that age differences in this task derive older adults' difficulty in the resource-consuming process of isolating and synthesizing meaning components from the text; rather, McGinnis and Zelinski argue, older readers from more generalized meaning representations, which are not as demanding on cognitive mechanics.

Collectively, these data suggest that an age-related increase in vocabulary (a crystallized ability) and a lifetime of reading experience (growth of particularized knowledge and proceduralized skill) can minimize deleterious effects of aging in word-level processing. On the other hand, older adults may be more disrupted in word decoding by sensory challenges and when meaning instantiation is resource-consuming (e.g., in the case of lexical novelty and the activation of inappropriate meanings that must be inhibited). Also, it is possible that age differences in the ability to construct a textbase representation (that we reviewed in the last section) may indirectly compromise word-level processing by slowing the availability of context. However, it is not yet clear how to reconcile these findings with notable examples of preservation (e.g., Light et al., 1991).

Discourse-level Processing—Also in contrast to the declines seen in textbase processing, it appears that both the use of discourse structures and situation model processing are well preserved, at least within the paradigms and ranges of difficulty tested. To the extent that the serial position effect (increased reading speed as one proceeds through a passage) is indicative of "structure building" (Gernsbacher, 1990), older readers show evidence of such construction that is at least as great as that among the young (Stine-Morrow et al., 1996). Older adults also show similar effects of canonical narrative structure on memory (Mandel & Johnson, 1984) and are at least as sensitive as the young to narrative structure (Stine-Morrow, Miller et al., 2001; Tun, 1989) and topic shifts in expository text (Miller, Stine-Morrow, Kirkorian, & Conroy, 2004) as they read.

There is also evidence that situation model construction is resilient among older readers. Radvansky, Gerard, Zacks, and Hasher (1990) showed that older adults make similar situational inferences from prepositions as the young (e.g., confusing "her feet were massaged at the podiatrist's" vs. "…by the podiatrist," but not "her handbag was stolen at the podiatrist's" vs. "by the podiatrist"). Younger and older readers have also been shown to represent the emotional experience of protagonists similarly (Soederberg & Stine, 1995). Morrow and colleagues (Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997) have provided evidence that older readers show a distance effect at least as strong as that of the young (i.e., increased reading times/probe times in narratives when objects spatially distant from the protagonist are referenced relative to those objects are proximal to the protagonist). Dijkstra, Yaxley, Madden, and Zwaan (2004) examined age differences in the "perceptual symbols effect" (Zwaan, Stanfield, & Yaxley, 2002) in which picture verification is faster following a sentence when the configuration of the picture (e.g., an eagle with its wings folded) is consistent with the perceptual features implied by the sentence (e.g., "The eagle is sitting in the tree" vs. "The eagle is flying over the tree"). This phenomenon is illustrates nicely the view that language understanding can evoke a perceptual simulation (Barsalou, 1999), so that meaning is essentially embodied in the language (Glenberg &

Robertson, 2000). Dijkstra et al. showed that this effect was even more robust among older adults than it was among the young, suggesting preservation of the situational representation.

Radvansky et al. (2001) produced additional evidence for intact situation model construction in older adults. They showed that younger readers had better discrimination (in a signal detection paradigm) for statements consistent with the textbase of an historical narrative, whereas older readers had better discrimination performance for statements consistent with the situation. Whereas Radvansky et al.'s younger readers allocated more time than the old did to newly introduced concepts (a textbase feature), their older readers allocated more time to new discourse entities (presumably a situation model feature), suggesting that the qualitative difference in memory performance arises from differences in attentional allocation between the textbase and the situation model.

Consistent with this view, some researchers have reported that the recall protocols of older readers are more governed by the metaphorical or interpretive meaning of a text in contrast to its literal content (Adams, 1991; Adams, Labouvie-Vief, Hobart, & Dorosz, 1990; Adams, Smith, Nyquist, & Perlmutter, 1997). For example, in summarizing a Sufi fable (Adams, 1991), adolescents included more exposition of content as represented in the textbase of the story (e.g., There was a debate between the stream and the wind), whereas middle-aged and older adults included more statements about its interpretation (e.g., The story is about the inherent tug of war between Faith and Skepticism").

Interactions among Levels of Analysis: Context Effects—As described above, as long as working memory limits are not taxed, context effects on behavioral measures of word recognition have been shown to be equally strong if not stronger for older relative to younger adults (e.g., Holtzman, Familitant, Deptula, & Hoyer, 1986; Stine-Morrow, Miller, & Nevin, 1999). In contrast to contextual effects on word processing, context effects on textbase processes have not been well researched in the cognitive aging literature, though it appears that here too, older adults show exaggerated effects of context (Miller & Stine-Morrow, 1998; Miller, Cohen, & Wingfield, in press). For example, Miller et al. (in press) investigated the effects of age and working memory span on reading efficiency (operationalized as reading time allocated per idea unit of text recalled) as participants read ambiguous texts that were either preceded by a disambiguating title or not. Participants read these texts under full or divided attention conditions, so as to provide a window into the requirements for attentional resources across contextual conditions. Two strands of evidence supported the hypothesis that context reduces cognitive load during reading. First, span had strong effects on efficiency when there was no title to contextualize the content, but this difference was considerably reduced when context was present. In fact, low-span readers were almost as efficient as high-span readers when context supported textbase processing. Second, the benefits of context were most pronounced among older readers in the divided attention condition, which presumably depleted the resources available for textbase construction. Thus, the work that has been done in this area suggests that discourse context can reduce the processing capacity needed to create a robust textbase, and that older adults may differentially rely on such mechanisms. We consider this issue further in the next section.

Resource Allocation: Self-Regulation as a Factor in Age Differences in Language Processing

At present there is strong evidence for involvement of age changes in cognitive resources as playing a role in age changes in text comprehension and recall. Certainly, age changes in episodic memory, in general, and text memory, in particular, do not occur in isolation. Even though age-graded changes in processing capacity are highly prevalent across different domains of cognition (Salthouse, 1996; Salthouse & Ferrer-Caja, 2003), there are also individual differences in rates of cognitive decline (e.g., Hertzog & Schaie, 1986; Lövden et al., 2004; Zimprich & Martin, 2002). Rates of age-related change differ for resources such as working memory that are known to be relevant for textbase construction and text recall (Hertzog, Dixon, Hultsch, & MacDonald, 2003). Moreover, longitudinal changes in working memory reliably predict changes in text recall (Hertzog et al., 2003; Hultsch et al., 1998). Thus some older adults, more than others, may be vulnerable to declines in processing that degrade text representations. Moreover, evidence from the Victoria Longitudinal study indicates that changes in knowledge retrieval correlate strongly with changes in both working memory and episodic memory, including text recall (Hertzog et al., 2003; Hultsch et al., 1998). Thus, the available data indicate that age deficits in both encoding and retrieval mechanisms influence changes in text processing and memory, and that there are individual differences in both the level and rate of change of these resources. The maintenance of communicative competence depends on the ability to monitor the current state of the information processing system in perpetual change and to adjust strategies of allocation accordingly.

Consequently, age-deficits in language performance may not be simply due to limited processing capacity, but also to a self-regulatory failure. There is evidence that older adults may use a resource allocation policy that is ineffective in overcoming age-graded declines in processing capacity. For example, Ratner, Schell, Crimmins, Mittelman, and Baldinelli (1987) showed faster reading times for older than younger adults, despite the fact that these faster times were accompanied by poorer recall. Such a finding suggests that older readers were either not accommodating their reading strategies to the demands of the text or engaging in strategies for comprehension that could affect the probability of later text recall. Similarly, Dixon, Simon, Similarly, Dixon, Simon, Nowak, and Hultsch (1982) and Taub (1979) found that older readers took less advantage than the young of self-pacing to improve text recall.

Zabrucky and Moore (1994) showed that older readers were less likely to reread sentences that were inconsistent with an earlier portion of the text than were the young, and that this failure could largely account for age differences in memory performance. Interestingly, older readers in this experiment slowed down when encountering the inconsistency, suggesting that it had been recognized as such, but that resources were not allocated in an attempt to resolve the inconsistency. The substance of these results is similar to findings reported Kemper et al. (2004), who examined age differences in processing syntactic ambiguities by measuring eye movements. In reading sentences with ambiguous relative clause constructions, older adults showed more regressive eye movements than the young, however, they showed no corresponding exaggeration in total fixation time. These data are consistent with the notion of an age-related self-regulatory failure in reading: age-related declines in working memory capacity reduce access to the surface code (e.g., Daneman & Carpenter, 1983) so that older readers look back to earlier portions of the text when faced with ambiguity; however, this attempt is not self-regulated so as to produce reanalysis of the meaning.

In a particularly compelling demonstration of these principles, Hartley et al. (1994) used threshold reading time (modeled on the staircase method used in psychophysics) to estimate the processing time per proposition needed for younger and older adults to remember single sentences. Their older readers needed more processing time per proposition than their younger counterparts (see also Stine and Hindman, 1994). However, measures of self-paced reading indicated similar reading times for the two age groups. To tie the ribbon on the package, Hartley et al.'s regression analysis revealed that recall performance (measured in a separate reading task) was negatively predicted by the threshold measure (i.e., processing efficiency) but positively predicted by the self-paced reading time measure. Assuming that reading time is an indicator of self-regulatory behavior and the allocation policy used by an individual, this pattern of data supports the argument that older adults do not always adapt reading behavior to maximize intentional learning of text.

Collectively, the studies just reviewed indicate that older readers may not optimally adapt their attentional allocation to age-graded changes in processing capacity, resulting in a relatively degraded construction of the textbase representation. Age differences in resource allocation may play a role in (a) the manifestation of age-related changes itself, and (b) compensatory changes in allocation policy. Concerning the latter, the ability to regulate language input so as to accommodate to age-related change may be highly variable due to (a) variability in the resource consumption demands of self-regulation itself (Kanfer & Ackerman, 1996), (b) individual differences in relevant knowledge in specific contexts, given the influence of knowledge-based processing (Miller & Stine-Morrow, 1998; Miller, Stine-Morrow et al., 2004; Miller, Cohen, & Wingfield, in press), and (c) affective and motivational factors such as interest in the passage content (Meyer, Talbot, Stubblefield, & Poon, 1998), emotional content (Carstensen & Turk-Charles, 1994), social context (Adams et al., 2002)), and self-referent beliefs about cognition and control that influence the recruitment of resources (e.g., Cavanaugh, 1990; Miller & Lachman, 1999). Whereas age deficits may well be the rule for decontextualized laboratory tasks (e.g., varied attentional mapping, paired associate learning, list learning; e.g., Kausler, 1994), discourse memory is one area of cognitive aging where this may not universally be the case (Hultsch & Dixon, 1984; Johnson, 2003). The available data suggest that an age deficits in discourse processing (when they occur) often involve an allocation policy by older adults that does not take into account age-graded declines in cognitive mechanics. We develop this argument further after defining more explicitly the construct of resource allocation and describing its measurement.

The Resource Allocation Approach—The resource allocation approach has provided an important perspective on how readers and listeners self-regulate language input. Developed by Aaronson (Aaronson & Ferres, 1984; Aaronson & Scarborough, 1976, 1977), Just and Carpenter (1980), Graesser (1981; Graesser, Hoffman, & Clark, 1980), and Haberlandt (1984; Haberlandt & Graesser, 1989a, 1989b; Haberlandt et al., 1986), this approach provides a way to operationalize the allocation policy of the output functions. The fundamental assumptions of this approach are that discourse understanding relies on a multilayered set of coordinated processing operations, that these operations require measurable amounts of time, and that the relative change in unit reading times in response to variation in text characteristics provides an index of how responsive a reader is to the processing demands imposed by a text. Indeed, readers allocate more reading time in response to multiple text features, including (a) longer words, in order to decode orthography (the written symbols); (b) low-frequency words to accommodate greater difficulty in lexical access; (c) words introducing new conceptual arguments, to allow time for instantiating them into the structure of the textbase; (d) words at the ends of syntactic constituents, to organize new concepts within an input cycle and to integrate them across input cycles ("wrap up"); and (e) for segments in narratives that introduce a temporal or spatial shift, to enable an update of the here-now point in the narrative and maintain coherence. Although some of these processes (e.g., lexical access, parsing) are to a large extent obligatory, others (e.g., conceptual integration, elaborative inferences) may be optional and dependent upon the cognitive capacity available. However, even "obligatory" processes can be conducted with varying amounts of thoroughness (Carpenter & Just, 1989), according to the "good enough" principle (Ferreira et al., 2001).

In the following paragraphs, we consider evidence showing (a) that interindividual differences in resource allocation can contribute to language performance differences, (b) that patterns of resource allocation reflect reliable individual differences, (c) that the allocation policy is sensitive to shifts in goals, (d) that there may be motivational influences on the allocation policy, (e) that the allocation policy is regulated at a functional level rather than on a computation-by-computation basis, (f) that there are age differences in the patterns of reference values such that older adults give priority to self-regulation at the discourse level relative to the textbase level, and (g) that the allocation policy is affected by knowledge.

Age Differences in Resource Allocation as a Moderator of Individual Differences in Performance—There is variation among individuals in resource allocation to different sorts of linguistic computations and these individual differences are related to language performance. This has been demonstrated with respect to syntactic processing (Stine-Morrow, Ryan, & Leonard, 2000), textbase processing (Haberlandt et al., 1986; Miller & Stine-Morrow, 1998; Stine, 1990; Stine et al., 1995; Stine-Morrow, Milinder et al., 2001; Stine-Morrow, Miller et al., 2001; Titone et al., 2000), situation model construction (Morrow et al., 1997; Stine-Morrow et al., 2004), and narrative schema development (Stine-Morrow, Miller et al., 2001).

For example, Titone, Prentice, and Wingfield (2000) used a self-paced listening paradigm to show that older adults were less sensitive to demands for resource allocation as a function of passage predictability than the young, differences that coincided with poorer memory performance. In a second experiment in which participant control over pacing was manipulated, older adults' performance was less enhanced by self-pacing, suggesting an age difference in the effectiveness of allocation policies for engendering good memory performance. In another example, Stine-Morrow et al. (2000) had younger and older adults read a series of target sentences including subject-relative (SR) constructions (e.g., The pilot that admired the nurse dominated the conversation) and object-relative (OR) constructions (e.g., The pilot that the nurse admired dominated the conversation) (King & Just, 1991). OR constructions are more difficult to understand, in part because, conventional subject-verb–object word order is violated and there is a dual thematic role assignment (i.e., the pilot is the agent of "dominate," but also the patient for "admire"). Thus, the computation of thematic roles (i.e., assigning concepts to particular argument slots in propositions) is a more complex task in OR than in SR constructions. In fact, both younger and older adults had more difficulty in answering an immediate comprehension question (e.g., Who dominated the conversation?) for OR sentences than SR sentences. Interestingly, younger and older readers showed equivalent accuracy for SR sentences, but there was an age deficit in accuracy for OR sentences. Both younger and older readers slowed down to process the relative clause in the critical region ("nurse dominated" for SR; "admired dominated" for OR), but only younger readers differentiated between the SR and OR constructions online, allocating extra time (presumably for thematic role assignment) for the OR sentences. Older adults' reading times were not sensitive to this subtle difference, suggesting that one source of their poorer comprehension was the failure to compute thematic role assignments.

Individual differences in responsiveness to word and textbase features are also related to language performance measures. Readers who demonstrate effective text memory allocate more time to (a) the elaboration of low frequency words, (b) the immediate processing of new concepts when they are introduced, and to (c) conceptual integration at the ends of constituents (Miller & Stine-Morrow, 1998; Stine-Morrow, Milinder et al., 2001; Stine-Morrow, Miller et al., 2001). Presumably, such variations in reading time reflect processing involved in the construction of an integrated textbase with distinctively encoded concepts, a process that supports subsequent search and retrieval.

Effective readers also appear to allocate attention to discourse-level features. For example, Miller and Gagne (in preparation) showed that allocation of time to the situation model while reading mysteries was predictive of problem solving performance. Similarly, Stine-Morrow et al. (2004) showed that attentional allocation to the perceptual qualities of expository and narrative texts was predictive of subsequent comprehension performance. In Morrow et al. (1997), younger and older adults read a series of narratives situated in a known spatial layout. Before reading, subjects studied a map of the setting, consisting of a set of rooms containing certain objects. In these narratives, a motivation was provided for the protagonist to move through the layout interacting with objects. For half of the critical sentences, the location of the object was explicitly mentioned, whereas in the other half the location was not mentioned.

Both younger and older adults took longer to read the sentences when the location was not mentioned, presumably because extra time was needed to infer location. Older adults who were above average in comprehension, however, showed an exaggerated effect of mention, suggesting that these effective readers were more thorough in their elaboration of the discourse context (i.e., they allocated more effort to tracking the protagonist through the discourse world).

Finally, Stine-Morrow, Miller et al. (2001) had younger and older adults read two extended narratives for immediate recall. The narrative structure of each story was described using a standard "story grammar" system (Mandler & Johnson, 1977). Following the logic of depth in the phrase structure to measure syntactic complexity (Kemper, 1992), segments were coded with respect to their depth in the narrative structure (e.g., higher numbers correspond to greater embedding in the causal chain of a narrative). With word and textbase features partialled out, this measure was negatively correlated with reading times, indicating that readers increased their speed as they moved more "deeply" into the narrative). Similarly, reading times were faster for reading episodic endings within the story. Greater attention to story grammar features was associated with better recall performance.

Collectively, these data suggest that discourse performance is measurably related to process-specific time allocation at encoding, supporting the SRLP assumption that the allocation policy is the proximal cause of performance. Furthermore, there is evidence that effective encoding involves processing at different levels of analysis. Age differences in language performance are sometimes associated with underallocation, and successful language performance among older readers appears to be engendered by differential patterns of resource allocation relative to the young (either quantitative accommodation or a qualitative shift toward more holistic features of discourse).

Resource Allocation as a "Habit of Mind"—Patterns of resource allocation, as measured by the regression parameters, appear to reflect reliable individual differences in engagement with text. Stine-Morrow, Milinder et al. (2001) tested 240 participants on two occasions about a month apart. At each testing they read two sets of 24 short passages, once reading for immediate recall and once reading for comprehension (sentence sets were carefully matched for length, syntactic complexity, and propositional density). Regression analyses were used to decompose word-by-word reading times into the resources allocated to particular components at each time of measurement for each task. With the exception of allocation to propositions (not unexpected when reading time is measured word-by-word; Graesser, 1981), all parameters were significantly correlated across the two times of measurement. Across both tasks, correlations ranged from .28 to .69 for young, and from .39 to .81 for old. Test-retest reliabilities were lowest for allocation to new concepts and clause wrap-up, and most reliable for sentence wrap-up. Surprisingly, there was no systematic relationship between allocation parameters and measures of working memory span, lexical decision speed, or vocabulary (see also Smiler et al., 2003).

More recently, we (Stine-Morrow, Miller, Gagne, & Hertzog, submitted) had a similarly large sample read three different types of text (sentences, narratives, and scientific expository passages) matched in readability level. Even though word and textbase processing was reduced in the context of connected discourse relative to single sentences (reflecting contextual facilitation), the allocation parameters across the three types of text also showed robust consistency in orthographic decoding (r's = .49 to .52), lexical access (r's = .54 to .69), conceptual instantiation (r's = .34 to .42), and sentence wrap-up (r's = .65 to .83). This study included a more expanded battery of ability measures, which produced more reliable measures of ability constructs and greater sensitivity to detect ability correlates of allocation parameters. Structural equation modeling showed that allocation to textbase processing was enhanced by higher verbal ability and that relatively greater allocation to word-level features appeared to compensate for lower working memory capacity. Collectively, these data suggest that the reader's allocation policy is to some extent consistent over time and texts, though the extent to which this consistency derives from more commonly measured abilities remains to thoroughly explored.

The Effects of Goals on Allocation Policy—There is evidence that a shift in readers' goals can change the reference value so as to increase the activity of the output functions and that these can have differential effects on the reference values as a function of adult age. In Stine-Morrow, Milinder et al. (2001), readers systematically exaggerated their allocation to word and textbase features (by a factor of 2) in recall as compared to comprehension. In this case, older readers (whose comprehension and recall performance was comparable to that of the young) showed a disproportionate slowing of the allocation parameters relative to the young, suggesting that the younger and older adults were similarly responsive to a shift in the reference value and that these older readers accommodated declines in mental mechanics so as to maintain a level of performance consonant with the reference value.

Stine-Morrow, Shake, Miles, and Noh, (submitted) also produced data that exemplify this phenomenon. Younger and older readers were asked to read sentences varying in propositional density under instructions to focus on accuracy of recall or on speed. Both younger and older adults increased their overall sentence reading time and showed better recall in the high-accuracy condition relative to the low-accuracy speeded condition. However, age differences emerged in this task context. Not only did younger readers allocate relatively more time when a high level of memory accuracy was the goal, but their reading times were also sensitive to propositional density. By contrast, older adults' reading times were less responsive to the goal instruction overall and did not significantly increase as a function of informational density. These findings are interesting because they show that younger adults (but not older adults) were selectively increasing their time allocation to process the textbase when the goal was to achieve high levels of accuracy. Interestingly, younger and older adults were similarly accurate in memory monitoring, as measured by JOLs, and similar in the use of a discrepancy reduction heuristic, suggesting that the reduced responsiveness of older readers to a stringent cognitive goal was not a metacognitive failure per se.

Together, these studies illustrate sensitivity of the allocation policy to reading goals, but present a muddy picture with respect to age differences. On the one hand, older readers appear to be able to make the shift for different types of retrieval goals (e.g., recall vs. recognition), but not for different levels of stringency in recall. This issue deserves more attention, especially with respect to the role of social and emotional goals on allocation policy.

Motivational Influences on Resource Allocation—Even though self-referent beliefs about cognition do not completely account for self-regulatory failure (e.g., Muraven & Baumeister, 2000), some evidence suggests that they may play a role in memory for language. For example, Riggs, Lachman, and Wingfield, 1997) showed in a spontaneous segmentation task that older listeners with higher levels of external control beliefs were more likely to select speech segments for recall that were outside the range of their ability to recall, suggesting that those with internal control beliefs were better at regulating input so as to achieve good language memory performance. Similarly, Miller and Gagne (2005) showed that only older adults with relatively strong beliefs about their ability to control memory outcomes adapted to increased text difficulty by increased allocation to wrap-up. Stine-Morrow, Shake et al. (submitted) used regression analysis to show that older adults' reduced responsiveness of reading times to the processing goal was predicted by both working memory capacity and memory self-efficacy. These data suggest that older adults did not fail to adapt to the goal because of a metacognitive failure, but because the cognitive goal had a reduced impact on the reference value (driven by lowered memory self-efficacy) and because of the resource demands of such cognitive regulation on working memory. Touron and Hertzog (2004) found that older adults' delayed shift from a rule-based to a retrieval-based strategy during skill acquisition was associated with lower levels of confidence in their ability to use retrieval, even though objective memory probes indicated that the retrieval strategy could have been effective for them. Similarly, in the Stine-Morrow, Shake et al. experiment, age differences in responsiveness to the goal were, in part, accounted for by independent estimates of memory self-efficacy (even when working memory capacity was controlled). Thus, to the extent that older readers sometimes fail to compensate for processing declines through sufficient resource allocation to the output functions, it is plausible that control and efficacy beliefs may partially mediate this effect.

Computational Architecture—There is some evidence that the feedback loops described in the SRLP model do not operate at the level of individual computations, but rather on principled clusters of computations. Consider two extreme models of how allocation of effort to different linguistic computations might be managed. At one extreme, there might be a unified heuristic for constructing the language representation (imagine a single feedback loop in Figure 1 in which language comprehension as a whole is monitored and regulated), for example, a single output function requiring n ms/unit for computation a, p ms/unit for computation b, q ms/unit for computation c, and so on. In this case, comprehension failure or a disturbance would cause the output function to uniformly increase its level of allocation to all components, e.g., by a factor of x, so that instead of the construction requiring na +pb + qc ms, it would require x(na +pb + qc) = xna +xpb +xqc ms. Assuming that within an individual, the multiplier is constant, allocation parameters for particular computations would be correlated, so that they would load on a single factor. At the other extreme, the heuristic for allocating effort might be to monitor and regulate each computation independently. In that case, comprehension failure or a disturbance would entail a unique multiplier for each computation, e.g., $x_1na + x_2pb + x_3qc$ ms, so that allocation parameters would be uncorrelated and the effects of disturbances would be highly specific.

The truth of the matter appears to lie somewhere in between. A factor analysis of allocation parameters derived from reading times for narrative texts (Stine-Morrow, Miller et al., 2001) showed that word and textbase allocation parameters loaded on one factor and that story grammar parameters loaded on another. In this case, readers who allocated relatively more time to process rare words also allocated more time to wrap-up, for example. Such data suggest that the choice of allocation policy may be made at a more general, higher-order level (i.e., textbase vs. discourse level, and not for example, lexical access vs. conceptual integration). Similarly, in the Stine-Morrow, Milinder et al. (2001) study, the allocation parameters for word and textbase processing were increased by the shift from comprehension to recall. In absolute terms, the increase in time allocation was greater for textbase than for word-level processes, but the increase was proportional, so that as in the narrative study, it appeared that word and textbase processes operated in concert, perhaps under the control of a common negative feedback loop.

However, there is evidence that allocation to word and textbase processes can be dissociated as well. For example, Smiler et al. (2003) found that a memory load imposed during reading disrupted wrap-up processes, but not lexical processes. In the Stine-Morrow, Miller et al. (submitted) study, a factor analysis of allocation parameters derived from reading times for three different text types (single sentences, narratives, and expository passages) yielded three well-defined factors: (a) a word factor with allocation coefficients reflecting orthographic processing and lexical access, (b) a textbase factor defined by coefficients reflecting new-concept processing and wrap-up at clauses and sentences, and (c) an expository genre factor defined by time allocated to process topic shifts and summarize lines of argument (cf. Britton, 1994).

Age Differences in Patterns of Reference Values—As noted earlier, older readers often differentially allocate resources to the more holistic levels of discourse analysis (i.e., narrative schema, situation model). Older readers are more facilitated by story grammar endings and by increasing serial position (indicative of "structure building" (Gernsbacher, 1990)) than are younger adults (Stine-Morrow et al., 1996; Stine-Morrow, Miller et al., 2001). A developmental shift toward more holistic levels of processing is also seen in resource allocation patterns with rereading. Young adult readers tend to allocate attention to process textbase features on their first encounter with text, then having established this level of representation, allocate relatively more attention to situation model features on rereading (Millis, Simon, & tenBroek, 1998; Zwaan, Magliano, & Graesser, 1995). Older readers, by contrast, appear to show relatively greater attentional allocation to situation model features (for narratives, operationalized as time allocated for low-imagery segments and for segments more important to the discourse as a whole; for expository texts, operationalized as time for low-imagery segments and spatial discontinuities) on the first reading than do younger readers (Stine-Morrow, Gagne, Morrow, & DeWall, 2004).

Other evidence that older readers may be more oriented toward situation model processing than younger readers comes from Stine-Morrow, Morrow, and Leno (2002). These data showed that (among readers showing good comprehension) older adults showed a reliable distance effect for objects whether they were memorized in the layout a priori or introduced into the narrative setting via the text, whereas younger adults only showed this distance effect if they had memorized the objects in the layout before reading. What is provocative about these data is that when younger adults were specifically probed, they could answer questions about the locations of objects (i.e., the objects were part of a declarative representation of the textbase), but the lack of a distance effect in online reading time suggested that the objects were not part of the situation model for this group. Older readers, however, showed an equivalent distance effect for both types of objects, suggesting that they had spontaneously incorporated this information into the situation model. Collectively, these data are consistent with the notion that there is an age-graded shift in reference values, such that textbase fidelity becomes relatively less important while discourse coherence and situational integrity become more important.

Effects of Knowledge on the Allocation Policy—Knowledge can impact the allocation policy -- in paradoxical ways. The most obvious effect of knowledge is that it can reduce demands on working memory by eliminating the need for certain computations. For example, Miller and Stine-Morrow (1998) asked subjects to read vague and ambiguous passages (a la Bransford and Johnson "washing clothes") for immediate recall. Passage titles, which simulated the effects of knowledge in providing a schema for integrating concepts, dramatically reduced the time allocated to wrap-up (cf. Sharkey & Sharkey, 1987), and this was especially true for older readers. These findings suggest that older readers can be differentially facilitated by schematic knowledge in on-line comprehension.

On the other hand, knowledge can encourage readers to increase resource allocation to conceptual processing in contexts that can further expand the knowledge base. For example, older readers who were knowledgeable about cooking allocated more time to wrap-up in cooking texts than they did to wrap-up in control texts (Miller, 2001) and in a study including both a younger and older group (Miller, 2003), both age groups showed this pattern. In a study assessing the effects of newly acquired knowledge on resource allocation to conceptual processing, only high-knowledge older adults showed an increase over their low-knowledge counterparts (Miller, Stine-Morrow et al., 2004). In this study, we trained a half of the younger and older participants about the processes and functions of the human heart and the other half about the human nerve cell and then all participants read target passages about the heart. Both age groups with the heart training knew more about the heart as reflected in higher scores on a heart knowledge test, but only the old high-knowledge readers spent more time on wrap-up relative to their low- knowledge counterparts (an Age by Knowledge interaction).

The literature just reviewed suggests that knowledge will affect self-regulatory processes differently depending on how well the text matches the reader's prior knowledge. A text relying on schematic knowledge, relative to domain knowledge, engenders reliance on pre-organized concepts. Whereas schematic knowledge renders the target text instantly familiar, domain knowledge may not. When text content in the domain of one's expertise has relatively little overlap with prior knowledge (e.g., reading something new that is connected with one's knowledge), the activation of related nodes encourages the productive expansion and integration of the knowledge base through active and resource-consuming integration of concepts (see also Kintsch, 1994, 1998; Graesser et al. 1987). Although aging clearly appears to bring differential reliance on schematic knowledge (Hess, 1990; Mather & Johnson, 2003; Miller & Stine-Morrow, 1998), a more conservative conclusion may be in order for domain knowledge; that is, older adults appear to be able to take up the resource-consuming task of integrating new knowledge at least as well as the young.

In addition to effects on conceptual processing, knowledge can influence time allocation to critical regions of text relevant to the situation model. For example, Morrow et al. (submitted) assessed the effects of age and aviation expertise on text processing for novices (general aviation pilots) and experts (airline pilots). The pilots read scenarios describing a problem that was either basic or complex in order to provide a solution to the problem. Novices allocated relatively more time to process syllables, while experts allocated relatively more time to critical regions for the complex but not the simple scenarios. Knowledge effects depended on the reader-text match; however, in this case, these effects appeared to be age invariant. These data suggest that knowledge encourages the allocation of resources similarly among younger and older readers to critical regions that presumably serve to create an effective situation model representation. This self-regulatory process is important to the extent that it leads to knowledge expansion and learning from text.

Conclusions and Unanswered Questions

The Self-Regulated Language Processing (SRLP) Model suggests that language processing depends on the coordinated allocation of attention to multiple levels of linguistic and pragmatic features of language. The heuristic governing the allocation policy appears to operate with some economy, not at the level of individual computations but rather on clusters of computations whose products are lexical and textbase representations, as well as certain aspects of the discourse structure and situation. Readers vary in the efficiency with which the output functions operate, as well as in the extent to which they allocate effort to these different computational systems, or in other words, in their "compliance" with "requests" from the text to create representations at different levels, creating representations that are "good enough" (relative to the array of reference values). Age-graded declines in processing efficiency are normative, but there are large individual differences in the heuristics for allocating effort among computational systems. As a function of task demands, goal salience, and individual differences in priorities, knowledge, and abilities, the allocation policy governing how effort will be distributed among these computations varies and has consequences for the representation that is created, and hence, for performance. Even while showing flexibility in response to task demands, the self-regulatory heuristic for word-level and textbase processing appears to be a reliable "habit of mind" that operates consistently over time and independently of the particular type of text encountered. To the extent that existing knowledge systems provide a schema for textbase and situation model construction, fewer resources may be required to construct a representation that meets a given standard of coherence, creating facilitation. To the extent that knowledge invites inference from text, greater allocation may be required to reach the reference value. Movement through adulthood, which provides potential for increasing crystallized abilities, may increase the reliance on knowledge of both sorts.

The SRLP model provides an integrative framework through which to consider the literature on aging and language processing. It also suggests areas that invite inquiry.

1. What are the sources of efficiency for and recruitment of resources to the output functions? Given the observed dissociations, one might suspect that they are differentially related to different sorts of cognitive and dispositional strengths in readers (e.g., verbal ability, working memory, self-efficacy, need for cognition).

2. What are the sources of influence that engender different arrays of reference values and hence differential distribution of effort among levels of analysis as a function of individual differences in ability and disposition, different sorts of text, and task demands? For example, to what extent might an age-related shift in affective priority differentially increase the reference value(s) for discourse-level coherence as an example of schematic processing (e.g., Mather & Johnson, 2003)?

3. From what does the consistency in allocation policy ultimately derive? Endogenous abilities appear to contribute. Are these "habits of mind" also engendered, for example, by educational practices and/or long-term reading habits?

4. What is the architecture of the discourse-level system or systems? For example, to what extent does attention to structural features of discourse represent a different capacity from the elaboration of perceptual symbols? Are there differential sensitivities to different genres of structure? Are there differential sensitivities to different dimensions of the narrative situation model (e.g., Zwaan et al., 1995; Friedman & Miyake, 2000)?

5. How modifiable is the allocation policy? Given its apparent reliability and its link to ability, there is relative stability. Nevertheless, insofar as the allocation policy is the proximal cause of the text representation, an open question is the extent to which it may be modified to engender better text performance. Certainly, not all older readers accommodate to processing limitations to maintain good comprehension and memory (e.g., Stine, 1990; Miller & Stine-Morrow, 1998). An important question is whether the allocation policy might be optimized by specific training (Meyer, Young, & Bartlett, 1989), reading experience (Manly et al., 2004; Ostrosky-Solis, 2004; Petersson, Reis, & Ingvar, 2001), or general cognitive engagement (Verghese et al., 2003).

The SRLP Framework and these sorts of questions are important for orienting research toward cognitive aging as "something we do" rather than "something we have." Because text processing is an essential activity in maintaining the capacity to learn, such a focus highlights the role of active engagement in cognitive processing for successful cognitive aging.

Acknowledgements

We are grateful for support from National Institute on Aging grant R01 AG13935.

We wish to thank Art Wingfield, Dan Morrow, Gary Dell, Art Kramer, Soo Rim Noh, Matt Shake, and Jeanine Parisi for insightful commentary on earlier drafts of this paper, and David Morrow for perfectly charming discussions about the phenomenology of reading.

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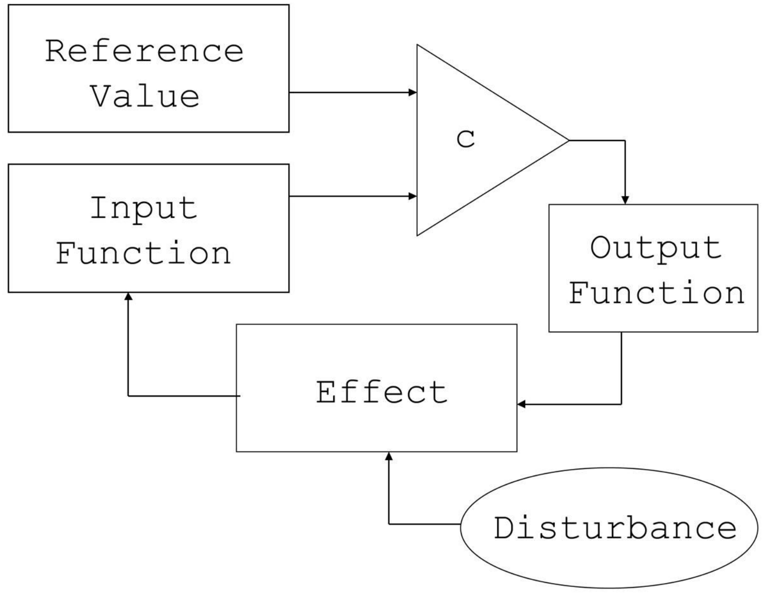

Figure 1.
A negative feedback loop.

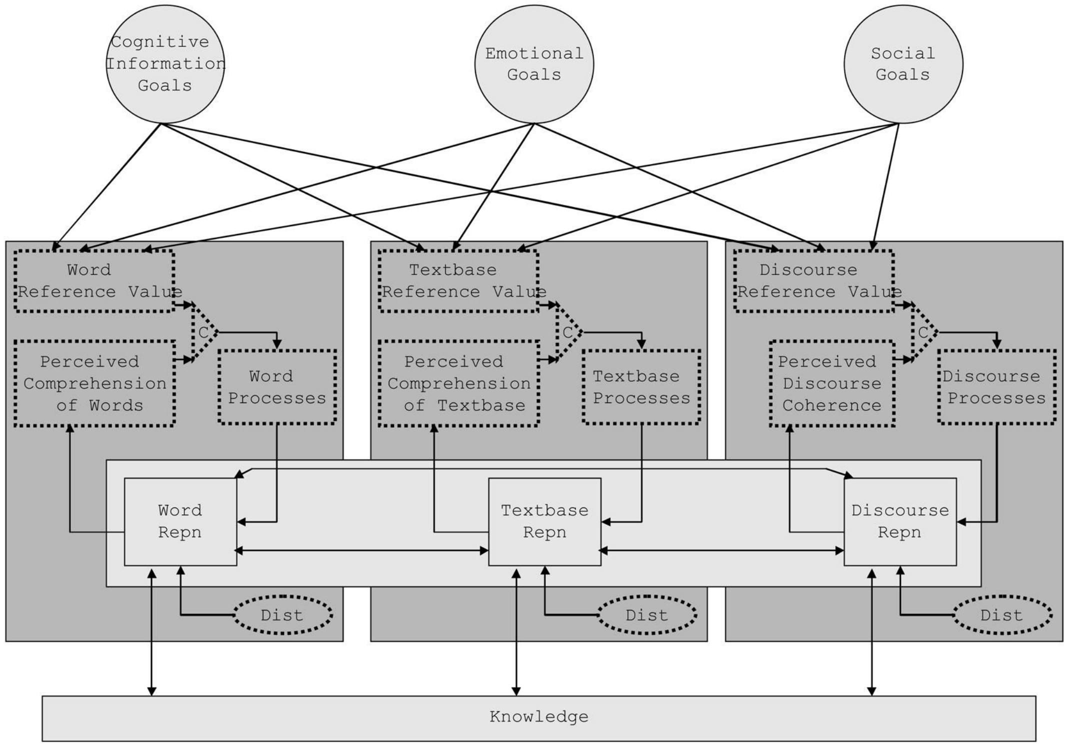

Figure 2.
Model of self-regulated discourse understanding.