Age-Related Changes in Reading Comprehension: An Individual-Differences Perspective

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Age-related Changes in Reading Comprehension:

An Individual-Differences Perspective

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Abstract

In this study, we show that Hannon and Daneman's (2001) component processes task can be used to investigate individual differences in older readers' comprehension performance, and to determine which components of comprehension are most susceptible to declines with normal aging. Results revealed that the ability to remember new text information, to make inferences about new text information, to access prior knowledge in long-term memory, and to integrate prior knowledge with new text information all accounted for a substantial proportion of variance in older adults' reading comprehension performance. Although there were age-related declines in all of these component processes, the components associated with new learning were more susceptible to age-related declines than were the components associated with accessing what already is known. The findings suggest that age-related declines in reading comprehension might be a consequence of declines in a number of component processes rather than one specific process.

Hannon and Daneman (2001) developed a new individual-differences tool that provides estimates of a reader's ability to remember new text information, to make inferences about new text information, to access prior knowledge from long-term memory, and to integrate prior knowledge with new text information. They showed that together these four components accounted for a substantial proportion of variance in young adult readers' performance on a standardized test of reading comprehension (see also Hannon & Daneman, 2006), and that the ability to integrate prior knowledge with text information was the single best predictor of reading comprehension ability. In this article, we show how Hannon and Daneman's component processes task can be used to identify which components of comprehension contribute most to individual differences in older adults' reading comprehension abilities, as well as which components of comprehension are most susceptible to age-related declines.

Skill at reading comprehension is no less important to everyday functioning for older adults than it is for younger adults (Stanovich, West, & Harrison, 1995). Indeed, some would argue that aging brings about an even greater reliance on written prose forms such as newspapers, books, and magazines as the primary sources for new learning (see, for example, Britton & Black, 1985; Johnson, 2003). It is not surprising, then, that considerable attention has been directed towards documenting and explaining age-related differences in comprehending and remembering text. Indeed, in a recent meta-analysis of the aging and prose memory literature, Johnson (2003) included 194 studies, all published between the years 1941 and 1996. This literature provides strong evidence that normal aging is associated with declines in the processing/remembering of text (e.g., Johnson, 2003; see also Gupta & Srivastava, 2000; Verhaeghen, Marcoen, & Goossens, 1993; Zelinski & Gilewski, 1988), with only a few isolated studies failing to show any age-related deficits (e.g., Mandel & Johnson, 1984; Meyer & Rice, 1981). However, the magnitudes of the age deficits vary as a function of factors such as the goals and characteristics of the reader, the nature and difficulty of the reading materials (Hultch & Dixon, 1984; Johnson, 2003; Meyer & Rice, 1989), and there is little consensus among researchers when it comes to explaining the cognitive factor(s) that underlie age-related deficits in text processing.

Some researchers have attempted to explain declines in comprehension in terms of one or more general factors known to be associated with cognitive aging, such as decline in speed of processing, decline in working memory capacity, or decline in the ability to inhibit irrelevant information (e.g., Brébion, 2003; Carpenter, Miyake, & Just, 1994; DeDe, Caplan, Kemtes, & Waters, 2004; Hartley, Stojacj, Mushaney, Kiku Annon, & Lee, 1994; Hasher & Zacks, 1988; Kwong See & Ryan, 1995; Norman, Kemper, & Kynette, 1992; Park et al., 1996; Salthouse, 1991, 1996; Salthouse & Babcock, 1991; Stine & Wingfield, 1990; Van der Linden et al., 1999; Zabrucky & Moore, 1994). Although researchers acknowledge that these three indices of processing efficiency are interdependent, there are vigorous debates as to which of the three plays the primary role in accounting for age-related declines in comprehension. For example, Van der Linden et al. (1999) have argued that the age-related reductions in processing speed and resistance to interference have an indirect influence on comprehension that is mediated by reductions in working memory capacity, whereas Kwong See and Ryan (1995) argue that the influence of working memory is secondary to the influences of processing speed and inhibitory efficiency.

In contrast to the global or general factor approach, other researchers have adopted a more specific analytic approach, attempting to identify the source(s) of age-related declines in comprehension in terms of the specific comprehension component processes used during the reading task itself. For instance, Till (1985) argued that age-related declines in processes involved in retaining text details influence comprehension outcomes, whereas Hess (1995) argued that age-related declines in processes that integrate prior knowledge with new text-based information influence comprehension outcomes. However, the analytic approach also has been plagued by debates and contradictory findings. One debate centers around whether older readers have deficits in their comprehension processes per se, or whether their deficits are simply memory problems that “masquerade as comprehension problems” (Light & Capps, 1986, p. 585; see also Light & Albertson, 1988; Stine, 1990). Another debate centers around the types of information, whether details or main ideas about a text, that are best processed and retained.

Some evidence suggests that older readers are good at recalling the main ideas in a text but are poor at recalling the details (e.g., Dixon, Hultsch, Simon, & von Eye, 1984). Other evidence suggests that older readers are almost as good as younger readers at recalling the details or simple facts from a text, but are poorer at recalling the main ideas or answering questions that require an inference (e.g., Cohen, 1979; Dixon, Simon, Nowak, & Hultch, 1982). Recently, Radvansky, Zwaan, Curiel, and Copeland (2001) concluded that older readers show inferior memory for all text-based information (what the text explicitly says), but equivalent or superior memory for situation model information (what the text is about). As Radvansky et al. point out, "The creation of a situation model is essentially an inference-making process in which the given information and general world knowledge is used to construct an understanding of the described situation" (p. 156). The preserved and even superior ability of older readers to create and use situation models is consistent with the view that older adults rely more on existing world knowledge when they read than do younger readers (Miller & Stine-Morrow, 1998; Miller, Stine-Morrow, Kirkorian, & Conroy, 2004), a strategy that would be highly adaptive for older adults given that "aging brings declines in mental mechanics but growth in crystallized knowledge" (Miller et al., 2004, p. 812; see also Baltes, 1997; Rybash, Roodin, & Hoyer, 1995).

It is unlikely that any one specific component can account for all the individual or age-related variance in performance on a task as complex as reading (see also, Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Carr, 1981; Daneman, 1991; Haeneggi & Perfetti, 1994; Stine-Morrow, Loveless, & Soederberg, 1996). Indeed, Hannon and Daneman (2001) showed that even their best single component process (i.e., knowledge integration) accounted for only 36% of the variance in the reading comprehension performance of young university-aged adults, whereas the multiple component processes together accounted for as much as 60% of the variance. Because of findings such as this one, we thought that using a multi-component processes approach might be an excellent way to examine age-related differences in some of the specific components of reading comprehension. However, Hannon and Daneman's component processes task is a complex task that requires participants to study a three-sentence paragraph well enough to form a mental representation of the complex relations among a set of five terms described in the paragraph, and then respond to a set of test statements each within a 12-s deadline, and so it was not immediately obvious that the task could be readily administered to an aging population. Furthermore, it would be a mistake to assume measurement equivalence for younger and older adults on any particular task (Babcock, Laguna, & Roesch, 1997; Baltes & Nesselroade, 1970). Therefore, the goals of the present study were to investigate whether Hannon and Daneman's task could be used to identify the components of comprehension that most contribute to individual differences in older adults' reading comprehension performance, and to identify the components of comprehension that are most susceptible to declines with normal aging. This approach allowed us to determine the extent to which the well-documented age-related deficits in text processing were more quantitative or qualitative in nature.

Accordingly, we administered Hannon and Daneman's (2001) component processes task and the Nelson-Denny test of reading comprehension to a group of younger and older adults. We also included measures of working memory capacity and vocabulary knowledge, both of which are known to be good predictors of reading comprehension performance in young adults (Baddeley et al., 1985; Daneman & Merikle, 1996; Dixon, LeFevre, & Twilley, 1988; Sternberg & Powell, 1983; Thorndike, 1973). These latter two inclusions allowed us to investigate the relative predictive powers of the component processes task versus working memory and vocabulary knowledge and the extent to which they make overlapping or separate contributions in accounting for individual differences in reading comprehension ability for the two age groups.

Method

Participants

The participants were 72 younger adults whose ages ranged from 18 to 25 years (M = 20.92 years, SD = 1.50) and 74 older adults whose ages ranged from 64 to 87 years (M = 72.51 years, SD = 4.87). The younger participants were recruited from students at the University of Toronto at Mississauga, and had obtained an average of 13.92 years of formal education (SD = 1.50). The older adults were volunteers from the local community in Mississauga, Ontario, and had obtained an average of 14.07 years of formal education (*SD* = 2.90). A questionnaire was administered to screen participants for general health, hearing, vision, and cognitive status. Only participants who reported good health and no history of serious pathology (e.g., stroke, head injury, neurological disease, seizures) were included in our study. All participants were fluent speakers of English and had normal or corrected to normal vision. Participants were paid $10/hr for their participation.

All participants were tested individually in two sessions. During the first session, they were administered a test of reading comprehension (Brown et al., 1981) and a test of working memory span (Daneman & Carpenter, 1980). During the second session, they were administered the Mill-Hill test of vocabulary knowledge (Raven, 1965) and the component processes task (Hannon & Daneman, 2001). These tests are described below.

Component Processes Task

The component processes task provides estimates of a reader's ability to recall text, make text-based inferences, access prior knowledge, and integrate prior knowledge with text-based information. The task accounts for an impressive 34-60% of the variance in performance on global measures of reading comprehension ability (i.e., the Nelson-Denny and the Verbal SAT) and up to 32% of the variance in performance on specific comprehension measures, each of which draws more heavily on one particular component process (e.g., Hannon & Daneman, 2001; 2006). It is better at predicting reading comprehension than typical measures of working memory or vocabulary (e.g., Hannon & Daneman, 2001; 2006) and confirmatory factor analysis indicates that the four components—text memory, text inferencing, knowledge access, and knowledge integration—are indeed separate factors (e.g., Hannon & Daneman, 2006). Finally, all the component processes appear to have high reliability with Cronbach alpha coefficients ranging from .86 to .88.

In the component processes task, participants study three-sentence paragraphs that describe the relations among a set of real and artificial terms, such as:

A NORT resembles a JET but it is faster and weighs more.
A BERL resembles a CAR but is slower and weighs more.
A SAMP resembles a BERL but is slower and weighs more.

By using the relations described in the sentences, participants can construct a number of linear orderings (e.g., a speed linear ordering, a weight linear ordering); however, some of the information is not explicitly mentioned in the paragraph, and so to complete an ordering (e.g., the speed ordering: NORT > JET > CAR > BERL > SAMP) participants must access their prior knowledge that *a jet is faster than a car* and integrate this prior knowledge with the new text-based information. After studying a paragraph, participants answer a set of true-false statements about the paragraph.

Materials. The materials consisted of a set of seven short paragraphs, with the first one serving as a practice paragraph. See Table 1 for two examples and Hannon and Daneman (2001) for the complete set of stimulus paragraphs. Each paragraph consisted of three sentences that were presented one at a time in the middle of a computer screen. Each paragraph included three nonsense terms, two real terms, and two, three, or four semantic features. For example, in the "vehicle" paragraph, shown in Table 1, NORT, BERL, and SAMP are the nonsense terms, JET and CAR are the real terms, and speed and weight are the two semantic features. The number of features per paragraph increased every two paragraphs. Thus, the first two experimental paragraphs included two features, the next two included three features, and the final two included four features.

-----------Insert Table 1 about here-----------

After studying a paragraph at their own pace, participants responded to true-false statements that related to the paragraph. Half of the statements were true and the other half were false. False statements were created by reversing the terms in the true statements, with the exception of the knowledge integration component (see Table 1). In all, participants responded to 216 test statements for the six experimental passages.

There were four main types of test statements: text memory, text inferencing, knowledge access, and knowledge integration. Text memory statements (e.g., “A NORT is faster than a JET”) tested memory for information explicitly presented in the paragraph; no prior knowledge was required. The total number of text memory statements for a paragraph depended on the number of semantic features in that paragraph. Paragraphs with two features had six true and six false text memory statements; paragraphs with three features had seven true and seven false text memory statements; paragraphs with four features had eight true and eight false text memory statements. Text inferencing statements tested inferences about information that was implied in the paragraph; no prior knowledge was required (e.g., “A SAMP is slower than a CAR” which can be inferred from the text facts “A BERL is slower than a CAR” and “A SAMP is slower than a BERL”). Paragraphs with two semantic features had two true and two false text inferencing statements; paragraphs with three semantic features had three true and three false text inferencing statements, and paragraphs with four semantic features had four true and four false text inferencing statements. On the other hand, the knowledge access statements tested access to prior knowledge; no information from the paragraph was required. There were two types of knowledge access statements: low and high. Low-knowledge access statements (e.g., “A JET is faster than a CAR”) tested access to a fact not presented in the paragraph although they included two real terms (JET and CAR) and a feature (faster than) that appeared in the paragraph. Paragraphs with two semantic features had two true and two false low-knowledge access statements; paragraphs with three features had three true and three false low-knowledge access statements, and paragraphs with four semantic features had four true and four false low-knowledge access statements. High-knowledge access statements (e.g., “A JET has a pilot, whereas a MOTORCYCLE doesn’t”) tested access to a fact not presented in the paragraph and included a real term (JET) that was presented in the paragraph, as well as a real term (MOTORCYCLE) and semantic feature (has a pilot) not presented in the paragraph. By including a term and a feature not explicitly mentioned in the paragraph, the high-knowledge access statements required more sophisticated access to and reasoning about the relations among sources of prior knowledge. For each paragraph, there were two true and two false high-knowledge access statements. Finally, the knowledge integration statements (e.g., "Like ROCKETS, NORTS travel in the air") required participants to access prior knowledge (e.g., that rockets travel in the air) and integrate that knowledge with text information (e.g., that NORTS resemble JETS and can therefore travel in air). Each statement included a nonsense term (NORT) that appeared in a paragraph, but neither the real term (ROCKETS*)* nor the semantic feature (travels in the air) appeared in a paragraph. Each paragraph included three true and three false knowledge integration statements.[1]

Procedure. As in Hannon and Daneman (2001), participants were explicitly instructed to use their world knowledge while performing the task. Each paragraph sentence was presented individually in the center of a computer screen. Participants controlled the display time for a sentence by pressing the '+' key when they were ready for the next sentence. After a participant had learned all three sentences of a paragraph and the last sentence had been removed from the screen, the test statements for that paragraph were presented one at a time in a random order. Participants responded to each test statement by pressing one of two keys labeled "yes" and "no." Participants had a maximum of 12 s to read and respond to a test statement. If the participant failed to respond within the 12-s deadline, the test statement was removed and replaced by the next test statement. All response failures were classified as errors. (These accounted for 1.2% of trials for younger adults and 1.3% of trials for older adults). Accuracy (i.e., number correct on each statement type) and speed of responding (i.e., average reaction time for correct responses) were analyzed.

Reading Comprehension Test

Participants were administered a standardized test of reading comprehension ability called the Nelson-Denny (Form E: Brown, et al., 1981). The Nelson-Denny consists of eight short prose passages and 36 multiple-choice questions. Participants were given 20 minutes to complete the test. Consistent with previous findings in the literature (Johnson, 2003; Verhaeghen et al., 1993), the older adults performed more poorly on the test of reading comprehension than did their younger counterparts (i.e., *M* = 21.4 versus *M* = 24.7 respectively), $t(144) = 3.28$, $p < .002$ (see Table 2).

Working Memory Span Test

Our working memory span test was the version of Daneman and Carpenter's (1980) reading span test that was used by Hannon and Daneman (2001); see also Daneman and Hannon (2001) and Daneman and Hannon (2007). Participants read aloud a set of unrelated sentences, made a sensibility judgment about each sentence, and then at the end of the set, recalled the last word of each sentence in the set. The measure was constructed with 100 unrelated sentences, 8 to 12 words in length, each ending with a different word. Sentences were presented one at a time on a computer screen. After participants responded with a 'yes' or 'no' to indicate whether the sentence made sense, they pressed the space bar for the next sentence. This procedure was repeated until a blue screen indicated that the trial was over, at which point participants recalled the last word of each of the sentences in the set. For example, in a 2-sentence set, participants might read, "An eerie breeze suddenly chilled the warm, humid air. The umbrella grabbed its bat and stepped up to the plate." They would respond 'yes' after reading the first sentence, 'no' after reading the second sentence, and then recall *air* and *plate* when prompted by the blue screen. Sentences were arranged in five sets of 2, 3, 4, 5, and 6 sentences, respectively. Participants were presented with increasingly longer sentence sets until all 100 sentences had been presented. Working memory span was the total number of sentence-final words out of 100 that the participant could recall. Consistent with previous findings in the literature (e.g., Brébion, 2003; Carpenter, et al., 1994; Van der Linden, Brédart, & Beerten, 1994), older adults performed more poorly on the measure of working memory capacity than did their younger counterparts (i.e., *M* = 47.2 versus *M* = 61.7 respectively), $t(144) = 7.21$, $p < .001$ (see Table 2).

Test of Vocabulary Knowledge

Participants were administered the Mill Hill (Raven, 1965) test of vocabulary knowledge. The Mill Hill consists of 20 multiple-choice items (e.g., *fecund* means [a] esculent, [b] profound, [c] sublime, [d) optative, [e] prolific [f] salic). Participants completed all 20 items at their own pace. Consistent with previous findings in the literature (e.g., Schneider, Daneman, Murphy, & Kwong-See, 2000; see Verhaegen, 2003, for a meta-analysis), older adults performed better on the measure of vocabulary knowledge than did their younger counterparts (i.e., M = 15.4 versus 13.8 respectively), $t(144) = 4.42$, $p < .001$ (see Table 2).

-------------------- insert Table 2 here ---------------------

Results and Discussion

Younger Adults

The first goal was to determine whether we replicated Hannon and Daneman's (2001) basic pattern of findings with our new group of younger adult readers. Table 2 shows the means and standard deviations for the younger participants on each component, and on the measures of reading comprehension, working memory span, and vocabulary knowledge. Table 3 shows how the components correlated with each other and with the other tests. Below we indicate how our findings largely replicated Hannon and Daneman's findings with respect to (1) the basic pattern of intercorrelations among the components of the component processes task; (2) the ability of each component to predict young adult readers' performance on a global test of reading comprehension; and (3) the superior predictive power of the component processes task over measures of working memory span and vocabulary knowledge.

-----------Insert Table 3 about here-----------

Intercorrelations among the components. For the accuracy data, the intercorrleations among the components closely replicated the pattern found by Hannon and Daneman (2001, 2006). As Table 3 shows, the two text-based components, text memory and text inferencing, were highly correlated with one another (.84), moderately correlated with knowledge integration, the component that taps text-based and knowledge access processes (.68 with text memory and .72 with text inferencing), and at best only weakly correlated with the knowledge access components (correlations ranging from .19 to .36). Taken together, these findings support Hannon and Daneman's (2001) finding that the two text-based components are tapping different skills than are the knowledge access components, but that the knowledge integration component is tapping both prior knowledge and text knowledge.

As in Hannon and Daneman (2001), we included only one speed of responding measure in our analyses because the correlations among the speed measures were all high (range = .53 to .79), and none of the speed measures was significantly correlated with its corresponding accuracy measure. This *speed* measure (see Table 2) was an average of the speeds of correct responses on all five types of test statements (text memory, text inferencing, knowledge integration, low-knowledge access, and high-knowledge access), and was taken to reflect some common factor associated with the speed of reading and responding to a test statement (see also Hannon & Daneman, 2001). This composite speed measure did not correlate significantly with most of the component accuracy measures. The one exception was the -.30 correlation between speed and knowledge integration (see Table 3).[2]

Predicting reading comprehension ability. Consistent with the findings of Hannon and Daneman (2001, 2006), all the components of the component processes task were significantly correlated with performance on the Nelson-Denny test of reading comprehension ability (see Table 3), with the magnitude of the correlations ranging from .31 to .60. Also consistent with the earlier research was the finding that knowledge integration was the best single predictor of reading comprehension ability; it alone accounted for 36% of the variance in the younger adult readers' comprehension performance on the Nelson-Denny. We believe that the knowledge integration component is a better predictor of reading comprehension ability than are the simple text-based components or the simple knowledge-access components because it is a complex component that draws not only on text-based processes and knowledge access processes, but also on the processes involved in integrating the new text information with prior knowledge (see also Hannon & Daneman, 2001, 2006, for a similar argument). These integration processes would be part-and-parcel of the kinds of thematic and predictive knowledge-based inferences that skilled readers make to embellish their text representations (see also Hannon & Daneman, 1998; Long, Oppy, & Seely, 1994; Oakhill, 1982).

We also examined the amount of variance in reading comprehension performance that could be accounted for by the component processes task as a whole by conducting a stepwise regression analysis in which all the components were allowed to freely enter the regression model. As depicted in Table 4, the results of the regression analysis revealed that together the components accounted for 54% of the variance in performance on the Nelson-Denny. These results are highly consistent with those of Hannon and Daneman (2001, 2006), and suggest that the component processes task is an excellent tool for predicting performance on a standardized global test of reading comprehension ability.

-----------Insert Table 4 about here-----------

Finally, we pitted the component processes task against working memory span and vocabulary knowledge, two measures that have been shown to be good predictors of reading comprehension ability (e.g., Baddeley et al., 1985; Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Dixon et al., 1988; Masson & Miller, 1983). Table 5 shows the results of two stepwise multiple regression analyses on the younger adults' reading comprehension scores; in panel (a), working memory and vocabulary were entered into the regression equation before the components of the component processes task; in panel (b), working memory and vocabulary were entered after the effects of the components were partialed out. As Table 5(a) shows, when entered first, working memory span and vocabulary accounted for 29% of the variance in reading comprehension performance. However, note also that the component processes accounted for an additional 29% of the variance in reading comprehension after the effects of working memory and vocabulary knowledge were partialed out statistically. On the other hand, when working memory span and vocabulary knowledge were entered into the regression equation after the 54% of variance accounted for by the component processes had been statistically removed, working memory and vocabulary knowledge accounted for only an additional 4% of unique variance (see Table 5b). This pattern of results is consistent with the pattern found by Hannon and Daneman (2001) inasmuch as it shows that the component processes task accounts for most of the variance in reading comprehension that is tapped by typical measures of working memory span and vocabulary knowledge.

-----------Insert Table 5 about here-----------

Older Adults

Our next goal was to determine whether the component processes task measures similar component processes in older adults as it does in younger adults, and whether the task captures a substantial proportion of variance in older adults' reading comprehension performance as well. Table 2 shows the means and standard deviations for the older participants on each component, and on the tests of reading comprehension, working memory span, and vocabulary knowledge. Table 6 shows how the components correlated with each other and with the other tests. The results were very similar to those found for the younger readers in that all the components of the component processes task predicted the performance of older readers on the Nelson-Denny test of reading comprehension.

-----------Insert Table 6 about here-----------

Intercorrelations among the components. For the accuracy data, the intercorrleations among the components were generally lower than those found for the younger readers (see Table 6). However, the pattern was similar in that the two text-based components, text memory and text inferencing, were highly correlated with one another (.64), moderately correlated with knowledge integration (.43 and .30), and more weakly correlated with the knowledge access components (correlations ranging from .21 to .23).

As was the case for the younger participants, the reaction time measures were all highly correlated with one another (mean correlation = .54), and so we included only one speed measure in our correlational and regression analyses. This speed measure (see Table 2) was an average of the speeds of correct responses on all five types of test statements (text memory, text inferencing, knowledge integration, low-knowledge access, and high-knowledge access), and was taken to reflect some common factor associated with the speed of reading and responding to a test statement (see also Hannon & Daneman, 2001). This composite speed measure did not correlate significantly with most of the component accuracy measures. The one exception was the -.25 correlation between speed and high-knowledge access (see Table 6).[3]

Predicting reading comprehension ability. Consistent with the findings for younger adults (see also Hannon & Daneman, 2001, 2006), the component processes task was an excellent predictor of older adults' reading comprehension performance (see Table 6). All of the components were significantly correlated with reading comprehension, with the magnitude of the correlations ranging from .33 to .51. As was the case for the younger adult readers, knowledge integration was the best single predictor of reading comprehension ability; it accounted for 26% of the variance in the older adults' comprehension performance on the Nelson-Denny.

In order to determine the amount of variance in reading comprehension performance that could be accounted for by the component processes task as a whole, we conducted a stepwise regression analysis that paralleled the one conducted on the data for the younger adults. As depicted in Table 7, the results revealed that our component processes task accounted for 51% of the variance in older readers' performance on the Nelson-Denny test of reading comprehension, an amount that was similar to that found for the younger adult readers in this study, $z = .29$, $p > .38$. These findings suggest that the component processes task is an excellent tool for predicting reading comprehension performance in an older adult population.

------ Insert Table 7 about here ------

Finally, in order to pit the component processes task against working memory span and vocabulary knowledge, we conducted two regression analyses that paralleled those conducted on the data for the younger adults. Table 8 shows the results of two stepwise multiple regression analyses on the older adults' reading comprehension scores; in panel (a), working memory and vocabulary were entered into the regression equation before the components of the component processes task; in panel (b), working memory and vocabulary were entered after the effects of the components were partialed out. As Table 8(a) shows, when entered first, working memory span and vocabulary accounted for 44% of the variance in reading comprehension performance, an amount not significantly different from that found for the younger adults. $z = 1.12$, $p > .13$.

Moreover, the component processes accounted for an additional 17% of the variance in reading comprehension after the effects of working memory and vocabulary knowledge were partialed out statistically, a finding that is also similar to that observed with the younger adults, $z = .94$, $p > .17$. On the other hand, when working memory span and vocabulary knowledge were entered into the regression equation after the variance accounted for by the component processes had been statistically removed (see Table 8b), working memory and vocabulary knowledge accounted for only an additional 10% of unique variance, a finding that is also similar to that observed with the younger adults, $z = .81$, $p > .20$. This pattern of results is consistent with the pattern found for younger adults in showing that the component processes task accounts for most of the variance in older adults' reading comprehension that is tapped by typical measures of working memory span and vocabulary knowledge.

------- Insert Table 8 about here ---------

What Declines with Aging?

So far, we have shown that the component processes task can be used to predict individual differences in the reading comprehension skills of older adult readers, and that the components accounted for a similar proportion of the variance in comprehension performance for older adult readers as it does for younger adult readers, with knowledge integration being the best single predictor for both age groups. In this section, we discuss which components are most susceptible to declines with aging.

There were age-related declines in performance on all components of the component processes task, with the knowledge access components showing the least decline. As Table 2 shows, older readers were less accurate than younger readers on the statements tapping text memory $t(144) = 11.96$, $p < .001$, text inferencing, $t(144) = 7.95$, $p < .001$, and knowledge integration, $t(144) = 12.04$, $p < .001$. These findings are consistent with previous research that has shown age-related declines in performance on tasks that measure memory for text details (e.g., Till, 1985; Verhaeghen et al., 1993), inferencing (e.g., Cohen, 1979; Zacks & Hasher, 1988), and knowledge integration (e.g., Fullerton, 1983; Hess, 1995). Older readers were also less accurate than younger readers on the statements tapping low-knowledge access, $t(144) = 2.33$, $p < .05$, and high-knowledge access, $t(144) = 5.60$, $p < .001$. However, a contrast that compared older and younger adults' performance on the knowledge access component (low-knowledge access, high-knowledge access) with their performance on the component associated with new learning (text memory, text inferencing, and knowledge integration) revealed that the age-related difference for the knowledge access component was significantly smaller than the age-related difference for the components associated with new learning, $F(1, 144) = 132.35$, $MSE = 19.51$, $p < .0001$. This finding is consistent with the view that semantic memory is less susceptible to declines with aging than is episodic memory (e.g., Backman, Small, & Wahlin, 2001; Foos & Sarno, 1998; Riby, Perfect, & Stollery, 2004), as well as the view that crystallized or knowledge-based abilities are less susceptible to declines with age than are fluid intellectual abilities (e.g. Baltes, 1997; Rybash et al., 1995). However, rather than identify aging differences in memory (i.e., episodic versus semantic memory) or intelligence (i.e., fluid versus crystallized intelligence) per se, our results suggest a contrast between types of cognitive processes that tend to serve somewhat different functions, namely the *learning* of new information versus the *accessing* of what is already known.

Finally, our components processes task showed the typical age-related differences in speed of processing (see Table 2), $t(144) = 5.81$, $p < .001$. This finding supports numerous findings in the literature that have shown age-related reductions in the speed of executing many cognitive processes (Birren & Fischer, 1995; Hartley et al., 1994; Salthouse, 1996).

Conclusions

Our multi-component processes approach toward understanding individual differences in age-related declines in reading comprehension revealed a number of interesting findings. For instance, we observed that all of the specific component processes that we measured (text memory, text inferencing, knowledge integration, and knowledge access) were susceptible to declines with aging. Although previous research has observed age-related declines in text memory (e.g., Till, 1985; Verhaeghen et al., 1993), text inferencing (e.g., Cohen, 1979; Zacks &

Hasher, 1988) and knowledge integration (e.g., Fullerton, 1983; Hess, 1995; Till 1985), the new finding here is that one's ability to access prior knowledge is also susceptible to age-related declines. More importantly though, the component processes associated with new learning (i.e., text memory, text inferencing, and knowledge integration) appear to be more susceptible to declines with aging than are the component processes for accessing prior knowledge (low-knowledge access and high-knowledge access). This later finding is consistent with the view that older adults rely more on existing world knowledge when they read (Miller & Stine-Morrow, 1998; Miller et al., 2004). Finally, our results showed that even though there were declines with aging for all of the component processes measured in our study, the powers of these component processes to predict performance on a measure of reading comprehension ability remained the same regardless of the age of our participants and even when the predictive powers of these processes were compared to those of working memory and vocabulary knowledge. Of course, skeptics might argue that a *lack* of a difference in the predictive powers of these component processes between younger and older adults is not particularly interesting. However, we interpret this finding as good news because it suggests that older adults still use the same cognitive processes to the same extent that younger adults use when they are comprehending text, a finding that suggests that the construct of *comprehension* might be the same for younger and older adults. In addition, this finding is consistent with two major theories of comprehension, namely Kintsch's (1988) view of comprehension as the encoding and integrating of new propositions with previously processed information, and Gernsbacher's (1990) view of comprehension as the building of mental structure based on information in the text and information in long-term memory.

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Footnotes

[1]These knowledge integration statements are called high-knowledge integration statements in Hannon and Daneman (2001). Hannon and Daneman's component processes task also included two other types of knowledge integration statements (low-knowledge integration and medium-knowledge integration) that required less complex knowledge access and integration processes. The high-knowledge integration statements, which were more strongly correlated with reading comprehension, are the ones used in the current study. For simplicity, we refer to them simply as knowledge integration statements.

[2]Positive correlations reflect speed-accuracy trade-offs, whereas negative correlations (like the one we observed here) indicate that higher performers on the accuracy measures tend to be fast responders and low performers on the accuracy measures tend to be slow responders.

[3]Again, this negative correlation indicated that higher performers on the accuracy measure also tended to be faster responders.

Table 1

Sample Paragraphs and Test Statements from Component Processes Task

VEHICLE ITEM

Paragraph

A NORT resembles a JET but is faster and weighs more.
A BERL resembles a CAR but is slower and weighs more.
A SAMP resembles a BERL but is slower and weighs more.

Features / Relations

speed	nort > JET > CAR > berl > samp
weight	nort > JET > CAR; samp > berl > CAR

Test Statements

Text Memory	
A NORT is faster than a JET.	(true)
A JET is faster than a NORT.	(false)
Text Inferencing	
A SAMP is slower than a CAR.	(true)
A CAR is slower than a SAMP.	(false
Low- Knowledge Access	
A JET is faster than a CAR. .	(true)
A CAR is faster than a JET.	(false)
High-Knowledge Access	
A JET has a pilot, whereas a MOTORCYCLE doesn’t.	(true)
A JET has a driver, whereas a MOTORCYCLE doesn’t.	(false)
Knowledge Integration	
Like ROCKETS, NORTS travel in the air.	(true)
Like MOTORCYCLES, NORTS travel across the land.	(false)
Like MOTORCYCLES, BERLS travel across the land.	(true)
Like ROCKETS, BERLS travel in the air.	(false)

Table 1 continued

BIRD ITEM

Paragraph

A MIRT resembles an OSTRICH but is larger and has a longer neck.
A COFT resembles a ROBIN but is smaller and has a longer neck.
A FILP resembles a COFT but is smaller, has a longer neck, and nests on land.

Features / Relations

size	mirt > OSTRICH > ROBIN > coft > filp
neck length	mirt > OSTRICH > ROBIN; filp > coft > ROBIN
nests on land	filp, OSTRICH
doesn’t nest on land	coft, ROBIN

Test Statements

Text Memory

A MIRT is larger than an OSTRICH.	(true)
An OSTRICH is larger than a MIRT.	(false)

Text Inferencing

A FILP is smaller than a ROBIN.	(true)
A ROBIN is smaller than a FILP.	(false)

Low-Knowledge Access

An OSTRICH has a longer neck than a ROBIN.	(true)
A ROBIN has a longer neck than an OSTRICH.	(false)

High-Knowledge Access

A BLUEJAY lives in CANADA, whereas an OSTRICH typically doesn’t.	(true)
An OSTRICH lives in CANADA, whereas a BLUEJAY typically doesn’t.	(false)

Knowledge Integration

Like PENGUINS, MIRTS can’t fly.	(true)
Like BLUEJAYS, MIRTS can fly.	(false)
Like BLUEJAYS, COFTs can fly.	(true)
Like PENGUINS, COFTS can't fly.	(false)

Table 2

Means and Standard Deviations for Tasks Completed by the Younger Adults (n = 72) and Older Adults (n = 74)

	Younger Adults		Older Adults	
Test	M(SD)	Range	M(SD)	Range
Component Processes Task[a]				
Text Memory	80.3 (13.73)	42.9 - 100	57.7 (8.65)	44.1 - 83.3
Text Inferencing	73.2 (14.74)	27.8 - 97.2	55.1 (12.71)	27.8 - 83.3
Knowledge Integration	76.4 (14.85)	41.7 - 100	52.5 (8.39)	36.1 - 77.8
Low-Knowledge Access	91.7 (6.37)	72.2 – 100	89.0 (7.58)	55.6 - 100
High-Knowledge Access	88.8 (7.36)	58.3 – 100	81.5 (8.34)	58.3 - 95.8
Speed (ms)	3793 (687.7)	2354 - 5135	4513 (699.5)	2745- 6572
Other Tasks				
Reading Comprehension (max = 36)	24.7 (5.55)	13 – 35	21.4 (6.43)	6 - 33
Working Memory (max = 100)	61.7 (12.09)	39 – 94	47.2 (12.42)	25 - 82
Vocabulary Knowledge (max = 20)	13.8 (2.10)	9 – 19	15.4 (2.20)	11 - 20

Note. [a]With the exception of the speed component, means, standard deviations, and ranges for the components in the component processes task are reported as percentages.

Table 3

Correlations Among the Components of the Component Processes Task, Reading Comprehension, Working Memory, and Vocabulary for the Younger Adults (n=72)

	2	3	4	5	6	7	8	9
1. Text Memory	.84***	.68***	.36**	.19	-.11	.51***	.48***	.27*
2. Text Inferencing	---	.72***	.33**	.22	-.22	.55***	.45***	.17
3. Knowledge Integration		---	.39***	.26*	-.30**	.60***	.43***	.32**
4. Low-knowledge access			---	.33**	-.19	.44***	.22	.28*
5. High-knowledge access				---	-.21	.31**	.22	.24*
6. Speed					---	-.52***	-.17	-.25*
7. Reading Comprehension						---	.47***	.41***
8. Working Memory							---	.39***
9. Vocabulary								---

Note. *$p < .05$; ** $p < .01$; ***$p < .001$

Table 4

Stepwise Regression Analysis on Younger Adults' (n = 72) Reading Comprehension Scores with Components of the Component Processes Task as Predictors

	Variable	R	R^2	ΔR^2	F
1.	Knowledge Integration	.60	.36	.36	38.86
2.	Speed	.69	.48	.12	15.62
3.	Low-knowledge Access	.72	.52	.04	5.22
4.	Text Memory	.735	.54	.02	4.17

Table 5

Regression Analyses on Younger Adults' (n = 72) Reading Comprehension Scores with Working Memory Span, Vocabulary, and Component Processes as Predictors

	Variable	R	R^2	ΔR^2	F
		(a) working memory and vocabulary first			
1.	Working Memory	.47	.22	.22	20.24
2.	Vocabulary	.54	.29	.07	5.83
3.	Knowledge Integration	.66	.44	.15	19.42
4.	Speed	.74	.54	.10	14.45
5.	Low-knowledge Access	.755	.57	.03	4.08
6.	Text Memory	.762	.58	.01	1.88
		(b) working memory and vocabulary last			
1.	Knowledge Integration	.60	.36	.36	38.86
2.	Speed	.69	.48	.12	15.62
3.	Low-knowledge Access	.72	.52	.04	5.22
4.	Text Memory	.735	.54	.02	4.17
5.	Working Memory	.755	.57	.03	4.99
6.	Vocabulary	.762	.58	.007	1.12

Table 6

Correlations among the Components of the Component Processes Task, Reading Comprehension, Working Memory, and Vocabulary for the Older Adults (n=74)

	2	3	4	5	6	7	8	9
1. Text Memory	.64***	.43***	.23*	.21	.02	.44***	.45***	.23*
2. Text Inferencing	---	.30**	.22	.23*	.09	.35**	.35**	.14
3. Knowledge Integration		---	.20	.13	-.15	.51***	.36**	.20
4. Low-knowledge Access			---	.22	-.05	.33**	.43***	.24*
5. High-knowledge Access				---	-.25*	.39***	.27*	.34**
6. Speed					---	-.41***	-.28*	-.35**
7. Reading Comprehension						---	.51***	.59***
8. Working Memory							---	.42***
9. Vocabulary								---

Note. *$p < .05$; ** $p < .01$; ***$p < .001$

Table 7

Stepwise Regression Analysis on Older Adults' (n = 74) Reading Comprehension Scores with Components of the Component Processes Task as Predictors

	Variable	R	R^2	ΔR^2	F
1.	Knowledge integration	.51	.26	.26	25.56
2.	Speed	.61	.37	.11	12.49
3.	Text memory	.67	.45	.08	9.85
4.	High knowledge access	.70	.49	.04	5.66
5.	Low knowledge access	.714	.51	.02	2.93

Table 8

Regression Analyses on Older Adults' (n = 74) Reading Comprehension Scores with Working Memory Span, Vocabulary, and Component Processes as Predictors

	Variable	R	R^2	ΔR^2	F
		(a) working memory and vocabulary first			
1.	Vocabulary	.59	.35	.35	38.83
2.	Working Memory	.66	.44	.09	10.58
3.	Knowledge integration	.74	.55	.11	16.85
4.	Speed	.76	.58	.03	3.87
5.	Text memory	.775	.60	.02	4.00
6.	High knowledge access	.78	.61	.01	2.24
7.	Low knowledge access	.782	.611	.001	.95
		(b) working memory and vocabulary last			
1.	Knowledge integration	.51	.26	.26	25.56
2.	Speed	.61	.37	.11	12.49
3.	Text Memory	.67	.45	.08	9.85
4.	High knowledge access	.70	.49	.04	5.66
5.	Low knowledge access	.714	.51	.02	2.93
6.	Vocabulary	.78	.61	.10	16.46
7.	Working Memory	.782	.611	.001	.44