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Age Differences in the Effects of Conceptual Integration Training on Resource Allocation in Sentence Processing

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Abstract

This research examined age differences in the accommodation of reading strategies as a consequence of explicit instruction in conceptual integration. In Experiment 1, young, middle-aged, and older adults read sentences for delayed recall using a moving window method. Readers in an experimental group received instruction in making conceptual links during reading while readers in a control group were simply encouraged to allocate effort. Regression analysis to decompose word-by-word reading times in each condition isolated the time allocated to conceptual processing at the point in the text at which new concepts were introduced, as well as at clause and sentence boundaries. While younger adults responded to instructions by differentially allocating effort to sentence wrap-up, older adults allocated effort to intrasentence wrap-up and on new concepts as they were introduced, suggesting that older readers optimized their allocation of effort to linguistic computations for textbase construction within their processing capacity. Experiment 2 verified that conceptual integration training improved immediate recall among older readers as a consequence of engendering allocation to conceptual processing.

Age deficits in memory for text, while highly variable, are well documented (Johnson, 2003; Thornton & Light, 2006). Some research has suggested that one source of these age deficits is a tendency among older readers to use nonoptimal strategies of attentional allocation to linguistic processes (e.g., Hartley, Stojack, Mushaney, Annon, & Lee, 1994; Stine, 1990; Zabrocky & Moore, 1994). For example, older readers may sometimes neglect relational processing of new concepts introduced in the discourse, which presumably results in a less distinctive, more fragmented, and/or more fragile mental representation for text content, which in turn, makes veridical retrieval less likely (e.g., Radvansky, Zwaan, Curiel, & Copeland, 2001; Stine-Morrow, Miller, & Hertzog, 2006).

In fact, successful text memory is selectively associated with the allocation of attentional resources to conceptual processing (Haberlandt, Graesser, Schneider, & Kiely, 1986; Miller & Stine-Morrow, 1998; Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine-Morrow, Miller, Gagne, & Hertzog, 2008). In the current studies, we investigated the effects of strategy instruction to focus attention on conceptual integration among younger and older readers, as way to both test the causal nature of the integration-recall relationship and to examine possible age differences in implementing such strategies.

The Nature of Text Processing

Language understanding has been modeled as a process of creating a coherent representation of relationships among the concepts expressed by the text (e.g., Aaronson & Ferres, 1984; Mitchell & Green, 1978; Kintsch, 1998). In the construction-integration model (Kintsch, 1988; 1994; 1998), this set of conceptual relationships has been called the *textbase*, and constitutes the mental representation upon which memory for text depends (Kintsch, 1994; Kintsch, Welsch, Schmalhofer, & Zimny, 1990). Inherent limitations in working memory entail that the textbase representation be constructed in cycles, the input of which typically corresponds to coherent syntactic constituents (e.g., noun phrases, clauses, or sentences). Within an input cycle, readers instantiate new concepts as they are introduced and organize them to represent a text's meaning. To some extent, the meaning of a sentence is incrementally constructed as the language unfolds (e.g., Just & Carpenter, 1980; Pickering & von Gompel, 2006). However, the incremental analysis may be incomplete so that readers move past (or regress from) a point in the text without having completed a full semantic analysis up to that point (Daneman & Carpenter, 1983; Mitchell, Green, & Hammond, 1981; Warren, McConnell, & Rayner, 2008). There is considerable evidence that at the end of the input cycle (typically at syntactic boundaries), readers attempt to more fully consolidate the semantic representation beyond the incremental construction on the fly, integrating the concepts currently held in working memory with the residual semantic representation from earlier cycles and resolving ambiguity. For example, reading times at the ends of clauses and sentences are typically relative long, a phenomenon called "wrap-up" (Just & Carpenter, 1980; Haberlandt et al., 1986). Furthermore, more time is allocated to wrap-up when text is more complex (e.g., has more new concepts to be integrated) or when ambiguity must be resolved (Aaronson & Scarborough, 1976; Daneman & Carpenter, 1983; Haberlandt et al., 1986; Haberlandt & Graesser, 1989; Miller & Stine-Morrow, 1998; Mitchell & Green, 1978; Wiley & Rayner, 2000). The N400 component of evoked potentials shows a more consistent response to semantic incongruity when the anomalous word is in the sentence-final position relative to when it is in a sentence-middle position (Osterhout, 1997). Also, when a semantically anomalous word occurs mid-sentence, its effects on the N400 are also clear (if not clearer) at the sentence-final word (Ditman, Holcomb, & Kuperberg, 2007; Hagoort, 2003). Collectively, these data suggest that clause and sentence boundaries are computational hotspots for semantic integration.

At the same time, individuals vary in the extent to which they allocate effort to conceptual processing, a phenomenon that has been demonstrated by regressing word reading times for individual readers onto text features reflecting particular processes of interest (an approach dubbed the resource allocation approach; Graesser, 1981; Lorch & Myers, 1990). For example, controlling for word-level features (e.g., length, frequency), reading time is longer for words introducing new concepts into the discourse, as well as at clause- and sentence-final words. These regression coefficients collectively represent the allocation policy with which a reader engages text (see Stine-Morrow et al., 2006, for a review), and provide a measure of the individual reader's attentional allocation to organize and integrate the textbase representation that gives rise to sentence understanding and text memory. This allocation policy shows some reliability within individuals across time (Stine-Morrow, Milinder et al., 2001) and across different genres of texts (Stine-Morrow, Miller, Gagne, & Hertzog, 2008). Readers who allocate more time for wrap-up tend to have higher levels of text recall (Haberlandt et al., 1986; Miller & Stine-Morrow, 1998), suggesting that wrap-up is important for creating a representation that will afford effective text memory and that the allocation policy is an important source of individual differences.

Age Differences in Text Processing

Older readers often show poorer recall of text (Johnson, 2003), which may arise in part from a nonoptimal allocation policy (Stine-Morrow, 2007). Stine-Morrow et al. (2006) have proposed a model of self-regulated language processing (SRLP), which articulates this view. According to the SRLP model, an individual reader's allocation policy reflects a heuristic for controlling attention to remember or comprehend the text. Self-regulated language processing is modeled as a set of negative feedback loops, which collectively control the construction of representations at the levels of the word, the textbase (e.g., conceptual processing), and the discourse. In this model, when a discrepancy is perceived between the perceived fidelity of the current representation and the desired state (e.g., comprehension failure), a reader may shift the allocation policy in such a way as to eliminate the discrepancy. At the same time, the stringency of the allocation policy depends on the current processing goals (e.g., information seeking vs. pleasure) and the knowledge of the reader. The capability of the reader to implement the allocation policy so as to reach the desired level of fidelity (or "standard of coherence"; van den Broek, Lorch, Linderholm, & Gustafson, 2001) depends on the availability of sufficient processing resources and skill. Hence, the allocation policy is defined as how much effort is allocated to particular linguistic computations so as to create a representation of the text that is "good enough" (e.g., Christianson, Hollingworth, Halliwell, & Ferreira, 2001) relative to the desired state. (See Metcalfe (1998) for a similar argument about metacognition in problem solving.) For example, if the reader's goal is to retain accurate information given by the text, the reader may differentially allocate more effort to conceptual processing so as to construct a coherent textbase representation (Stine-Morrow, Shake, Miles, & Noh, 2006).

Age-related declines in processing capacity as well as growth in knowledge can influence the quantity and quality of resource engagement for linguistic computations in reading, especially in textbase construction (Radvansky & Dijkstra, 2007; Radvansky et al., 2001; Stine-Morrow, Miller et al., 2006; Thornton & Light, 2006). For example, older adults show decreased efficiency in encoding individual propositions (Stine & Hindman, 1994), and exhibit particular difficulties in processing text with complex syntactic structures (Kemper, 1987; Kemper, Jackson, Cheung, & Anagnopoulos, 1994). These age-related deficits in encoding the textbase may result in older adults being more likely to engage in "good enough" processing at the textbase level, as long as a situational representation is possible (Christianson, Williams, Zacks, & Ferreira, 2006). Thus, older adults may be less thorough in conducting conceptual processing. When they do engage in conceptual processing, it can produce relatively good levels of text memory, even if this effort appears to be more "diluted" in its effect on performance (Hartley et al., 1994; Stine-Morrow et al., 2008). Similarly, neuroimaging data reveal that in order to maintain good comprehension of syntactically complex sentences, older adults must recruit additional frontal lobe resources (Wingfield & Grossman, 2006). Thus, these findings provide evidence that attentional control for textbase construction requires more effort for older adults, and that ironically, they may sometimes allocate less.

In sum, these findings suggest that the quality of reading engagement may be both a source of age deficits in text memory as well as a means for compensation. However, the studies from which these data derive are uniformly correlational. It is, therefore, uncertain whether resource allocation actually plays a causal role in language performance. An important goal in the current study was to test this idea by directly manipulating allocation to conceptual processing via instruction. Another goal was pragmatic. Even though older readers may compensate for an impoverished textbase processing by relying on situation-level representation (Miller, Cohen, & Wingfield, 2007; Miller & Stine-Morrow, 1998; Radvansky et al., 2001; Radvansky & Dijkstra, 2007; Stine-Morrow, Gagne, Morrow, &

DeWall, 2004) or discourse-level structures (Meyer & Poon, 2001; Stine-Morrow, Miller, & Leno, 2001; Stine-Morrow et al., 2008), there are times when learning the exact propositional content of a text in the absence of knowledge-based processes can be extraordinarily useful (e.g., learning in a new domain, remembering the content of postoperative procedures, or comprehending instructions to complete tax forms), so we were interested in whether strategies of resource allocation at the textbase level would show plasticity, thereby suggesting an avenue for an intervention to improve memory for text in adulthood. As a consequence, the processes we are targeting, those requiring a fraction of second to create associations among concepts, are at a relatively microlevel of language processing.

Rationale and Overview of the Current Studies

For both experiments, participants read a series of unrelated sentences for recall in two phases using the moving window method. The first phase was a control phase during which participants were instructed to read naturally. In the second phase, these readers were randomly assigned to an experimental group, who received explicit instruction in making conceptual links as they read, or a control group, who were encouraged to read passages well. We examined the effects of age and strategy training on the allocation policy with respect to conceptual processing, with particular interest in whether the locus of these effects would be at the point at which new concepts were introduced (“immediacy”) or at wrap-up (“buffering”) at syntactic boundaries either within or between sentences (cf. Haberlandt et al., 1986; Haberlandt & Graesser, 1989; Rayner et al., 1989). The way in which readers regulate, or “schedule,” text integration processes as a function of individual differences in texts and readers is of long-standing interest in the psychology of language (Green et al., 1981; Haberlandt, Graesser, & Schneider, 1989; Hirotsu, Frazier, & Rayner, 2006; Millis & Just, 1994; Rayner, Kambe, & Duffy, 2000), and there is some evidence that aging may bring a qualitative shift in the way in which integration processes are scheduled. Older readers may allocate attention to organize new concepts more frequently (Miller & Stine-Morrow, 1998), and this may be especially true for older adults with good text memory (Stine, 1990; Stine, Cheung, & Henderson, 1995). Such an age-related shift may serve the function of accommodating reduced processing resources (Stine-Morrow et al., under review).

The first experiment was designed to investigate whether change in reading strategy via instruction at this level of process was even possible. Given arguments in the literature that some aspects of language processing are modular, obligatory, and stimulus-driven (e.g., Fodor, 1983; Caplan & Waters, 1999), and the ambiguous scope of this principle, we were not at all sure whether we would find evidence for plasticity. In this first study, we tested a large sample including younger, middle-aged, and older adults, measuring reading time. If the allocation policy for conceptual integration is malleable, we would expect instruction to increase effort to conceptual processing, particularly for wrap-up, and thereby recall. We were also interested in age differences in responsiveness to instructions. To the extent that older adults regulate attention differently from the young to accommodate more limited capacity, we suspected that there may be age differences in the way in which adults would respond to the instructional manipulation. This design provided a rich data set with respect to information about encoding, but resulted in a somewhat long and demanding protocol for participants. For this reason, we made the choice to forego free recall after each sentence; rather (as we describe in detail later), we asked participants to make sensibility judgments after each trial to encourage participants to pay careful attention to meaning, and probed recall at a delay. Such task demands are sufficient to engage attention to textbase processing (i.e., conceptual integration to encode the meaning of the sentence; cf. Smiler et al., 2003), but yield a relatively insensitive measure of recall (in part, because the textbase

representation fades quickly; Kintsch, Welsch, Schmalhofer, & Zimny, 1990; Schmalhofer & Glavanov, 1986). The focus of the second experiment was to assess the effects of instruction on memory performance, so we tested a smaller sample of participants. This produced a more sensitive measure of recall, but of course, reduced the power to detect the predicted four-way interaction in reading time. Collectively, the two experiments allowed us to examine the effects of conceptual integration strategy training on both resource allocation and memory performance.

Experiment 1

The focus of the first experiment was to explore age differences in the shift in reading strategy in response to conceptual integration training, as well as the role of conceptual processing in the formation of metacognitive judgments. Because our focus was on textbase (conceptual) processes, materials were short fact-based passages that have minimal discourse context. Using the judgment of learning (JOL) paradigm, participants estimated their level of learning immediately after reading. So in this first experiment, participants read a series of sentences, and then, after conceptual integration training (or control instructions), read a different set of sentences. Some research has suggested that increased depth of processing during reading may result in a more accurate assessment of learning (Maki, Foley, Kajer, Thompson, & Willert, 1990). To the extent that enhanced conceptual integration contributes to more distinctive mnemonic cues (Koriat, 1997; Koriat & Ma'ayan, 2005) from the textbase representation, we thought it would be possible that our instructional manipulation might enhance the accuracy of memory monitoring (as well as of recall itself).

Method

Participants—Participants were 56 younger ($M_Y = 23.43$ years; $SD = 5.18$), 56 middle-aged ($M_M = 49.14$ years; $SD = 5.87$) and 51 older ($M_O = 70.10$ years; $SD = 5.37$) adults. Two additional participants were tested, one younger and one older adult, but their data were omitted from analysis (in one case, due to experimenter error, and in the other, to the participants' inability to fluidly read and comprehend the text (with an education level of 8 yrs, vocabulary could not be assessed with our measure)). Participants were recruited from the community in the Urbana-Champaign area, and received \$15 for their participation with the exception of a subset ($n=22$) of the younger adults who were undergraduate students from an introductory educational psychology class at the University of Illinois and participated for extra course credit. Individuals were native speakers of English and had no history of neurological or medical impairments. The sample of participants was representative of the diversity in Champaign County, including 79.8% Caucasian, 9.2% African American, 5.5% Asian, 3.7% Hispanic, and 1.2% multiracial individuals. All participants rated their health as good or excellent, and were examined for corrected visual acuity using a Snellen eye chart (at a distance of 20 feet) and also using a Rosenbaum pocket screener (held at a 14-inch reading distance). Most of the participants ($n=163$) had at least 20/20 vision, and almost all had at least 20/30 acuity. There were three subjects with very poor visual acuity (20/40 to 20/100), but experimental passages were programmed on a computer using a large font (Courier New, size 24) that closely approximated the letter size at 20/100 on the Rosenbaum chart. Those who had relatively poor corrected acuity did not reveal any idiosyncratic patterns of reading times (e.g., exaggerated allocation to word decoding).

Means and standard errors for individual difference measures are reported in Table 1. Age groups differed in years of formal education, $F(2,157) = 4.39$, $p = .053$, $MSE = 31.96$, $\eta^2 = .05$. Middle-aged adults, on average, were higher in education level than younger adults, but not higher than older adults, while younger and older adults did not differ in education level.

Age groups did not perform differently on the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981) vocabulary subtests, $F < 1$. Working memory was assessed by a composite of the Stine and Hindman (1994) reading and listening sentence span tasks, which measure simultaneous linguistic processing and storage (Daneman & Carpenter, 1980). A significant main effect of Age, $F(2,154) = 13.13$, $p < .001$, $MSE = 15.58$, $\eta^2 = .146$, showed that working memory span monotonically decreased with increasing age. None of these measures showed a Condition effect or an Age by Condition interaction, confirming that our random assignment to different instructional conditions was effective in balancing individual differences in abilities across age-instructional groups.

Stimulus Materials—Text materials were two sets of 24 sentences, adapted from Stine-Morrow et al. (2001), about diverse topics in history, science and nature that were drawn from popular magazines. Target sentences were each 18 words long; the two sets of sentences were equated in terms of mean number of propositions and syntactic complexity (see Stine-Morrow et al. (2001) for details). Each target sentence was followed by a short (5 to 8 words) filler sentence for which reading times were not measured. This enabled us to obtain estimates of time allocation on the sentence-final words that were associated with comprehension processes and not affected by preparation for retrieval. In order encourage participants to read passages for comprehension, we paired target sentences with sensible and nonsensible fillers and asks participants to make a judgment for each passage as to whether the filler sentence made a sensible continuation of the first sentence. For half the trials, fillers were sensible continuations of the target, and for the other half, fillers were randomly paired with targets so that continuations were not sensible (see Table 2 for examples, and the Appendix A for the complete stimulus set). Two sets of six practice passages were developed for each session, and each set of experimental texts was preceded by one warm-up passage.

Procedure—Each participant took part in two sessions about a week apart. Participants were tested individually in a quiet room. Each session lasted under two hours. Participants were told that they would read a series of short passages on the computer, one word at a time, and decide whether the second sentence was a good continuation of the first sentence. The participants were asked to read naturally in a way that was comfortable for them, but that they should read carefully so that they would be able to make accurate judgments of sensibility and to later recall as much as they could about each topic when given cues.

The first session was a control session at which participants were simply instructed to read carefully. At the second session, participants were randomly assigned to a Conceptual Integration Training (CIT) Group, who received explicit instruction in making conceptual links as they read, or a Control Group, encouraged to improve their recall from the first session. Readers in the CIT Group were told that they would read a new set of passages this time, and they would learn a reading strategy that may help improve to their memory for this information:

Here's how the strategy works: We can think about sentences as expressing a set of related ideas or facts. These ideas describe relationships among concepts. For example, "The skin of the elephantfish feels to the touch as if woven of raw silk and aluminum foil," tells you that an "elephantfish has skin" and that "the skin has a certain feel to it" and that "the texture feels like it is woven of silk and foil" and so on. We have found that readers who take the time as they read to think about these ideas and to actively relate each new concept to ideas that have come before show better memory for the whole sentence. These readers even pause momentarily (a fraction of a second!) in the middle of sentences to make sure they grasp these relationships. So for example, in the sentence above, a person with good memory

may take time to find these connections at the underlined words: The skin of the elephantfish feels to the touch as if woven of raw silk and aluminum foil. It is particularly important to do this at the end of each sentence before going on to the next sentence. The goal is not to try to remember the exact wording of the sentence, but to think about how the concepts are related.

The example presented in the instructions highlighted plausible wrap-up points, the new concepts introduced in sentence (Kintsch & van Dijk, 1978) starting with the second one introduced. Readers were first presented with a practice passage and tried to use the conceptual link strategy that they had just learned. In order to determine if the readers understood the strategy, they were also asked to report to the experimenter what the key concepts were in the passage as well as ideal positions for organizing these concepts. Explicit verbal feedback in organizing concepts was provided and then these readers further practiced the reading strategy with the practice passages. The readers were allowed to repeat the readings until they felt comfortable. The procedure for readers in the Control Group was identical, except that they were not taught the conceptual integration strategy. In order to encourage them to believe that they would do well without providing any actual instruction in reading strategy, they were told that, “we have found that people who perform this type of task more than once usually show higher levels of memory performance, even for new information.” This was an important element in the design to control for expectancy effects.

It is important to note that participants read different sets of sentences in the first and second sessions of the experiment, so that reading times at the second session reflect encoding of new information (not relearning information encountered in the first session). For both sessions, texts were presented using the moving window method (Just, Carpenter, & Wooley, 1982) on a Macintosh G3 computer using Power Laboratory software (Chute, Westall, & Barisa, 1996) in Courier New 24-point font. At the beginning of each passage, the participants saw a “READY?” signal and they pressed the space bar to replace the signal with a plus sign (+) at the top left corner of the screen to fixate their eyes onto the point where the first word of the first sentence would appear. When they pressed the space bar again, the plus sign went away and the first word of the passage appeared along with an array of dashes and appropriate punctuation. The first word was replaced with the dashes by pressing the space bar, and then the second word appeared where its dashes had been. They continued reading the whole passage in this way, and were not able to go back to previous words. After they were finished reading a passage, a series of question marks (?????) appeared to signal them to decide whether the second sentence was a good continuation of the first sentence (sensibility judgment: SJ) by pressing the YES or NO key. Following the SJ, participants were asked to make a JOL (with instructions to “make a subjective estimate of how well you feel that you have learned this information so that you will remember it later”). JOLs were made by clicking on a vertical scale ranging from “Not well at all” to “Complete mastery.” The participants made a JOL for each passage.

After reading the entire set of passages, participants took a short break and then repeated the read-SJ-JOL sequence for the same set of passages.¹ At the end of the session, participants were presented with a series of twenty-four cues and asked to tell everything they remembered about that topic. Cues were selected from the first sentence for each passage and were either topical nouns (e.g., Galileo) or phrases (e.g., Housewives in Bali) that represented each sentence’s subject matter. Participants’ recall was tape-recorded for later transcription and scoring of propositional content. Performance on SJs was at ceiling,

¹Sentence wrap-up times at rereading were faster relative to those at the first rereading, and this rereading benefit was, as might be expected, somewhat greater in the CIT condition, $F(1,147) = 5.37, p < .05, MSE = 21,543, \eta^2 = .035$. Otherwise, effects and interactions were closely mirrored in rereading. Therefore, we only report the data from sentence processing on the first reading trial.

suggesting that immediate sentence comprehension was generally very good, so results from these judgments are not reported.

At the beginning of the first session, participants made subjective assessments about their overall levels of health and completed the vision screening and WAIS-R vocabulary subtest. The second session began with the reading task and then all participants completed the working memory span tasks.

Results

Resource Allocation—For each participant, reading times from the target sentence in each passage were used to compute allocation parameters. Raw reading times greater than 5 SDs above the mean for that participant within each session and each trial were replaced with the upper limit. Because we were using regression to model the allocation policy of individual readers with raw reading times (and not for example, trying to tighten distributions to detect differences between means), we were very conservative in removing outliers. This strategy resulted in replacements amounting to less than 0.7% of the data points in each age group.

Raw reading times for each individual were decomposed into components representing particular computations by regressing them onto an array of text features representing distinctive demands of sentence processing (e.g., Lorch & Myers, 1990; Millis et al., 1998; Stine-Morrow et al., 2008). This allowed us to isolate the resources allocated to conceptual processing while controlling for word-level processes (i.e., orthographic processing, operationalized as the time allocated per syllables; lexical access, operationalized as change in reading time as a function of log word frequency; Francis & Kucera, 1982), as well as the right-to-left sweep to a new line of text (i.e., dummy-coded indicator for occurrence for words at a new line).

To isolate the time allocated to conceptual processing in the regression, each word was coded for three text variables theoretically reflecting conceptual instantiation and integration. First, each word was dummy-coded for whether or not it introduced a new noun concept (NC) (or as described in the case grammar language of Kintsch, Kozminsky, Streby, McKoon, & Keenan (1975), a “new argument”; see also Haberlandt et al. (1986, 1989)). Second, each word was coded for whether it occurred at an intrasentence boundary weighted by the conceptual load to that point in the sentence (IntsB; e.g., clauses, main noun phrases). This was computed by multiplying the dummy code for the presence of a constituent boundary by the cumulative number of new concepts introduced up to that point in the sentence. Third, each word was coded for whether it occurred at a sentence boundary weighted by the conceptual load of the whole sentence (SntB). The importance of weighting the boundary terms by the number of cumulative concepts up to that point is that the resultant regression coefficients are all on the same scale, interpretable as the time allocated *per new concept* at that point in sentence processing. Thus, NC represented time allocated to new concepts as soon as they were introduced (immediacy); IntsB represented the time allocated per new concept to organize new information at wrap-up points within the sentence (buffering across within-sentence constituents); and SntB, represented the time allocated per concept to consolidate the conceptual representation at the sentence-final word (sentence-level buffering) (i.e., immediacy vs. buffering within or at the end of the sentence; cf. Haberlandt et al., 1986; Haberlandt & Graesser, 1989).

Table 3 presents the mean allocation coefficients reflecting word and textbase processing, as well as the mean variance accounted for and intercepts. ² Given the theoretical questions of interest, we focus on the indices reflecting conceptual processing. Figure 1 shows these allocation coefficients for readers in the CIT and control groups as a function of age (vertical

panels) and processing location (horizontal panels). These data were analyzed in a 3 (Age) $\times$ 2 (Condition: CIT, Control) $\times$ 3 (Process: NC, IntsB, SntB) $\times$ 2 (Session: before and after instruction) repeated measures ANOVA. The critical test of whether the manipulation was effective in boosting conceptual processing is whether there was a disproportionate increase in resource allocation across sessions for the CIT group relative to the control (i.e., Condition by Session interaction). In fact, this interaction was highly reliable, $F(1,149) = 24.96$, $p < .001$, $MSE = 255,949$, $\eta^2 = .143$. However, as suggested by Figure 1, the size of this interaction varied as a function of both age and processing locus. The four-way interaction depicted in Figure 1 was reliable, $F(4,298) = 3.78$, $p < .01$, $MSE = 32,985$, $\eta^2 = .048$.

To simplify interpretation of this interaction, we examined resource allocation at the second session controlling for these values at baseline by regressing post-training coefficients onto baseline coefficients and analyzing the residuals. This has the advantage over the analysis of difference scores, for example, in that we are able to examine change that is uncorrelated with baseline scores. This analysis confirmed that the Age $\times$ Condition $\times$ Process interaction after the training was reliable, $F(4,298) = 3.88$, $p < .01$, $MSE = 99,082$, $\eta^2 = .050$, controlling for baseline levels of resource allocation. After training (Session 2), younger and middle-aged adults in the CIT group showed larger coefficients relative to the control group for intrasentence boundary processing [$t(50)=2.69$, $p=.01$ and $t(51)=3.71$, $p<.001$ for young and middle-aged, respectively] and for sentence wrap-up [$t(50)=3.45$, $p<.001$, $t(51)=1.98$, $p=.055$ for young and middle-aged, respectively]. Neither of these age groups showed a reliable effect of training on the immediacy of conceptual processing [$t(50)=1.38$, and $t(51)=.52$, for young and middle-aged respectively]. By contrast, the older readers, showed the most reliable effects of training in an increase in processing time at intrasentence boundaries, $t(48)=3.70$, $p<.001$, but also a trend toward increased allocation to immediacy, $t(48)=1.76$, $p=.09$; their trend toward an increase in sentence wrap-up as function of instruction was not reliable, $t(48)=.59$.

Collectively, the data in Figure 1 show that adult readers, regardless of age, responded to CIT by changing their reading strategy, but that there were subtle differences in the qualitative nature of how this strategy was implemented. Younger adults were differentially responsive to the instruction to integrate concepts at sentence boundaries, while older adults allocated more effort as soon as concepts were introduced and at constituent boundaries within the sentence, which may have reduced the cognitive load of sentence processing (Stine-Morrow et al. (under review, but see Haberlandt et al. (1989)).

Recall Performance—For each participant, recall for target sentences was scored for idea units correctly recalled using a gist criterion for propositional recall (Turner & Greene, 1978). With this technique, a proposition (an idea that expresses a relationship among two or more concepts) is scored as correct if the idea is present in the protocol even if worded differently (e.g., “skin of the elephantfish” might be expressed as “the elephantfish has skin” or “the outer covering of an elephantfish”). Four raters participated in the scoring of recall

²The variance in individuals' reading times collectively accounted for (R^2) by the text variables (syllable length, log word frequency, new line (0/1), new concept (0/1), conceptual load at intrasentence boundary (0/cumulative new concepts), conceptual load at sentence boundary (0/cumulative new concepts) was analyzed in a 3 (Age) $\times$ 2 (Condition: CIT, Control) $\times$ 2 (Session: before and after instruction) repeated measures ANOVA, in which Age and Condition were between-subjects variables and session was a within-subject variable. Overall, text variables accounted for more variability in the reading times in the CIT Group than in the Control Group ($M_{CIT} = .26$, $SE = .02$; $M_{CIT} = .19$, $SE = .01$), $F(1,149) = 10.42$, $p < .01$, $MSE = .34$, $\eta^2 = .065$. Reading times were under tighter control of text features in the second session relative to the first, $F(1,149) = 25.81$, $p < .001$, $MSE = .29$, $\eta^2 = .15$, but this effect was greater for the CIT Group ($MS_1 = .21$, $SE = .02$, $MS_2 = .31$, $SE = .02$) than for the Control Group ($MS_1 = .18$, $SE = .02$, $MS_2 = .21$, $SE = .02$), as shown by a significant Condition $\times$ Session interaction, $F(1,147) = 8.34$, $p < .01$, $MSE = .09$, $\eta^2 = .053$, suggesting the conceptual integration training engendered more focused attention to text features among participants in the experimental group so as to shape reading strategy.

protocols. To ensure good interrater reliability, eight protocols from each session (four young and four old) were randomly selected to be scored by all four raters. Pearson correlations between raters' scores reached at least .95 for each pair of raters. Table 4 provides means and standard errors for recall performance.

Recall scores from Session 2 were regressed onto those from Session 1 and the effect of training condition on the residuals was tested with a priori tests, so as to examine the effectiveness of training controlling for baseline scores. For the younger adults, the CIT group showed higher levels of recall than the control group, $t(51)=2.03$, $p=.024$, but this difference was not reliable for the middle-aged, $t(47)=.38$, or older, $t(44)=.44$, adults. Younger adults appeared to have benefited more from CIT in recall. However, as we had feared, because the textbase representation quickly fades over time (Kintsch et al., 1990; Schmalhofer & Glavanov, 1986), our delayed recall measure may not have been sensitive to the presumably more distinctively encoded textbase in the training group.

The Relationship between the Resource Allocation and Text Recall—The findings in Figure 1 indicated that training tended to increase conceptual processing, however, there was variability in the extent to which participants responded to conceptual integration training. This variation in how well participants in the instruction condition adopted the strategy (as well as the possibility that participants in the control condition may have independently discovered it) may have contributed to the fact that the analysis of mean change in recall performance did not show consistent effects of the instructional manipulation. To examine this possibility, we examined correlations between resource allocation parameters to conceptual processing and recall performance, as well as the change across session (Δ) in both conceptual processing and recall performance (see Table 5). Note that in this analysis, data are collapsed across experimental condition under the rationale that we were interested in the way in which recall performance changed as a function of manipulated change in resource allocation. Shaded areas show correlations between performance measures and the most proximal measures of resource allocation (i.e., resource allocation and recall within session and their change). Overall, there were small to moderate relationships. Generally, these correlations were higher for the more proximal measures (i.e., on the diagonals relative to those off). Importantly, there were reliable relationships between improvement in recall and increased effort in conceptual processing, particularly for the wrap-up terms. The fact that change in resource allocation (which was promoted by training) was predictive of change in recall (even with our delayed measure) suggests that our strategy instruction had a beneficial effect on recall for some subjects.

Notably, these relationships were reliable for the middle-aged group but much weaker (or nonexistent) for the older group. This is likely due to the fact that the older readers showed a much reduced range in the effect of instruction on sentence wrap-up (i.e., there was simply not a subset of older readers who increased conceptual integration at the sentence level to enable us to test the effects on recall). Recall, however, that older readers tended to implement the conceptual integration strategy through allocation at new concepts (immediacy) and intrasentence boundaries (within-sentence buffering); in fact, there was a lack of association between these shifts in allocation and increased recall among older adults as well, so it may be an integrated textbase representation is simply not used by older adults in text memory. For example, this might be the case if older readers rely on alternative processing routes for memory (e.g., situation model processing; Stine-Morrow et al., 2004). Alternatively, the delayed recall design would have especially penalized older adults if they are less capable of retaining textbase representation over time (Radvansky et al., 2001). With a less durable textbase, older adults would show a weaker relationship between the accommodation of reading strategies and delayed text memory, even if the textbase

representation had been initially encoded in a distinctive way. Our second experiment was aimed at sorting out these different explanations.

Memory Monitoring—Participants' immediate JOLs of the material were coded in a 0–100% scale in 4-point increments. Using these JOLs, we examined the relative accuracy of memory monitoring (i.e., the degree to which readers accurately predicted the likelihood of actual recall for one item relative to another) by calculating Goodman-Kruskal gamma correlations between JOLs on Trial 2 (which were the more proximal to recall performance) and actual recall. These indices were analyzed in a 3 (Age) $\times$ 2 (Condition) $\times$ 2 (Session) repeated-measures ANOVA (see Table 4). There was a significant age difference in monitoring accuracy, $F(2, 157) = 5.71, p < .01, MSE = .431, \eta^2 = .068$. Gammas were greater among the young and middle-aged adults than they were among the older adults, replicating a previous finding of age deficits in monitoring accuracy (Miles & Stine-Morrow, 2004). A significant Age $\times$ Condition $\times$ Session interaction, $F(2, 157) = 3.61, p < .05, MSE = .206, \eta^2 = .044$, suggested that there were age differences in the improvement of monitoring accuracy across session as a function of instruction. Younger adults in the instruction group increased in monitoring accuracy more across sessions than those in the control group, $F(1, 54) = 9.25, p < .01, MSE = .505, \eta^2 = .146$, for the Condition $\times$ Session interaction, whereas the gammas of neither the middle-aged nor older adults showed this interaction, $F < 1$, for both. This finding suggests that conceptual integration training was solely effective for younger adults in enhancing the sensitivity of memory monitoring reading.

Discussion

Experiment 1 demonstrated plasticity in conceptual processing, a key component of learning from text, as a consequence of a fairly modest instructional manipulation. This training-induced shift in strategy was developmentally sensitive to age-related constraints in processing capacity. While younger and middle-aged adults allocated more effort toward buffering and integration at both intrasentence and sentence boundaries, older readers engaged a strategy of buffering and integration at the more frequently encountered boundaries (and to some extent, exaggerated immediacy). Assuming that sentence integration processes are particularly resource-consuming, the strategy of differentially increasing allocation to smaller chunks of information would presumably be a way to compensate for reduced processing capacity among older readers (Stine-Morrow et al., under review). As suggested by one reviewer, an alternative interpretation of these age differences in responding to instruction is that older readers were perhaps more diligent in following the instructions. This is possible, but in our instructions we emphasized both consolidation within sentences as well as at the ends of sentences, so the fact that older adults were relatively more diligent in immediate consolidation than at sentence-final consolidation is hard to attribute simply to demand characteristics.

While conceptual integration training improved the mean level of text recall only among younger adults, the correlation between (manipulated) change in the allocation policy and change in recall strongly suggests that among those readers who were most responsive to training in adjusting their resource allocation, enhanced text memory was a result. Allocation to integration of larger segments (i.e., sentence and clausal wrap-up) appeared to be relatively more effective in engendering good memory among younger and middle-aged adults than for older adults, possibly because a relatively larger processing capacity would allow them to integrate units of information across a wider swath. Furthermore, the memory monitoring data showed that younger adults differentially benefited from conceptual integration training in enhancing the sensitivity of metacognitive monitoring.

Collectively, the data from the first experiment suggested that instruction in conceptual integration was effective in shifting the allocation policy of adult readers in a way that was compatible with working memory limits. However, enhanced processing of the textbase may have been most beneficial for relatively younger adults, in part, by enhancing memory monitoring, and did not appear to enhance text memory for the old at all.

Experiment 2

The second experiment was designed to specifically examine the effects of conceptual integration training on text memory. The methodological approach was as in the first experiment, with the following exceptions. First, in order to obtain a more sensitive measure of memory for sentence content, we measured immediate recall of each sentence rather than probing at a delay (cf. Schmalhofer & Glavanov, 1986; Radvansky et al., 2001). Second, only younger and older adults participated in this experiment. Third, we were concerned that the lack of association between resource allocation and recall in the older group might have been partly attributable to distraction from the JOL task (see Stine-Morrow, Shake et al., 2006, for evidence that memory monitoring may draw resources away from reading so as to compromise the ability to learn from text); consequently, we simply asked participants to read and recall each passage (without making JOLs). Finally, all target sentences were followed by sensible continuation fillers, which is more representative of naturalistic reading and more likely to enable conscientious readers to form an integrated semantic representation. Under these conditions, it was expected that increasing attentional allocation to conceptual processing would benefit readers' memory for text. Our question was whether increased conceptual processing could enhance immediate recall among older adults.

Method

Participants—Participants were 27 younger ($M = 27.04$ years; $SD = 8.32$) and 24 older ($M = 73.00$ years; $SD = 9.02$) adults drawn from the same populations as those in the first experiment. Participants received \$15 for their participation with the exception that thirteen of the younger adults, who were students at the University of Illinois, participated as a requirement or for extra credit in an introductory educational psychology class. The sample of participants were again representative of the local county, and included 78.4% Caucasian, 15.7% African-American, 2.0% Asian, 2.0% Hispanic and, 2.0% multiracial individuals. The majority of participants (78.4 %) rated their health as good or excellent, and the rest (21.6%) rated it as average or fair. Most of the participants ($n=50$) had at least 20/20 vision, and all but one participant (with 20/40) had at least 20/30 acuity.

The means and standard deviations of individual difference measures for participants are described in Table 6. Older participants had more years of formal education than the younger participants, $F(1,47) = 9.85, p < .01, MSE = 46.73, \eta^2 = .173$, but age groups did not differ in vocabulary, $F(1,47) = 1.07, p = .307, MSE = 81.38, \eta^2 = .022$. As in the first experiment, the younger participants had an advantage over the older participants in terms of working memory, $F(1,47) = 14.26, p < .001, MSE = 15.70, \eta^2 = .233$. Neither a Condition effect nor an Age by Condition interaction was associated with any measure of individual difference.

Stimulus Materials and Procedure—Two new sets of 24 target sentences and fillers were drawn from Stine-Morrow et al. (2001) in order to enhance generalizability to new materials. In all cases, filler sentences were sensible continuations of the target sentences. The entire experiment was conducted in one two-hour session. All participants read the first set of materials under the identical instruction to read naturally, and then read the second set of materials with either the experimental or control version of instructions (as in the first

experiment). After reading each passage one time, participants recalled as much as they could from what they had just read.

Results

Resource Allocation—Word-by-word reading times were trimmed and analyzed as in the first experiment (replacements for 0.65% of the data for the younger adults and 0.70% of the data for older adults). Allocation coefficients were calculated for individual readers as in the first experiment; means and standard errors are reported in the right portion of Table 3. Because of the relatively small sample, allocation parameters more than 2.5 *SDs* away from the mean within the individual's age group for Sentence Set 1 (before instruction) and within age-condition data sets for Sentence Set 2 (after instruction) were replaced with the upper or lower limit (this resulted in replacements for < .5% of the data). As in the first experiment, the coefficients reflecting conceptual processing (NC, InstB, SntB) from reading after training were regressed onto those before training. Residuals reflecting allocation after training controlling for baseline were analyzed in a 2 (Age: young, old) $\times$ 2 (Condition: CIT, control) $\times$ 3 (Process: NC, IntsB, SntB) repeated measures ANOVA.

Replicating Experiment 1, readers in the CIT Group increased allocation to conceptual processing ($M_{S1} = 41$, $SE = 10$; $M_{S2} = 113$, $SE = 15$) more than did readers in the Control Group ($M_{S1} = 50$, $SE = 10$; $M_{S2} = 41$, $SE = 15$), $F(1,47) = 17.42$, $p < .001$, $MSE = 226,893$, $\eta^2 = .270$. With this smaller sample size, we did not detect reliable modulation of this effect across process type as a function of age, $F(2,94) < 1$.

Recall Performance—Three raters contributed to the scoring of recall protocols. Six protocols (three from the young and three from the old) were randomly selected to be scored by all three raters, and interrater reliability reached at least .98 across pairs of raters. The recall data for one older subject were excluded because of a substantial decrease in recall performance for Set 2 compared to Set 1 (.60 vs. .31). Cell means and standard errors for recall are presented in Table 7. Even though participants were randomly assigned to instructional condition and we detected no age by condition differences in individual difference measures, there were unexpected initial differences between groups in recall for Set 1 for older adults. As before, we regressed scores from Set 2 onto those of Set 1 and tested for group differences in the residuals. For the young, the difference in the residuals between the CIT and control groups was not significant, $t(25) = 1.00$, $p = .16$, but in this case, the older adults showed a robust effect of training, $t(21) = 2.93$, $p = .004$, with the CIT group showing improvement in recall post-training and the control group showing some decline.

The Relationship between the Resource Allocation and Text Memory—

Measuring immediate recall, we found that older adults not only benefited from conceptual integration training, but in fact, showed greater memory enhancement than the young. Correlations between resource allocation and recall also suggested that immediate recall (unlike delayed recall) was improved by more thorough textbase processing among older readers. In this case, older adults showed strong relationships between the changes in NC processing and SntB wrap-up, and improvement in recall (see Table 8).

Discussion

This experiment replicated the key finding from the first experiment that resource allocation to instantiate and integrate new concepts in text can be enhanced through instruction. The important finding here was that older adults enhanced their immediate recall of sentences as a consequence of increased allocation to conceptual processing. We considered a number of reasons why older adults' recall was not improved through conceptual integration training in the first experiment (e.g., the less than optimal engagement of an immediacy strategy vs.

differential decay of the memory trace with delay). The strong correlation between the engagement of an immediacy strategy (i.e., NC processing) and immediate recall among the older readers in the current experiment suggests that this was, in fact, an effective encoding strategy to promote good text memory. The more plausible explanation, then, is that older readers were able to use the conceptual processing strategy to enhance the textbase representation, but it was more fragile and less resilient over time – possibly as a consequence of it being less coherent without integration at sentence wrap-up. When probed with delayed recall in the first experiment, it was impossible to detect this initial improvement, whereas immediate recall in the second demonstrated the memory benefits of encouraging older readers to allocation attentional resources to textbase construction.

General Discussion

Across two studies we showed that reading time patterns and subsequent text memory could be altered with strategy focused on conceptual integration. Using the resource allocation approach (cf. Stine-Morrow et al., 2006, for a review) we isolated the components of reading time theorized to reflect attentional allocation to instantiating and organizing new concepts. With regression, we controlled for variance in reading times attributable to word-level processes (word length and frequency) and measured increases in reading time specifically allocated when new concepts were introduced (immediacy of processing), as well as per-concept increases at the ends of intrasentence constituents (e.g., clauses) and sentences. These indices of the reader's allocation policy have proven to be a source of individual differences that can impact subsequent text memory (Stine-Morrow et al., 2008). This investigation is, to our knowledge, the first to provide evidence that the allocation policy with which readers engage text can be altered by specific training, and that this change in strategy is related to change in memory performance. These findings hold theoretical implications for models of language processing and for how language processing changes with age, as well as practical implications for application.

By providing training to focus attention on conceptual processing, we found evidence for plasticity of the allocation policy at a very microlevel among adults from a wide age range. In terms of the SRLP model (Stine-Morrow, Miller et al., 2006), we found evidence that the regulation of effort to construct the textbase could be enhanced through process-targeted instruction. Given earlier findings that older adults may be less likely, relative to young, to increase effort to semantic analysis with simply a goal of high recall accuracy (Stine-Morrow, Shake, et al., 2006), these findings suggest that older readers may require more specific support than the young to increase their standard of representational fidelity. This is also interesting in light of assertions that interpretive processes in language are modular and not subject to executive control (Caplan & Waters, 1999), with our findings providing counterevidence to this principle, or perhaps suggesting that propositional construction is not interpretative but falls into the province of post-interpretive processing. In other words, depth of semantic analysis to create an integrated conceptual network appears to be subject to strategic control; the representation that is “good enough” (Christianson et al., 2001; Ferreira, Bailey, & Ferraro, 2002) is amenable to instruction.

We found tentative evidence for age differences in the way in which readers of different ages engaged effort for semantic integration. First, we note that middle-aged and older adults did show sentence wrap-up at pretest without training (see Table 4), so it would be incorrect to assume that aging brings complete neglect of conceptual consolidation at the sentence level. However, assuming that the efficiency of propositional coding (conceptual integration) is reduced with age (i.e., it takes more time per proposition for effective encoding; Hartley et al., 1994; Stine & Hindman, 1994), comparable levels of resource allocation across age groups may result in poorer memory among older readers (Stine-

Morrow et al., 2006). Thus, good memory performance among older readers has been associated with overallocation relative to young (Stine-Morrow et al., 2001), and there is some reason to focus on this process as a target for training. Second, in the first experiment, we found age differences in the way in which readers shifted their conceptual integration strategy as a function of instruction. Older adults, with their more limited resources, appeared to organize new concepts more frequently within sentences (Miller & Stine-Morrow, 1998; Stine, 1990; Stine-Morrow et al., under revision); in contrast, younger adults showed this accommodation at sentence-level integration. Consistent with earlier adult life-span research in this area, effects appeared to be graded, with middle-aged adults showing patterns of regulatory adaptation intermediate between college-aged and older adults (Ferstl, 2006). We note, however, that age differences in the patterns of conceptual integration (Figure 1) did not replicate in the second experiment with the smaller sample, so that caution is needed. The larger point that should not be lost, however, is that across two experiments, adults from a wide age range showed reliably enhanced conceptual integration in response to instruction.

Consistent with previous findings, we found in both experiments that conceptual wrap-up was associated with better text recall (e.g., Haberlandt et al., 1986; Stine-Morrow et al., 2001). However, by engendering a change in wrap-up that also changed recall, our study extends this earlier research by demonstrating a causal connection between the thoroughness of conceptual processing and memory performance. This is significant for theories of self-regulated cognition and cognitive enrichment (e.g., Hertzog, Kramer, Wilson & Lindenberger, 2009; Stine-Morrow, Miller, & Hertzog, 2006).

Moreover, among older adults, the combination of a weak relationship between the accommodation of reading strategies and delayed text memory and a strong relationship between the accommodation of reading strategies and immediate text memory suggests that older adults are able to construct a textbase representation, but less capable of retaining it over time. Thus, our results suggest that older adults' attention to textbase encoding can be enhanced by providing explicit instruction in strategies, but that such representations decay relatively quickly among older readers. This may be one factor that contributes to enhanced allocation to discourse and situational features when that is possible (e.g., Stine-Morrow, Miller et al., 2001; Noh, Shake, Joncich, Parisi, Morrow, & Stine-Morrow, 2007). One might argue that if the textbase representation decays quickly (and perhaps even more quickly among older readers), then the conceptual integration strategy is essentially useless. However, in providing a scaffold for the situation model (Radvansky et al., 2001), even a transient textbase representation that is accurate could enhance text memory through multiple routes, even if it is not via direct retrieval.

These findings build on earlier research showing that older readers' memory for text can be improved through strategy instruction that is focused on encoding (Meyer & Poon, 2001; Meyer, Young, & Bartlett, 1989). Interestingly, these successful interventions are similar in focusing on organizational processing of text. While the structure training strategy (e.g., Meyer & Poon, 2001) enhances older readers' ability to organize content around larger discourse structures, the conceptual integration strategy enhanced the organization of individual concepts. Both appear to be effective, highlighting an important role for organizational processing for enhancing text memory among older readers. A significant facet of the current research was the ability to measure online change in strategy implementation that mediated the effect of instruction on improved memory.

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Appendix A

Stimulus Materials for Experiments 1 and 2 (randomized for presentation)

Experiment 1

Session 1: Sensible

1. Every morning housewives in Bali put some rice on small pieces of banana leaves to ward off spirits. The rice is considered to have magical properties.
2. Most Turkish peddlers pool their meager funds in order to travel to big cities in tired old buses. They live in these buses selling wares by day.
3. For thousands of years Utah has seemed a promised land to Native Americans, mountain men, and religious pilgrims. To many today, Utah still holds that promise.
4. Whitehall Castle, a favorite of King Henry the Eighth, was furnished with the earliest steam bath in England. King Henry's fondness for luxury is well documented.
5. The ancient Greeks never included any ball games in their Olympics, dismissing them literally as only child's play. They preferred instead games of raw physical strength.
6. Galileo got tired of using his telescope to spot ships and pointed it to the starry sky instead. From then on astronomy was his supreme passion.
7. Uniting in the Middle Ages, merchants wrestled power from feudal lords and gave rise to a middle class. From that middle class early trade unions were formed.
8. Teddy Roosevelt was the one who established national parks in America to preserve the beauty of the wilderness. His farsighted ideas still have merit with modern Americans.
9. Years ago physicians believed that an abnormal imbalance of bodily humors was the underlying cause of mental illness. Such beliefs led them to cures like blood letting.
10. A gigantic water reserve under the central Midwest provides most of the irrigation water used by seven states. This reserve is called the High Plains aquifer.
11. The streets of Toronto are laid out in long rows of tidy brick houses and tall shade trees. Family neighborhoods back up to metropolitan centers.
12. Every September citizens of the Virgin Islands set aside a legal holiday to pray for protection from hurricanes. They believe that prayer appeases angry Nature gods.

Session 1: Nonsensible

13. The innermost layer of fur on a Husky, which is as soft as goose down, keeps it warm. Still many Burmese risk this and work in the paddies.
14. In many species it is the females who shape evolution through their subtle exercise of choice in mating. It consists of a blanket of sulfuric acid.
15. The white-backed night heron hides by day in reed beds and does not venture out until after twilight. A ship can traverse its length in eight days.
16. As a boy, Norman Rockwell drew pictures of sailing ships copying them from packs of American Fleet cigarettes. They often choose mates who are bolder or brightly colored.
17. The atmosphere of Venus has temperatures similar to those of a self-cleaning oven and incinerates any foreign objects. During the day their speed is their best defense.
18. At night impalas rely on big ears and a keen sense of smell as their defense against predators. His talents were evident even then.
19. A leopard is strong and agile enough to be able to tackle prey weighing twice its own weight. Other kinds of dogs would freeze in the cold.
20. The Saint Lawrence seaway unites the five Great Lakes with the whitecaps and whales of the Atlantic Ocean. It then hauls the prey up trees for safe feasting.
21. The average height of adult Pygmies is four feet six inches because they can't process normal growth hormones. It rises gracefully from the reeds at sunset.
22. Experienced hunters in the Canadian north are able to build an igloo in thirty minutes using hard-packed snow. This silt eventually settles on the ocean floor.
23. Cobras and vipers lurk near the rice paddies in Burma making snakebites a frequent cause of deaths there. "Pygmy" in Greek means "the length of a forearm."
24. The coastal waters in Alaska are sometimes murky due to the silt that runs off of the glaciers. This skill is necessary for survival when storms arise.

Session 2: Sensible

1. Lions have relatively small hearts that cannot withstand the demands of long chases in the heat of day. That's why they prefer to hunt at night.
2. Jet noise has been extremely stressful to wildlife but military combat training is still allowed over animal sanctuaries. Newer regulations on altitude restrictions are slow in coming.
3. Throughout the Ming Dynasty, Chinese craftsmen used to make special markings on porcelain pieces to honor the emperor. These markings add to the value of the pieces.
4. Most fig seeds that fall in the rain forest fall onto the shadowed ground and fail to flourish. These dried seeds are a treat for smaller animals.
5. The white-chinned swift of Latin America grows a garden by planting bits of live moss in its nest. This garden attracts insects that feed the swift's young.

6. Florida panthers are susceptible to ringworm as the result of an immune system deficiency brought on by inbreeding. However, ringworm is more an irritant than a danger.
7. Hippos are brutes who have fearsome tusks in their mouths which they use on anything in their way. They are not as docile as we once believed.
8. Puritans who hailed from the east of England introduced the forerunner of baseball which they called "town ball." It required a ball of feathers wrapped with leather.
9. Pole vaulting was first invented by the Dutch who would vault over canals in order to stay dry. Later it became an official sport in Ireland.
10. Early Japanese archers shot from horseback and were required to hit the target or take their own lives. Japan's cavalry was much feared by its enemies.
11. Deals flow like water on the riverbanks of Brazil where local fishermen and peddlers sell the daily catch. Neither storms nor pirhannas stand in their way.
12. Some Japanese groups tattoo mustaches on their daughters by rubbing soot into small knife cuts above the lips. For these groups mustaches are a sign of status.

Session 2: Nonsensible

13. Late in the day vast schools of dwarf herring begin to feed, covering reefs and filling coral caves. These people treat hunting with both reverence and respect.
14. Each summer Hindus and Buddhists enjoy flame-juggling acrobats during ten days of parades that include elephants and drummers. They, in turn, are food for the tarpon.
15. Ancient ruins in Mexico reveal a civilization of people who were both highly skilled artisans and bloodthirsty warriors. Owners claim that sled dogs are too busy to bark.
16. Male tropical fish swim loops and grunt loudly in order to attract the females to the shallower waters. Scholars are only beginning to investigate the Mayan culture.
17. The face of the red velvet fish is as soft as a pillow but its tentacles are venomous. Thousands turn out for the festivities.
18. It is considered a sacrilege to shout in the Siberian pastures of Ukok for it offends the spirits. It is nutritious and can grow in many climates.
19. Romans used to believe that they could cure baldness with a mixture of pig's lard and seahorse ashes. In this manner they avoid daytime and nighttime predators.
20. Dog sleds are not permitted on hiking trails in Idaho because officials believe that barking will frighten wildlife. Today seahorses are sought for other medicinal purposes.
21. Rice provides twenty-five to eighty percent of the calories in the daily diet of half the world's population. Their calls can be heard for hundreds of feet.
22. Hunting caribou is a rite and a necessity for the native Indians of the Arctic Village in Alaska. They sweep up from its face in a pompadour.

23. A century ago James Naismith nailed up peach baskets at a YMCA in Massachusetts and basketball was born. These majestic pastures whistle with their own windswept music.
24. In Puerto Rico tree frogs spend the night in the treetops, leaping to the ground just before sunrise. Only later were the baskets replaced by nets.

Experiment 2

Set 1

1. Since George Washington's time United States Presidents have received presents from both ordinary citizens and heads of state. Many of these are displayed at the White House.
2. Rice that is tinted with turmeric and blessed by a priest is showered over Hindu brides and grooms. This is to bless the couple with prosperity.
3. In redwood forests mosses reach a foot thick and contain more green leafy material than the trees themselves. This moss is vital to a forest's ecosystem.
4. Conservationists in South Africa hope to preserve a balance between the nation's wildlife and an expanding human population. This, of course, is a difficult goal to achieve.
5. The luminous mists and airy sheep-cropped valleys that have bewitched English poets still delight the eye and heart. Much of England's lake country is still untouched.
6. Many treasure hunters have to abandon sunken ship sites in order to escape threatening weather and bounty-hunting pirates. Treasure hunting is as dangerous as it is rewarding.
7. Bearded seal pups live on small blocks of ice so catching them for study is a challenging task. Pups take to the sea shortly after birth.
8. Pitting muscles against mountains, volunteers haul boulders to shore up overused hiking trails in England's fabled lake country. Thousands of people hike these trails every year.
9. Cutthroat trout congregate around the shallower waters which makes them accessible to shore-dwelling animals that hunt for fish. They are also sought by sport fishermen.
10. The Galapagos penguin, which stands only twenty inches high, is one of the smallest and rarest of penguins. Its northern cousins are much taller and heavier.
11. The skin of the elephantfish feels to the touch as if woven of raw silk and aluminum foil. The elephantfish gets its name, however, from its long snout.
12. Jane Goodall spent thirty-five years in Africa living among the chimpanzees while studying their habits and daily lives. She found that they make tools and share technology.
13. Both summer and winter monsoons feed the swollen rivers that gush from the mountains of beautiful Sri Lanka. Natives call this place "Serendib," or "serendipity."
14. In the Basque region of western France the chore of clearing rocks from farmland led to stone-lifting competitions. Some competitors lift boulders weighing over three hundred pounds.

15. Foreigners introduced the game of tug-of-war to Filipinos early in this century as a peaceful substitute for head-hunting. At that time tug-of-war had newly become an Olympic event.
16. Whereas most Greek temples were built with open spaces, the Temple of Zeus has walls between the columns. Embedded in those walls are giant stone statues.
17. The Lakota people honor the buffalo as a life giver and purify its hide with sage and cedar. These plants are burned in an abalone shell.
18. Great White sharks hunt for sea lions, harbor seals, and other sea creatures in many prime surfing spots. Humans share these waters at great risk to themselves.
19. In spite of the fact that male silverback gorillas swagger and slap the ground, they are not aggressive. They only attack when they are strongly provoked.
20. Skeletal remains of wild dogs indicate that Asian seafarers introduced the dingo to Australia thousands of years ago. This wild dog has changed very little over time.
21. The wombat sleeps in a burrow by day emerging at night to nibble grass in the Australian outback. Wombats are solitary quiet creatures who usually live alone.
22. Swordfish and marlins have muscles behind their eyes which adjust the temperatures of their brains in colder waters. This allows them to feed in a range of depths.
23. Native people in Venezuela are known to dine on giant tarantulas whose legs span a ten-inch dinner plate. The tarantula's fangs then make good toothpicks.
24. The city of Venice, with its canals and its magnificent architecture, only covers a mere three square miles. You could walk from end to end in an hour.

Set 2

1. The Atlantic puffin takes on vivid bill colors and facial embellishments during its spring and summer breeding season. This helps it attract a mate.
2. Quilts made by the Mennonite women in Ohio differ greatly from those made by the Mennonites of Pennsylvania. Both types of quilts are lovely and distinctive.
3. Eagles prefer tall trees with widely-spaced branches which allow clear flight paths to and from their large nests. There they can hatch and care for their young.
4. Southern elephant seals can stay submerged to feed on squid for almost two hours in icy Antarctic waters. Air bubbles in their fur keep them insulated.
5. For some African lionesses a meal is often as much a matter of luck and circumstance as skill. They usually wait for meals to come to them.
6. Saudi Arabians who travel to Syria drink beer, which is forbidden by strict Islamic laws in Saudi Arabia. It seems some Saudis enjoy sampling a Syrian lifestyle.
7. Scientists are exploring the lives of the Neanderthals, an ancient people who dominated Europe long before modern man. Neanderthals were probably hunters and gatherers rather than farmers.

8. Genghis Khan and his warriors gained invincibility by taking sandstorm baths and drinking the blood of their horses. Khan conquered one-sixth of the globe in his lifetime.
9. Fungus is big business in the Kennet Square region of Pennsylvania where mushrooms are the major cash crop. Almost half of our mushrooms come from that area.
10. New evidence suggests that infants may have highly active minds even in the first few months of life. They process language concepts long before they can speak.
11. The magnificence of northern Arizona constantly calls to mind all that we imagine the Wild West to be. It stirs within us a yearning for adventure.
12. Herdwick sheep, whose wool is used mainly in rugs, are descended from lambs introduced by the Viking settlers. Their wool is warm enough for harsh Nordic winters.
13. Crocodiles have valves in their throats that close to prevent drowning when they open their mouths under water. Crocodiles can stay submerged for more than an hour.
14. Lions had all but disappeared from South Africa by the turn of the century due to unbridled hunting. Now, thanks to conservationists, their numbers are climbing.
15. Dams and canals on the upper Nile have diverted the river's path opening the land for more residents. Now dams trap ninety-eight percent of the Nile's sediment.
16. Great Britain ruled Ceylon for over a century leaving behind a deep passion for cricket and pipe smoking. Ceylon has a decidedly multi-cultural feel.
17. Suburbs surround the salt ponds beside San Diego Bay where black skimmers and many other bird species nest. Air pollution is wreaking havoc on their habitats.
18. Leatherback turtles will grow to a size of over six feet on a diet consisting mainly of jellyfish. They begin life smaller than a child's hand.
19. Japanese fans are fearful that many of their great baseball players will go west to the United States. There is little space for baseball parks in Japan.
20. Leafcutter ants are serious pests for farmers and ranchers but benefit grasslands and forests by aerating the soil. Organic farmers now try to cooperate with these pests.
21. The sky-high world of the rain forest canopy is a biological frontier where there is much to discover. The canopy supports ninety percent of the forest's organisms.
22. Windsor Castle was erected on a bluff in a valley which is an ideal spot for a fortress. Originally the castle was nothing more than a wooden stockade.
23. Russians crowded into major thoroughfares with their pushcarts last year when selling goods on the street was legalized. This made some streets nearly impassable for cars.
24. Male buntings are super singers who are able to produce over one hundred notes in their distinctive songs. Each bird sings a different, original melody.

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Figure 1. Resource allocation to new concepts, and to intrasentence and sentence boundary wrap-up as a function of session and instructional condition for younger, middle-aged and older adults (CIT=conceptual integration training).

Table 1
Means and Standard Errors of Individual Difference Measures as a Function of Age and Condition (Experiment 1)

Age groups	Education			Vocabulary			Working Memory		
	Cnt	CIT	Overall	Cnt	CIT	Overall	Cnt	CIT	Overall
Young									
<i>M</i>	14.80	14.81	14.80	47.33	46.76	47.04	5.35	5.36	5.36
<i>SE</i>	.26	.37	.23	1.49	2.03	1.26	.24	.22	.16
Middle									
<i>M</i>	16.13	16.48	16.29	49.35	45.32	47.55	4.91	4.75	4.84
<i>SE</i>	.48	.59	.37	1.86	2.10	1.42	.21	.20	.14
Old									
<i>M</i>	15.65	15.82	15.74	48.37	50.12	49.41	4.14	4.40	4.26
<i>SE</i>	.63	.71	.47	1.53	1.60	1.10	.16	.23	.14
All Participants									
<i>M</i>	15.55	15.66	15.60	48.52	47.37	47.96	4.81	4.86	4.83
<i>SE</i>	.28	.33	.21	.95	1.14	.74	.12	.13	.09

Note. Cnt = Control Group; CIT = Conceptual Integration Training Group.

Table 2**Sample Stimulus Materials**

Sensible

Every morning housewives in Bali put some rice on small pieces of banana leaves to ward off sprits. The rice is considered to have magical properties.

Nonsensible

The atmosphere of Venus has temperatures similar to those of a self-cleaning oven and incinerates any foreign objects. During the day their speed is their best defense.

Table 3
Means of Allocation Coefficients (and Standard Errors) for Experiment 1 and Experiment 2

Experiment 1						Experiment 2					
Session 1			Session 2			Session 1			Session 2		
Cnt	Inst		Cnt	Inst		Cnt	Inst		Cnt	Inst	
Young											
SYLL	4 (5)	7 (5)	9 (10)	24 (10)		78 (17)	60 (12)		23 (11)	78 (15)	
LogWF	-12 (4)	-6 (4)	-17 (9)	-46 (10)		-21 (3)	-27 (5)		-14 (7)	23 (12)	
NC	15 (10)	18 (10)	-10 (25)	14 (25)		49 (19)	39 (23)		65 (34)	173 (33)	
InsB	1 (4)	-3 (4)	6 (10)	26 (10)		-11 (13)	6 (12)		-10 (10)	23 (12)	
SntB	52 (12)	51 (12)	78 (30)	247 (30)		89 (27)	93 (26)		69 (33)	146 (42)	
Intercept	393 (30)	346 (30)	409 (50)	598 (50)		374 (65)	561 (63)		430 (67)	480 (65)	
AdjR ²	0.14 (0.02)	0.14 (0.02)	0.17 (0.03)	0.27 (0.03)		0.23 (0.03)	0.21 (0.03)		0.11 (0.02)	0.12 (0.02)	
Middle-Aged											
SYLL	19 (5)	7 (5)	32 (10)	44 (11)							
LogWF	-18 (3)	-14 (4)	-33 (9)	-43 (10)							
NC	15 (9)	32 (10)	27 (24)	58 (27)							
InsB	1 (4)	2 (4)	-4 (9)	39 (10)							
SntB	48 (11)	70 (13)	85 (29)	178 (32)							
Intercept	439 (28)	460 (32)	531 (48)	648 (54)							
AdjR ²	0.17 (0.02)	0.17 (0.02)	0.20 (0.03)	0.26 (0.03)							
Old											
SYLL	7 (5)	16 (5)	21 (11)	51 (10)		73 (13)	64 (17)		51 (12)	77 (25)	
LogWF	-18 (4)	-23 (4)	-35 (9)	-72 (10)		-40 (11)	-33 (9)		-4 (6)	6 (18)	
NC	24 (10)	47 (10)	19 (26)	142 (26)		35 (19)	44 (20)		60 (34)	150 (37)	
InsB	8 (4)	6 (4)	19 (10)	58 (10)		34 (13)	15 (14)		8 (10)	49 (11)	
SntB	62 (13)	74 (13)	98 (31)	147 (31)		100 (27)	48 (29)		53 (33)	135 (36)	
Intercept	546 (31)	594 (31)	631 (51)	816 (53)		641 (65)	668 (71)		502 (67)	830 (73)	
AdjR ²	0.14 (0.02)	0.20 (0.02)	0.17 (0.03)	0.28 (0.03)		0.24 (0.03)	0.16 (0.04)		0.11 (0.02)	0.13 (0.02)	

Note. LogWF=word frequency; SYLL=syllables; IntsB=intrasentence boundary; SntB=sentence boundary; AdjR²=adjusted R-squared.

Means and Standard Errors of Performance Measures (Recall and Relative Monitoring Accuracy) as Function of Age and Condition for Each Session (Experiment 1)

Table 4

Performance measure	Young			Middle			Old		
	Cnt	CIT	Overall	Cnt	CIT	Overall	Cnt	CIT	Overall
Session 1									
Recall									
<i>M</i>	0.40	0.42	0.41	0.38	0.38	0.38	0.39	0.44	0.42
<i>SE</i>	0.03	0.03	0.02	0.03	0.04	0.02	0.04	0.04	0.02
Monitoring γ									
<i>M</i>	0.26	0.14	0.20	0.11	0.17	0.14	0.02	0.01	0.01
<i>SE</i>	0.06	0.05	0.03	0.05	0.06	0.04	0.06	0.06	0.04
Session 2									
Recall									
<i>M</i>	0.45	0.54	0.50	0.45	0.47	0.46	0.43	0.48	0.46
<i>SE</i>	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.03
Monitoring γ									
<i>M</i>	0.09	0.24	0.17	0.16	0.15	0.16	0.07	0.13	0.10
<i>SE</i>	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.03

Note. Monitoring γ = the gamma correlation between judgments of learning on second trial and proportion of propositions recalled.

Table 5
Correlations between Allocation Parameters and Recall Performance for Experiment 1

Resource	Young			Middle			Old			All			
	Allocation	Recall 1	Recall 2	ΔRC	Recall 1	Recall 2	ΔRC	Recall 1	Recall 2	ΔRC	Recall 1	Recall 2	ARC
Session 1													
NC	.21	.27	.14		.27	.32	.14	.26	.33	*	.25	.28	.07
IntsB	.03	-.05	-.10		.32	*	-.30	*	.04	.27	.16	.12	-.19
SntB	.35	.41	**	.19	.31	*	-.18	.35	*	.42	**	.30	**
Session 2													
NC	.04	.05	.02		.12	.33	.31	*	.08	.24	.08	.17	*
IntsB	.04	.37	**	.52	.28	.34	*	-.11	.13	.17	.09	.25	**
SntB	.01	.35	*	.53	.17	.31	*	-.07	.26	.22	.04	.32	**
ΔAllocation													
NC	-.09	-.12	-.08		-.05	.13	.21	.02	.16	.13	-.02	.06	.07
IntsB	.03	.38	**	.54	.16	.31	*	-.12	.03	.19	.04	.23	**
SntB	-.08	.26	.51	**	-.04	.25	.49	**	.00	.29	-.10	.22	**

Note. NC = new concepts; IntsB = intrasentence boundary; SntB = sentence boundary.

* $p < .05$

** $p < .01$.

Table 6
Means and Standard Errors of Individual Difference Measures as a Function of Age and Condition (Experiment 2)

Age groups	Educational Level			Vocabulary			Working Memory		
	Cnt	CIT	Overall	Cnt	CIT	Overall	Cnt	CIT	Overall
Young									
<i>M</i>	14.12	14.12	14.12	41.85	48.00	44.92	5.19	5.57	5.40
<i>SD</i>	1.65	1.19	1.41	11.29	6.66	9.61	1.28	1.10	1.19
Old									
<i>M</i>	16.38	15.54	15.98	48.77	46.75	47.80	4.42	3.94	4.19
<i>SD</i>	2.53	3.00	2.74	5.60	10.26	8.06	0.88	0.67	0.80
All Participants									
<i>M</i>	15.25	14.80	15.03	45.31	47.40	46.33	4.80	4.79	4.80
<i>SD</i>	2.39	2.31	2.34	9.42	8.42	8.91	1.15	1.22	1.17

Note. Cnt = the Control Group; CIT = Conceptual Integration Training Group.

Table 7

Means and Standard Errors of Recall as Function of Age and Instructional Condition (Experiment 2)

	Young		Old	
	Cnt	CIT	Cnt	CIT
Before Instruction (Set 1)				
<i>M</i>	0.52	0.59	0.56	0.42
<i>SE</i>	0.05	0.05	0.05	0.06
After Instruction (Set 2)				
<i>M</i>	0.54	0.64	0.54	0.47
<i>SE</i>	0.05	0.06	0.05	0.06

Table 8

Correlations between Allocation Parameters and Immediate Recall Performance for Experiment 2

Resource	Young			Old			All		
	Allocation	Recall 1	Recall 2	ARC	Recall 1	Recall 2	ARC	Recall 1	Recall 2
Before Instruction (Set 1)									
NC	.05	.08	.11		-.19	-.33	-.23	-.04	-.05
IntsB	.28	.17	-.25		.47	.46	-.16	.28	.18
SntB	.40	.44	.19		.37	.24	-.37	.39	.38
After Instruction (Set 2)									
NC	.04	.20	.46		-.29	-.06	.55	-.11	.09
IntsB	.42	.43	.15		.11	.22	.20	.23	.28
SntB	.30	.44	.45		-.07	.16	.49	.15	.33
Δ Allocation									
NC	.01	.15	.39		-.23	.09	.70	-.09	.12
IntsB	.08	.24	.47		-.33	-.22	.33	-.09	.07
SntB	-.09	.05	.37		-.26	.02	.64	-.17	.03

Note. NC = new concepts; IntsB = intrasentence boundary; SntB = sentence boundary.

* $p < .05$ ** $p < .01$