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Age differences in learning from text: The effects of content preexposure on reading

Soo Rim Noh, Matthew C. Shake, Jeanine M. Parisi, Adam D. Joncich, Daniel G. Morrow, and Elizabeth A.L. Stine-Morrow
University of Illinois at Urbana-Champaign, USA

This study investigated age differences in the way in which attentional resources are allocated to expository text and whether these differences are moderated by content preexposure. The organization of the preexposure materials was manipulated to test the hypothesis that a change in organization across two presentations would evoke more processing effort (i.e., a "mismatch effect"). After preexposure, reading time was measured as younger and older adults read a target text to produce recall, answer comprehension questions, and solve a novel problem. Relative to the young, older readers allocated more time as they encountered new discourse entities and showed a stronger serial position effect, which are patterns of resource allocation that suggest more extensive processing of the discourse situation. Younger adults took advantage of repeated exposure to produce more extensive reproduction of text content, as well as more text-specific solutions to solve a problem. Older adults generated more elaborated inferences and were similar to young adults in terms of the dimensional complexity of problem solutions. Whereas younger readers showed weak evidence for a mismatch effect, older readers did not. These data are consistent with the proposal that older readers favor the situation model over textbase content in allocating resources to text, but this effect was not enhanced by introducing organizational difficulty in reprocessing.

Keywords: aging; comprehension; learning from text; memory; reading; resource allocation

Learning from expository text requires attentional allocation to multiple levels of analysis, which can depend on the use of prior knowledge for understanding new information (Kintsch, 1994, 1998). Some research suggests that older readers differentially rely on discourse-level structures and knowledge-based processes to understand language (Miller & Stine-Morrow, 1998; Miller, Stine-Morrow, Kirkorian, & Conroy, 2004). Providing content preexposure to learn about target topics (e.g., outlines, definitions) has been known to be an effective way to direct readers to attend to the relevant aspects of the text so as to enhance text memory (Mayer, 1983; Rawson & Kintsch, 2002). A few available studies have suggested that older adults benefit from content preexposure to attain equal levels of text comprehension as younger adults (Thompson, 1997, 1998). Even rereading, as a form of preexposure to text content, may be beneficial for older adults (Harris, Rogers, & Qualls, 1998). Thus, our goal in this study was to explore age differences in resource allocation to expository text and how information given in advance of reading might affect younger and older readers' attentional allocation and memory performance.

The multidimensional nature of reading

Readers engage in three different levels of text processing while reading: word, textbase, and discourse levels (Stine-Morrow, Miller, & Hertzog, 2006). *Word-level processing* refers to orthographic decoding and lexical analysis to access word meaning. *Textbase-level processing* refers to the process of identifying relationships among concepts to construct propositions (idea units) and integrating them into the semantic representation of the text (Kintsch & van Dijk, 1978). *Discourse-level processing* includes processes geared toward building a situation model, an elaborated representation in which the propositional content of text is integrated with information from the reader's prior knowledge (Kintsch, 1994). The situation model can also be conceptualized in terms of constructing coherent macrostructures of the text to understand the situation given by the text (Kintsch, 1998). For example, readers tend to build situation models by monitoring multiple dimensions (e.g., temporal, spatial, and causal continuity; Zwaan, Magliano, & Graesser, 1995). In particular, readers monitor the introduction of new characters or discourse entities around which the discourse revolves (Radvansky, Zwaan, Curiel, & Copeland, 2001). Another way of conceptualizing discourse-level processing is in terms of building mental structures of the text, detecting coherence of incoming information with the previous information, and shifting to establish a new structure (Gernsbacher, 1990). For expository texts, readers create a representation of an expository structure, in part, by identifying whether the author is expanding on a previous topic, moving on to a new topic, or integrating (unitizing) earlier information (Britton, 1994). The serial position effect is a key index of

Correspondence should be sent to Elizabeth A.L. Stine-Morrow, Department of Educational Psychology, University of Illinois at Urbana-Champaign, 210 Education Building, 1310 South Sixth Street, Champaign, IL 61820–6990, USA; e-mail: eals@uiuc.edu

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contextual facilitation in that subsequent processing of related concepts is accelerated by a concept in the preceding text, which is indicated by increased reading time from earlier text than from later text (Gernsbacher, 1990; Haberlandt, 1984). Another behavioral indicator of the construction of the situation model is the production of elaborative inferences and the ability to use the information to solve novel problems (Kintsch, 1994). Thus, the reading process consists of multiple levels of processing to create a coherent multilevel representation of the text. Readers must continually derive meaning from text and integrate this new information with what they already know.

Optimizing learning from text

A good deal of research has suggested that inducing readers to engage in active processing, such as by integrating incoming information with knowledge and by generating inferences, is essential to true learning from text (Mannes & Kintsch, 1987; McNamara, 2001; McNamara & Kintsch, 1996). Therefore, creating conditions that optimize such processing is important to understand how to improve learning from text. Schmalhofer and Glavanov (1986) varied the instructions they gave their readers, either emphasizing summarization of the text or knowledge acquisition. They found that readers working toward knowledge acquisition outperformed on recognition probes requiring inferences, whereas readers with the summarization instruction scored better on the recognition probes requiring explicit textbase information. They argued that the summarization instruction evoked attention to the textbase, but that when subjects focused on knowledge acquisition, they attended more to situation-model construction, enabling more flexible mental structures that could be used in novel contexts.

Increasing processing difficulty

According to Schmidt and Bjork (1992), introducing "desired difficulties" for learners can play a beneficial role in enhancing long-term retention and transfer, whereas making learning easier may speed short-term learning but does not necessarily encourage active cognitive processing that optimizes learning in the long run. For example, the advantage of varied versus consistent input (of letter strings) on recall has been well-documented (Ellis, Parente, & Walker, 1974). Extending this principle to reading, O'Brien and Myers (1985) have demonstrated that introducing processing difficulty improves conceptual integration during reading. They embedded either a predictable or unpredictable target word from a previous context in their passages. By using reading times and recognition tasks, O'Brien and Myers showed that readers took longer to read a sentence when it contained an unpredictable target word than when it contained a predictable target word, but they had better recognition of the unpredictable target word (Experiment 1). Moreover, readers were more likely to recall those passages that included an unpredictable target word, and this recall advantage was due to proportionally higher recall of ideas that occurred prior to the target word (Experiment 2), suggesting that the additional processing time for the unpredictable target word was used to reprocess the previous concepts to integrate them with the target.

Knowledge can have paradoxical effects on reading. In the extreme case when knowledge provides a readily available schema for what is to come, it can facilitate processing (see Sharkey & Sharkey, 1987), so that more information is retained even though less effort is devoted to encoding the text. By contrast, when one knows something about the content presented in a text that otherwise conveys novel information, more effort may be allocated in an attempt to connect the new information to the established knowledge base, an idea called the "strenuous inference generation" (SIG) hypothesis (Graesser, Haberlandt, & Koizumi, 1987). For example, Britton and Tesser (1982) showed that readers with relevant domain knowledge increased their response time to a secondary task, whereas readers who had low levels of domain knowledge did not, suggesting that the processing of domain-related texts can be resource-consuming. Britton and Tesser argued that reading more about something already known may require additional processing to search through one's larger knowledge system in order to select the most relevant information for comprehending the text.

One way to introduce desired comprehension difficulty is through strategic mismatching of the organization of a reader's prior knowledge with the structure of the target text (Mannes, 1994; Mannes & Hoyes, 1996; Mannes & Kintsch, 1987). For example, Mannes and Kintsch (1987) manipulated the structure of the advanced organizer to the target text, while the information content was held constant. They asked participants to read a target text preceded by an outline that was either consistent with the organization of the target text (the industrial use of bacteria) or inconsistent with it (the characteristics of bacteria). A set of tasks, including textbase (summary) and situation-model tasks (cued-response, problem-solving tasks), was developed to measure different levels of text presentation as a function of the outline structure. When readers were asked to summarize the text, those readers who had read the consistent outline were better at producing textbase information than were those who had read the inconsistent outline. However, readers who read the inconsistent outline outperformed on the situation-model tasks, such as inferencing and problem solving. These readers also produced more elaborative responses to cues from distinct parts in the text, and were more likely to connect text content to ideas from the outline than the other groups were.

Rereading

Another way to enhance learning from text is via rereading. When readers reencounter information, previously created memory representations help to facilitate the processing of that information; this is called the *rereading benefit* (Levy et al., 1995; Millis, King, & Kim, 2000; Raney, Therriault, & Minkoff, 2000). There is a shift in rereading such that readers attend more to the situation model and less to textbase representation, which was given priority during the first reading (Millis, Simon, & tenBroek, 1998; Millis et al., 2000; Stine-Morrow, Gagne, Morrow, & Herman, 2004). Millis et al. (1998) examined resource allocation across two readings of a series of scientific texts to assess comprehension among younger adults. In two experiments measuring sentence-by-sentence and word-by-word reading times, resource allocation to particular text processes was estimated by regressing reading times for each reader onto text features that reflect language processes (Lorch & Myers, 1990). Textbase processing (as measured by the beta weights for propositions and new argument nouns) decreased during the second reading, whereas allocation to situation-model processing (as measured by beta weights for sentence importance) increased. Thus, the facilitation of textbase processing may free resources for more thorough construction of a situation model during successive encounters with the text (see also Zwaan et al., 1995). This evidence suggests that rereading facilitates textbase processing so as to allow more situation-model processing – at least, among younger readers.

Age differences in resource allocation during reading

As in the Millis et al. (1998) study just described, resource allocation to text is measured by decomposing reading times (or listening times) through regression analysis in which unit processing times are regressed onto an array of text characteristics reflecting component processes (Lorch & Myers, 1990; Titone, Prentice, & Wingfield, 2000). For example, readers take longer to read segments of text that have more syllables, introduce new concepts, or describe a shift in the spatial or temporal setting. When reading times of individual readers are regressed onto these variables, the regression coefficients correspond to the amount of time, or attention, allocated to these processes, i.e., in this example, orthographic decoding, instantiation of new concepts, and updating the spatial and temporal situation, respectively (Millis et al., 1998; Zwaan et al., 1995). Another example of such decomposition of effects is that readers tend to increase their speed as they progress through a passage, a serial position effect that has been interpreted as contextual facilitation later in the passage as a function of structure-building (Gernsbacher, 1990) or situation-model construction (Haberlandt, 1984) earlier on. High familiarity reduces this serial position effect among younger adults (Little, Prentice, Darrow, & Wingfield, 2005), supporting the contention that this effect reflects structure-building because greater familiarity would be expected to reduce the effort required for situation-model construction.

Research on age differences in resource allocation during reading has suggested that older adults allocate more effort to situation-model processing, such as in processing new discourse entities (Radvansky et al., 2001) and instantiating text setting and structure (Miller & Stine-Morrow, 1998; Stine-Morrow, Loveless, & Soederberg, 1996), and relatively less effort to textbase processing (for reviews, see Stine-Morrow et al., 2006; Thornton & Light, 2006). For example, Stine-Morrow et al. (1996) asked younger and older readers to read expository passages and measured sector-by-sector reading times. Young readers who achieved high levels of recall allocated relatively more time to word and textbase features, whereas older readers who achieved good recall allocated relatively more attention to early segments, indicating that older adults are more attentive to structure-building earlier in the passage. Similarly, Stine-Morrow, Miller, and Leno (2001) showed that older adults who demonstrated good narrative recall were especially attentive to narrative structure. Stine-Morrow et al. (2004) demonstrated that older adults may allocate relatively more effort to situation-model processing on the initial encounter with text, whereas younger adults allocate relatively more effort to situation-model processing only in rereading (Zwaan et al., 1995). Interestingly, there were no age differences in text comprehension after rereading, which supports the idea that aging brings qualitative differences in reading, emphasizing a situation model which appears to be essential for older adults to achieve the equivalent comprehension of young adults.

Older adults are more likely to generate inferences in order to relate new information presented to existing knowledge (Charness, 1981; Miller et al., 2004). Miller et al. (2004) have demonstrated that prior knowledge plays a beneficial role in the self-regulation of on-line reading among older adults. They showed that there are age differences in reading time allocation during knowledge-based processing. Unlike younger adults, older readers with relevant domain knowledge increased the effort they devoted to conceptual integration and organization, and produced more elaborated inferences based on that knowledge. These findings suggest that knowledge can have beneficial effects on the elaborated situation-model representation, particularly for older adults. Thus, as mental mechanics (e.g., working memory) decrease with age, older readers rely more on their knowledge to create a situation model to enhance their conceptual processing and remember the text.

Collectively, these data suggest that aging leads to less effective textbase processing and encourages more effort to construct a situation model. With the growth of knowledge throughout the lifespan, older adults may be more likely to be attentive to the situation model when making inferences and elaborating text content based on their knowledge base. With relevant knowledge older adults effectively regulate their resource allocation (e.g., increasing efforts in conceptual processing), which appears to be a key strategy to optimize comprehension and memory. However, we know relatively little about how prior knowledge and prior experiences of content influence readers' dynamic processing, or whether age differences exist in this processing. Readers may encounter new information knowing nothing about the topic, knowing something about the topic, or knowing much about the topic. It is important to understand how different levels of knowledge or prior experiences affect reading processes differently. This could also be helpful in finding conditions that engender a desired level of difficulty for older adults that reduce age differences in text memory.

Rationale for the present study

Given the beneficial role of situation-model processing in learning from a text, the primary goals of this study were to examine age differences in how attention is allocated to situation-model processing in reading expository text and the way in which this attentional allocation may be moderated by content preexposure. In our experiment, participants read a target passage about the habits and habitats of unfamiliar Australian animals that was organized according to taxonomic category (e.g., mammals, birds). They were randomly assigned to one of three preexposure conditions that varied in the type of experience made available to them before reading the target passage. In the consistent organization condition, participants previewed an outline and an article that presented a slightly expanded version of the target text with the same topical organization as the target text (consistent preexposure: CP). In the inconsistent organization condition, the same topics and propositional content were previewed but in a different topical arrangement by types of environmental adaptations (e.g., camouflage, defense) (inconsistent preexposure: IP). In the control condition, participants performed tasks unrelated to the reading task (no preexposure: NP). Moreover, the preexposure conditions offered multiple opportunities to review the material in different modalities of representation (e.g., text, outline, tree diagram). There was a desirable lack of control in this phase, which gave participants the flexibility to learn the material using their own criteria under these conditions (Stine-Morrow et al., 2006).

This manipulation allowed us to test several hypotheses: (a) we expected the CP group to derive benefit from the repetition of the content, devoting relatively less effort to textbase processes in reading the target text than the other two groups, but remembering more content than the other two groups; (b) if older adults are relatively less likely to attend to the textbase, they would be expected to show less preexposure benefit for textbase processes than the young (i.e., relatively greater allocation in the CP and IP conditions, relative to the NP condition); (c) because the IP group encoded a situation model that was then changed, this group was expected to expend more effort in situation-model processing in an attempt to integrate the different representations, and would consequently learn better than the other two groups (Mannes & Kintsch, 1987); (d) if older adults are more reliant on a situation model, then this effect would presumably be exaggerated, as would the consequences for performance.

Methods

Participants

Participants were 31 younger (M_Y = 21.2 years; *SE* = .70) and 31 older (M_O = 66.9 years; *SE* = 1.47) adults. Two additional participants (one younger and one older) were tested, but their data were omitted from analysis because of their unusual familiarity with the topic (e.g., travel, internship in Australia). Younger adults were undergraduate students from an introductory psychology class at the University of Illinois at Urbana-Champaign; they participated in the study for extra course credit. Older adults were recruited from the community in the Urbana-Champaign area, and received $15 for their participation. Individuals were native speakers of English and had no history of neurological or medical impairments. The sample of participants was 91.9% White, 1.6% African American, 1.6% Asian, 1.6% Hispanic, and 3.2 % of unknown ethnicity. Younger and older participants rated their health as good or excellent. All participants were examined for corrected visual acuity using a Snellen eye chart (at a distance of 20 feet) and with a Rosenbaum pocket vision screener (held at least 14 inches away from the face); most (n = 59) had at least 20/20 vision, and all had at least 20/25 acuity.

Participants' vocabulary level was assessed using the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981). Working memory was assessed by a composite of reading and listening sentence span tasks (Daneman & Carpenter, 1980; Stine & Hindman, 1994). To determine whether participants had any prior knowledge of the information covered in the target passages, all individuals were asked to name any Australian animals they knew about and to list any course taken or personal experiences during which they learned about Australian animals.

To determine whether participants in the age-preexposure groups differed in age, ability or prior knowledge, 2 (Age: young, old) × 3 (Preexposure Condition: NP, CP, IP) ANOVAs were conducted on age, education level, vocabulary scores, working memory, and the total number of Australian animals cited, and from these, the number of Australian animals cited that were contained in the target text. Table 1 shows the means and standard deviations for all individual-difference measures for the six groups. The results indicated that preexposure groups did not differ in age, nor was there an Age × Preexposure interaction, $F < 1$, for both. Younger adults had an advantage over older adults in working memory span, $F(1, 60) = 10.81$, $p < .002$, $MSE = 9.50$, $\eta^2 = .17$. Preexposure groups did not reliably differ in working memory span, $F(1, 60) = 2.61$, $p = .083$, $MSE = 2.29$, $\eta^2 = .09$, nor was there a significant Age × Preexposure interaction, $F(1, 60) = 2.28$, $p = .112$, $MSE = 2.00$, $\eta^2 = .08$. Older adults were, on average, higher in education level, $F(1, 61) = 7.88$, $p < .007$, $MSE = 49.44$, $\eta^2 = .13$; however, there was neither a condition effect nor an Age × Preexposure interaction, $F < 1$, for both. There were no effects of age, $F(1, 62) = 1.51$, $p = .225$, $MSE = 95.05$, $\eta^2 = .03$, condition, $F < 1$, or an Age × Condition interaction, $F < 1$, on vocabulary. The preexposure groups did not differ in the number of Australian animals cited, $F < 1$, nor was there an age effect, $F(1, 62) = 1.54$, $p = .220$, $MSE = 3.46$, $\eta^2 = .03$, or an interaction effect, $F(1, 62) = 2.06$, $p = .137$, $MSE = 4.62$, $\eta^2 = .07$. Finally, these effects were also not significant for the number of animals cited that had appeared in the text, $F(1, 62) = 2.91$, $p = .093$, $MSE = .582$, $\eta^2 = .05$ for age, $F(2, 62) = 2.41$, $p = .099$, $MSE = .48$, $\eta^2 = .08$, for condition, and $F < 1$ for the interaction. This suggests that the randomization procedure was effective in balancing individual differences across experimental groups.

Text materials

The target passage was developed from Poignant's (1967) book on Australian animals and several websites related to Australian animals. The passage dealt with wildlife in Australia, focusing on nine unfamiliar but interesting Australian animals, and was fairly demanding in terms of the level of detail. The passage was organized around four groups of animals including mammals, birds, reptiles and aquatic creatures. For each animal, the text provided a detailed description of features that enabled these animals to adapt to a particular niche. The target passage was 1177 words in length, contained 402 propositions (Turner & Greene, 1978), and 165 new concepts. The Flesch-Kincaid grade level was 8.4.

As described earlier, two extended versions of the target passage (that elaborated on the target text with a more detailed description of each animal) and accompanying outlines were created for the preexposure phase. These preexposure materials contained exactly the same propositional content, but were organized so as to be either consistent (CP) or inconsistent (IP) with the target passage. The article for the CP condition was 1699 words in length and the article for the IP condition was 1755 words in length. The Flesch-Kincaid grade levels were 8.7 and 8.8, respectively. Printed copies of the preexposure articles were provided to the participants with the appropriate outline prior to the target text, and were presented in Courier New 16-point font, in about five pages. As with the text, the two outlines contained exactly the same topical information about Australian animals, but only differed in organization. The target passage and the two outlines are given in the Appendix.

Table 1
Means and standard errors of individual difference measures as a function of age and preexposure condition

	Young				Old				Overall		
	NP	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*
n	10	10	11	31	10	11	10	31	20	21	21
Age											
M	20.20	20.90	22.36	21.19	64.80	68.00	67.70	66.87	42.50	45.57	43.95
SE	0.49	0.67	1.84	0.70	2.83	2.53	2.39	1.47	5.30	5.43	5.27
WM											
M	5.47	5.18	5.10	5.24	4.67	3.75	4.94	4.44	5.07	4.46	5.03
SE	0.32	0.27	0.30	0.17	0.25	0.20	0.43	0.19	0.22	0.23	0.25
Educ											
M	14.30	14.30	14.09	14.20	16.60	15.73	15.78	16.03	15.45	15.05	14.85
SE	0.42	0.52	0.41	0.50	1.36	0.89	0.68	0.58	0.74	0.54	0.42
Vocab											
M	49.40	46.50	47.00	47.61	52.00	48.64	49.70	50.06	50.70	47.62	48.29
SE	1.89	2.14	2.41	1.24	2.53	2.44	3.23	1.55	1.56	1.61	1.96
AA											
M	2.50	2.30	1.82	2.19	2.10	2.64	3.30	2.68	2.30	2.48	2.52
SE	0.62	0.40	0.38	0.27	0.23	0.56	0.50	0.27	0.33	0.34	0.34
AT											
M	0.00	0.20	0.18	0.13	0.10	0.36	0.50	0.32	0.05	0.29	0.33
SE	0.00	0.20	0.12	0.08	0.10	0.15	0.17	0.09	0.05	0.12	0.11
T/F Task											
M	0.66	0.90	0.87	0.81	0.66	0.80	0.83	0.77	0.66	0.85	0.85
SE	0.03	0.03	0.03	0.02	0.02	0.03	0.04	0.02	0.02	0.02	0.02

Note. NP = the no preexposure group; IP = the inconsistent preexposure group; CP = the consistent preexposure group; WM = working memory span; Educ = years of education; Vocab = vocabulary; AA = the number of Australian animals cited; AT = the number of Australian animals presented in the target text; T/F Task = a true–false test about Australian animals.

Procedure

Participants were tested individually in a quiet room and were told that they would learn about some interesting animals from Australia. Participants were also informed that there were different tasks that had been planned to help them learn about these animals and recall the material later. Before the experimental session, participants answered questions concerning demographic information (e.g., age, education, health) and were checked for corrected visual acuity. Participants were next administered the WAIS-R vocabulary and Forward/Backward Digit Span tasks and probed about their experiences with and knowledge of Australia and its wildlife. At the end of the experimental session, participants completed the reading- and listening-span tasks.

The experiment consisted of three phases: preexposure, reading, and testing. In the preexposure phase, participants in the CP and IP groups were given a set of materials and activities and told that they could spend as much time on each activity as they needed to learn about these animals. At the beginning, these participants were shown a laminated tree diagram of the nine animals organized either by taxonomy (CP) or adaptation (IP) category. Participants were also told that the outline and article to follow would be organized in the same way. After studying the outline at a comfortable pace, the participants were given the appropriate article depending on the condition assigned, and were asked to read at a normal and comfortable pace. Participants were allowed to refer back to the outline at any time, however, no pens or paper were provided. The study time (including both the outline and passage reading) for participants in the CP and IP conditions ranged between 10 and 20 min. Participants in the CP and IP conditions completed a matching task after the preexposure materials were taken away. For example, participants in the CP condition were asked to select all the animals in each taxonomic category (e.g., for birds, these were helmeted honeyeater and white-winged chough), and participants in the IP condition were asked to choose all the animals relevant to each adaptation category (e.g., for camouflage, Tasmanian thylacine, thorny devil, leafy sea-dragon, and giant cuttlefish). After the matching task, individuals were given feedback on their performance and asked to return to the outline and passage again to find the answers to the incomplete and wrong items. Participants in the NP condition instead received a battery of cognitive tests unrelated to the purpose of the experiment that were approximately the same duration (20 min) as the preexposure so as to control for fatigue effects.

At the end of the preexposure phase, a true–false test about Australian animals was administered; this test consisted of 18 true–false items to assess the participants' knowledge at this point. The true–false items were constructed by selecting 18 statements from the preexposure materials. These items consisted of a mixture of adaptation and taxonomic information. In order to assess the effectiveness of our preexposure session, the mean percent correct from the Australian animal test was analyzed with a 2 (Age) × 3 (Preexposure) ANOVA (Table 1). A reliable main effect of preexposure, $F(2, 55) = 26.84$, $p < .001$, $MSE = .25$, $\eta^2 = .49$, verified that the training manipulation was effective. Both CP and IP groups scored higher than the NP group but the two preexposure groups did not differ in their performance. There was a marginal age difference in performance, $F(1, 55) = 3.82$,

$p = .06$, $MSE = .04$, $\eta^2 = .07$, showing that younger adults did somewhat better than older adults. The lack of a significant Age × Preexposure interaction, $F(2, 55) = 1.40$, $p > .10$, $MSE = .01$, $\eta^2 = .05$, indicated that the effect of training did not depend on age.

In the reading phase, all participants read the same target text presented on the computer. Instructions and then the passage were presented one sentence at time on a Macintosh G3 computer using Power Laboratory software (Chute, Westall, & Barisa, 1996) in Courier New 36-point font. Participants pushed the space bar to progress from sentence to sentence; they were not able to go back to previous sentences. The participant was instructed to read the text at a normal and comfortable pace. The computer recorded the sentence reading times for each participant.

Finally, in the testing phase, participants performed a series of activities to allow assessment of what they had learned and could remember about Australian animals. For each activity, subjects were allowed as much time as needed. First, they were asked to recall aloud the names of all the animals they could remember from the target text. They were then asked to recall aloud everything they could remember from what they had just learned from the passage. Next, participants completed a cued-recall task in which recall was probed with a laminated grid consisting of 45 cells defined by the names of the nine animals (organized by taxonomic category) and the five adaptation topics. They were first instructed to point to any box and to name the animal and its adaptation topic, and then to describe everything they could remember about that information. Participants were encouraged to choose as many boxes as they could to help them remember the passage.

Following the free-recall and the cued-recall tasks, participants completed a comprehension task and a problem-solving task. For the comprehension task, a series of 48 true–false statements (that did not overlap with those used to assess the effects of preexposure) were developed. There were three different kinds of statements: (a) textbase statements in which the information was paraphrased from the original text (24 statements); (b) inference statements that required the integration of textbase context with knowledge (e.g., it was not directly stated in the passage that the thorny devil was well suited for a dry climate, though there was a description of how grooves in the skin allowed it to capture water falling on its back; 20 statements); and (c) global statements which dealt with information that did not occur in the text, but required some type of generalization for the topic (4 statements). Statements were constructed so that they were not likely to differentially probe information highlighted in either preexposure condition (see examples in the Appendix). For the problem-solving task, participants were asked: "you are the curator of the local zoo, and are planning to hold an Australian animal exhibit. What things would you take into consideration to design the exhibition?" This was an open-ended question.

Results

Reading time

Trimming outliers. Raw reading times were screened for outliers that were greater than an upper limit of 5 SD above the median for each individual. Reading times that exceeded this value were replaced with the upper limit value, resulting in the replacement of 0, 0.2, and 0.2% of the data for no preexposure (NP), consistent preexposure (CP) and inconsistent preexposure (IP) younger readers, respectively, and 0.1, 0.2, and 0.1% for NP, CP, and IP older readers, respectively.

Sentence reading times. The average median sentence reading time was 4.5 s ($SE = .3$) for the young and 5.8 s ($SE = .3$) for the older readers; this difference was significant, $F(1, 53) = 10.45$, $p < .01$, $MSE = 23{,}849{,}172$, $\eta^2 = .17$. The NP group required more time to read each sector than did either the CP or the IP group ($M_{NP} = 6.0$ s, $SE = .4$; $M_{CP} = 4.7$ sec, $SE = .4$; $M_{IP} = 4.5$ $SE = .3$), $F(2, 53) = 5.52$, $p < .01$, $MSE = 12{,}603{,}269$, $\eta^2 = .17$. This condition effect did not vary with age, $F < 1$, for the interaction. In spite of the overall age differences, the two groups showed similar responsiveness to the preexposure conditions in mean sentence reading time. This lack of an Age × Condition interaction was inconsistent with some previous reports (Harris et al., 1998; Stine-Morrow et al., 2004) that older readers show relatively less facilitation in reexposure to text content. Recall, however, that our preexposure conditions included multiple routes to familiarize readers with text content and structures. It may be that this more extended period of study afforded older readers the same benefit.

Resource allocation to component processes. To obtain an estimate of reading time allocation to the particular demands exacted by the text, sentence reading time for each subject was regressed onto text features (Lorch & Myers, 1990) reflecting those word-, textbase-, and discourse-level properties known to affect processing. The regression coefficients represent the time allocated (in ms) per unit change in the text feature. Each of the 77 sentences of the passage was coded for (a) the number of syllables (to estimate time allocation to orthographic decoding); (b) the number of new concepts introduced (conceptual instantiation and integration; Radvansky et al., 2001; Stine-Morrow et al., 1996); (c) the serial position of the sentence within the passage (structure building; Stine-Morrow et al., 1996); (d) the introduction of a new discourse entity, a particular concept around which the discourse is focused, in this case, coded as the introduction of a new animal; Radvansky et al., 2001); and (e) the serial position of the sentence within a topic (i.e., construction of the expository argument; Britton, 1994; Miller et al., 2004). The range and means of these text features are presented in Table 2. The array of resulting regression coefficients represents word-level processing (syllables), textbase processing (new concepts) and situation-model processing (serial position, new animals and serial position within a new topic) for each individual reader.

As noted above, those five text variables were entered as independent variables into regressions with each sentence's

Table 2
Text characteristics

Text variables	M	SD	*Min*	*Max*
Syllable (Syll)	23.03	7.87	6	42
New concept (NC)	2.14	1.61	0	8
Serial position (SP)	39.00	22.37	1	77
New discourse entity (New_DE)	0.12	0.32	0	1
Serial position within a topic (SP_T)	9.08	5.91	0	22

reading time as the dependent measure. These analyses were performed separately for each individual. The means and standard errors of all allocation parameters, mean variance accounted for, and mean intercepts as a function of age and preexposure condition are reported in Table 3. Overall, readers spent about 100–200 ms per syllable for orthographic decoding and 200–500 ms per new concept for conceptual instantiation and integration. Readers increased their speed as they read through the text at a rate that varied from no increase up to 30 ms per sentence. Constructing the expository argument took time. Readers allocated up to about 2 s to process the introduction of a new discourse entity. Once a new topic was introduced, readers allocated 50–90 ms per new segment to build the argument.

The five text variables accounted for more of the variance in reading times (R^2) for the older than the younger readers, $F(1, 53) = 4.15$, $p < .05$, $MSE = .12$, $\eta^2 = .07$, suggesting that overall reading times among the older subjects were under slightly tighter control of the text demands we measured than were the reading times of the younger readers ($M_Y = .24$, $SE = .04$; $M_O = .33$, $SE = .03$). Although there was no difference in the mean variability accounted for across conditions, $F < 1$, there was a significant Age × Condition interaction, $F(2, 53) = 4.33$, $p < .05$, $MSE = .13$, $\eta^2 = .14$, such that for younger adults, relatively more variability in reading time was accounted for in the IP condition. Specifically, in the young group text variables explained 19 and 16% of the variability in the NP and the CP conditions, respectively, showing that these readers were less attentive to the text features than were IP readers, for whom 36% of the variability was explained. This pattern is what would be expected if the IP condition were promoting greater engagement with the text. In contrast, there were no differences among older readers in the variance accounted for across the conditions. Finally, the regression constant, which reflects sensorimotor slowing as well as resource allocation not captured by the five text variables, did not vary with age or condition, $F < 1$, for the main effects and interaction.

Regression coefficients reflecting the relative time allocation to each of the text processes (in ms), were analyzed in a 2 (Age: young, old) × 3 (Preexposure: NP, CP, IP) × 5 (Process Type: Syll, NC, SP, New_DE, SP_T) repeated-measures analysis of variance (ANOVA) in which reading process was a within-subject measure; note that p-values in this and all subsequent analyses are reported after doing a Huynh-Feldt correction.

The significant Age × Process Type interaction, $F(4, 212) = 12.14$, $p < .001$, $MSE = 8{,}363{,}692$, $\eta^2 = .19$, and the significant Preexposure × Process Type interaction, $F(8, 212) = 4.78$, $p < .01$, $MSE = 3{,}191{,}361$, $\eta^2 = .15$, suggested that reading time allocation to different text features was moderated by both age and preexposure condition. There was also a marginally significant three-way Age × Preexposure × Process Type interaction, $F(8, 212) = 2.81$, $p = .06$, $MSE = 1{,}938{,}164$, $\eta^2 = .10$, reflecting the fact that age differences in the effects of preexposure depended on the type of processing. A series of 2 (Age) × 3 (Preexposure) ANOVAs was conducted on each process to clarify these relationships.

WORD-LEVEL AND CONCEPTUAL PROCESSING

Older adults allocated more resources to orthographic decoding, $F(1, 53) = 7.212$, $p < .05$, $MSE = 46{,}887$, $\eta^2 = .12$, and new concepts, $F(1, 53) = 7.74$, $p < .01$, $MSE = 762{,}202$, $\eta^2 = .13$, than did the younger adults. Preexposure condition did not significantly affect allocation to orthographic decoding,

Table 3
Means and standard errors of allocation parameters

	Young				*Old*				*Overall*		
Allocation parameter	*NP*	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*
Syll											
M	127	109	94	110	205	164	129	166	165	112	136
SE	38	17	21	15	25	21	30	15	24	17	14
NC											
M	288	199	138	208	573	240	494	436	431	316	219
SE	84	51	118	51	116	111	104	68	78	88	60
SP											
M	–15	–16	2	–10	–46	–24	–9	–26	–30	–3	–20
SE	5	5	8	4	10	8	11	6	6	7	5
New_DE											
M	601	830	–329	367	2,227	900	990	1,386	1,414	330	865
SE	237	245	150	152	334	522	339	257	273	233	281
SP_T											
M	76	36	37	50	89	10	20	40	82	28	23
SE	12	15	8	7	35	21	23	17	18	12	13
Adj R^2											
M	0.19	0.36	0.16	0.24	0.40	0.27	0.32	0.33	0.30	0.23	0.31
SE	0.07	0.05	0.06	0.04	0.06	0.06	0.05	0.03	0.04	0.04	0.04
Intercepts											
M	2,316	1,792	2,128	2,079	2,518	2,364	2,108	2,338	2,417	2,119	2,078
SE	553	572	597	322	431	411	552	254	342	389	349

Note. NP = the no preexposure group; IP = the inconsistent preexposure group; CP = the consistent preexposure group; Adj R^2 = adjusted R square.

$F(2, 53) = 2.16$, $p = .13$, $MSE = 14{,}018$, $\eta^2 = .08$ or to process new concepts, $F(2, 53) = 2.28$, $p = .11$, $MSE = 224{,}473$, $\eta^2 = .08$. When the two preexposure conditions were collapsed, however, the contrast between the preexposure conditions and the control did approach significance, $F(1, 55) = 3.45$, $p = .069$, $MSE = 22{,}043$, $\eta^2 = .06$, for syllables, and $F(1, 55) = 3.65$, $p = .061$, $MSE = 367{,}353$, $\eta^2 = .06$, for new concepts. In none of these analyses did preexposure effects vary with age.

SERIAL POSITION

Older readers allocated relatively more time than younger readers did early in the passage, showing greater contextual facilitation as they moved through the passage, $F(1, 53) = 6.14$, $p < .05$, $MSE = 3{,}837$, $\eta^2 = .10$. The effect of preexposure was significant, $F(1, 53) = 5.74$, $p < .01$, $MSE = 3{,}589$, $\eta^2 = .18$. Post hoc tests confirmed that only the NP, $t(19) = 4.73$, $p < .01$, and IP, $t(19) = 4.36$, $p < .01$, groups showed a reliable serial position effect, whereas the CP group did not, $t(18) = .49$, $p = .63$. These results also provide some support that introducing desirable comprehension difficulty evokes situation-model processing relative to simple repetition. Thus, readers in the IP groups exerted more effort to creating a new discourse structure earlier in the text as shown by stronger contextual facilitation relative to readers in the CP group who reinstated the structure from preexposure. The effect of age on serial position did not vary by preexposure group, as shown by a nonsignificant Age × Preexposure interaction, $F(2, 53) = 1.20$, $p = .31$, $MSE = 747$, $\eta^2 = .04$.

NEW DISCOURSE ENTITIES

The main effect of age on allocation to new discourse entities was significant, $F(1, 53) = 14.26$, $p < .01$, $MSE = 14{,}877{,}250$, $\eta^2 = .21$, indicating that older adults allocated more time than the younger adults to establish the representations for new animals. The main effect of preexposure was significant, $F(2, 53) = 5.48$, $p < .01$, $MSE = 5{,}717{,}504$, $\eta^2 = .17$, but was moderated by age in a significant Age × Preexposure interaction, $F(2, 53) = 3.24$, $p < .05$, $MSE = 3{,}384{,}068$, $\eta^2 = .11$. For younger adults, the IP and NP groups allocated time to process discourse entities, but the CP group tended toward facilitation. Older adults, however, generally allocated more time to process discourse entities, particularly when they were reading text for the first time. This suggests that older adults allocate more time for the processing of new discourse entities overall relative to the young especially on the first encounter. These findings again provide evidence that for younger adults mismatching the topic structure encourages situation-model processing at rereading, however, this manipulation did not appear to be particularly beneficial for older adults.

SERIAL POSITION WITHIN A NEW TOPIC

Readers allocated extra time to process the expansion of a line of argument. A main effect of preexposure, $F(2, 53) = 5.01$, $p < .05$, $MSE = 21{,}411$, $\eta^2 = .16$, supported the observation that readers in the CP and IP groups spent less time as they read through arguments within a topic being currently processed than did readers in the NP group, $t(37) = 2.47$, $p < .05$, and, $t(38) = 2.68$, $p < .05$, respectively. The two preexposure groups devoted similar amounts of time to construct an expository argument, $t(37) = .33$, $p = .743$, indicating that changing the structure of the argument did not evoke extra time in reprocessing. Neither the age nor the Age × Preexposure interaction was significant, $F < 1$ for both.

Collectively, these analyses suggest that although the inconsistency manipulation may have had some effects on resource allocation of the young toward increased situation-model processing (i.e., as indicated by R^2 values and coefficients for serial position and new discourse entities), it was relatively ineffective for the old. At the same time, older readers were highly responsive to discourse-level features regardless of preexposure condition, showing a large effect of serial position and allocating more time to new discourse entities through the text (Miller et al., 2004). Older readers also allocated more time to word and textbase processes, so we directly tested whether their allocation to new discourse entities and situation construction early in the text were disproportionate relative to their allocation to textbase processing. Taking allocation to new concepts as the benchmark of textbase processing, we compared age differences in resource allocation to situation-model features in two 2 (Age) × 3 (Preexposure) × 2 (Level: textbase versus situation model) repeated measures ANOVAs, one for each situation-model effect. Older adults were differentially responsive to both new discourse entities, $F(1, 53) = 8.70$, $p < .01$, $MSE = 445, 231, 3$, $\eta^2 = .13$, and serial position, $F(1, 53) = 8.70$, $p < .01$, $MSE = 437, 101$, $\eta^2 = .14$, as shown by reliable Age × Level interactions in each case. These findings suggest that our older readers were relatively more attuned to situation construction (Radvansky, 1999; Radvansky et al., 2001; Stine-Morrow et al., 1996, 2004).

Memory performance

Recall was measured in three ways: free recall of the animal names, and free and cued recall of text content. Name-recall data for two young adults, free-recall data for one younger and two older adults, and cued-recall data for one older adult were lost because of experimenter error.

Name recall. Name recall was scored in three different ways using criteria varying in stringency. This allowed us to examine age differences in retrieval of proper names from discourse (James, 2004; Stanhope, Cohen, & Conway, 1993). At the least stringent level, a name was scored as identifiable if any portion of the name could be unambiguously identified as a particular animal or a description of an individual animal was recalled (e.g., Leafy something). The core name was scored if the main name of the animal was recalled without a modifier, or with an incomplete modifier (e.g. Sea-dragon). At the most stringent level, the full name was scored if there was the complete name of the animal including a main name and a modifier (e.g., Leafy Sea-dragon). Thus, recall at the least stringent level reflected recall of the concept, whereas recall at the most stringent level reflected recall not only of the concept but also of the verbatim form of the name.

These data were analyzed in a 2 (Age) × 3 (Preexposure) × 3 (Stringency) repeated measures ANOVA. A significant age effect, $F(1, 53) = 4.87$, $p < .05$, $MSE = 52.35$, $\eta^2 = .08$, indicated that younger adults remembered more animals than did the older adults. There was also a significant effect of condition, $F(2, 53) = 7.95$, $p < .01$, $MSE = 85.46$, $\eta^2 = .23$, suggesting that participants in both CP and IP conditions did better in recalling the animals relative to the NP group. The stringency effect, $F(2, 106) = 162.94$, $p < .01$, $MSE = 169.10$, $\eta^2 = .76$, indicated that recall scores decreased as stringency of scoring increased ($M_I = 5.36$, $SE = .28$; $M_C = 3.94$, $SE = .29$; $M_F = 1.9$, $SE = .25$). A significant Stringency × Condition interaction, $F(4, 106) = 2.83$, $p < .05$, $MSE = 2.94$, $\eta^2 = .10$, indicated that performance of participants in the CP and IP groups disproportionately increased as the scoring criterion was relaxed (see Figure 1), suggesting that preexposure differentially enhanced conceptual processing relative to the surface form of the text. Surprisingly, this effect did not interact with age (e.g., Stanhope et al., 1993). Thus, preexposure enabled young and older adults to retrieve key concepts, even if their retrieval lacked specificity of the verbatim form.

Free and cued recall. Table 4 contains the means and standard errors for free and cued recall performance measures as a function of age and preexposure. Free recall and cued protocols were scored for the presence of textbase recall (propositions) and elaborative inferences using the same criteria. Three raters scored three recall protocols, with correlations above .95 for both measures. Textbase recall was scored for idea units recalled using a gist criterion (Turner & Green, 1978). Elaborative inferences were correct additions or conceptual clarifications that went beyond the textbase information. The proportion of propositions needed to express elaborative inferences relative to the textbase recall was used as the dependent variable. An example of an elaboration would be a statement that a thorny devil has a crevice on its body so that "if it rains on him" all the water drips into his mouth. The original passages only mentioned that thorny devils can drink any water that falls on their bodies because they have small grooves leading to the corners of mouth. Therefore, the idea units (IF [RAIN-ON HIM]) were counted as two elaborative propositions.

Textbase recall and inference production were analyzed separately in 2 (Age) × 3 (Preexposure) × 2 (Cuing) ANOVAs. Cued recall tended to be greater than free recall, but these effects did not reach significance, $F(1, 51) = 2.36$, $p = .13$, $MSE = 1{,}434.95$, $\eta^2 = .04$, for textbase recall, and $F(1, 51) = 1.39$, $p = .24$, $MSE = .024$, $\eta^2 = .03$, for elaborative inference production. In addition, the cueing effect did not vary as a function of age, or condition, $F < 1$ for both. Therefore, the analysis of these data was simplified by creating composite scores. This was done by standardizing textbase retrieval in free and cued recall ($r = .42$) and inference production in free and cued recall ($r = .32$), and averaging these z-scores to make composite variables for textbase recall and elaborated inference production. These data were analyzed in a 2 (Age) × 3 (Preexposure) × 2 (Type of Production: textbase recall, inference production) repeated measures ANOVA.

Neither the age effect nor the condition effect nor their interaction was significant, $F < 1$, for all. However, as shown in Figure 2, there was an Age × Type of Production interaction, $F(1, 51) = 12.76$, $p < .01$, $MSE = 7.26$, $\eta^2 = .20$, reflecting the fact that age differences in memory performance depended on the type of recall production. The simple main effect of Age on Textbase Recall, $F(1, 51) = 4.24$, $p < .05$, $MSE = 2.87$, $\eta^2 = .08$, verified that young readers recalled more textbase content than did older adults. The simple main effect of age on inference production demonstrated that older readers produced more inferences than did young readers, $F(1, 51) = 10.61$, $p < .01$, $MSE = 4.48$, $\eta^2 = .17$. These effects were not moderated by preexposure condition.

Planned paired comparison tests (Keppel, 1982; Keppel & Wickens, 2004) were carried out based on the a priori prediction that the CP group would show greater enhancement of the textbase from the repetition of the content than the NP group and that the IP group would show superior production of inferences than the NP group due to the enhanced situation-model processing. In addition, it was expected that the benefit from CP on textbase recall would be particularly likely for younger adults, but the benefit from IP on inference production would be particularly likely for older adults. One-tailed t tests were used to test these predictions. The recall of textbase content in the CP group ($M = .24$, $SE = .24$) was significantly better than that of the NP group ($M = .20$, $SE = .13$), $t(36) = 1.64$, $p = .05$. This difference was marginally significant for younger adults, $t(17) = 1.61$, $p = .06$, but not significant for the old, $t < 1$. For inference production, the IP group ($M = .09$, $SE = .18$) did not differ significantly from the NP group ($M = .06$, $SE = .17$), $t(36) = .09$, $p = .23$. Older adults in the IP group did not score significantly higher on inference generation than those in the NP group, $t(18) = .65$, $p = .13$, though the difference was in the predicted direction.

Overall, the recall data suggest that whereas younger readers produced more extensive reproductions of text content, older readers were more likely to generate more inference-based elaborations. This pattern replicates previous studies that show

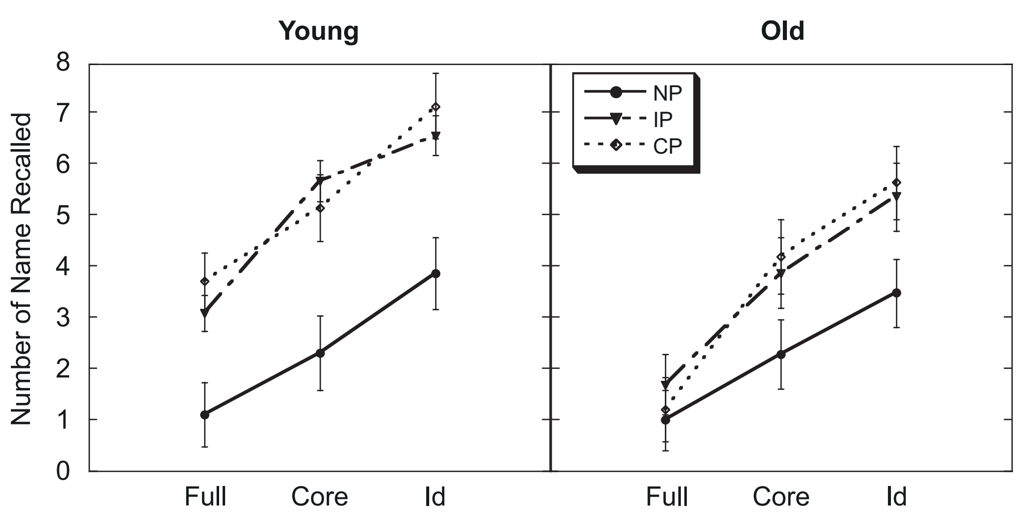

Figure 1. Name recall as a function of age and preexposure condition (NP = the no preexposure group; IP = the inconsistent preexposure group; CP = the consistent preexposure group; Full = full name; Core = core name; Id = identifiable name).

Table 4
Means and standard errors of recall performance measures as a function of age and preexposure condition

	Young				*Old*				*Overall*		
Measures	*NP*	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*
Free recall textbase											
M	25.44	49.22	57.00	44.36	29.20	25.60	33.78	29.38	27.42	36.79	46.00
SE	6.27	15.09	16.83	8.11	4.77	8.92	8.93	4.34	3.80	8.75	9.94
Elab inf											
M	0.04	0.04	0.02	0.03	0.11	0.15	0.09	0.12	0.08	0.10	0.00
SE	0.02	0.01	0.01	0.01	0.06	0.10	0.03	0.04	0.03	0.05	0.02
Cued recall textbase											
M	43.56	48.70	54.18	49.17	36.10	37.20	38.89	37.34	39.83	42.95	47.30
SE	8.34	7.93	10.63	5.21	10.00	6.03	5.71	4.25	6.46	5.02	6.47
Elab inf											
M	0.11	0.04	0.05	0.06	0.14	0.19	0.14	0.16	0.13	0.11	0.09
SE	0.04	0.01	0.02	0.02	0.06	0.06	0.05	0.03	0.04	0.04	0.03

Note. NP = the no preexposure group; IP = the inconsistent preexposure group; CP = the consistent preexposure group; Elab inf = Elaborative inference.

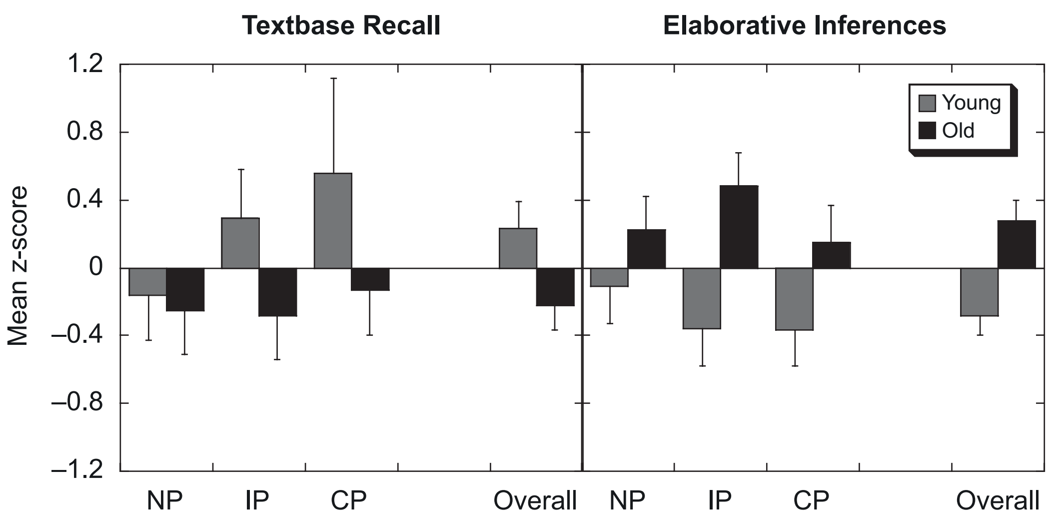

Figure 2. Textbase recall and inference production as function of age and preexposure condition.

an age-graded increase in knowledge-based elaboration during text recall in which older adults tend to interpret text information to be meaningful for them, as they embellish the text information based on their personal knowledge or experience (Adams, Smith, Nyquist, & Perlmutter, 1997; Gould, Trevithick, & Dixon, 1991; Miller et al., 2004). Consistent with Rawson and Kintsch (2002), the young CP group was better in textbase recall as a consequence of repeated content exposure than was the NP group which only read the information once, though unlike Rawson and Kintsch, we found this effect in the level of recall (rather than in organization, which we did not measure).

Comprehension

The mean percent correct was computed separately for textbase, inference, and global questions, and entered into a 2 (Age: young, old) × 3 (Preexposure: NP, CP, IP) × 3 (Question Type: textbase, inference, global) repeated-measures ANOVA.

The main effect of age was not significant, $F(1, 54) = 1.98$, $p = .17$, $MSE = .046$, $\eta^2 = .04$, showing that younger and older adults did not differ in comprehension overall ($M_Y = .74$, $SE = .02$; $M_O = .68$, $SE = .01$). Neither the condition effect, $F(2, 54) = 1.20$, $p = .31$, $MSE = .028$, $\eta^2 = .04$, nor the Age × Condition interaction, $F(2, 54) = 1.84$, $p = .169$, $MSE = .043$, $\eta^2 = .06$, was significant. There was a significant main effect of question type, $F(1, 108) = 18.61$, $p < .001$, $MSE = .33$, $\eta^2 = .26$, indicating that both textbase and inference questions were more difficult than global questions ($M_{TB} = .71$, $SE = .14$; $M_{INF} = .69$, $SE = .15$; $M_{Global} = .83$, $SE = .24$). However, this effect was moderated by age in a significant Age × Question Type interaction, $F(2, 108) = 3.45$, $p < .05$, $MSE = .07$, $\eta^2 = .06$, shown in Figure 3. Young readers scored higher than the old on inference questions, $F(1, 54) = 11.59$, $p < .01$, $MSE = .12$, $\eta^2 = .18$, but not on textbase, $F(1, 54) = 2.28$, $p > .10$, $MSE = .02$, $\eta^2 = .04$, or global questions, $F < 1$. Thus, older adults were less able to verify particular inferences based on specific details from the text, although recall that they made elaborative inferences during the recall phase of the experiment, a

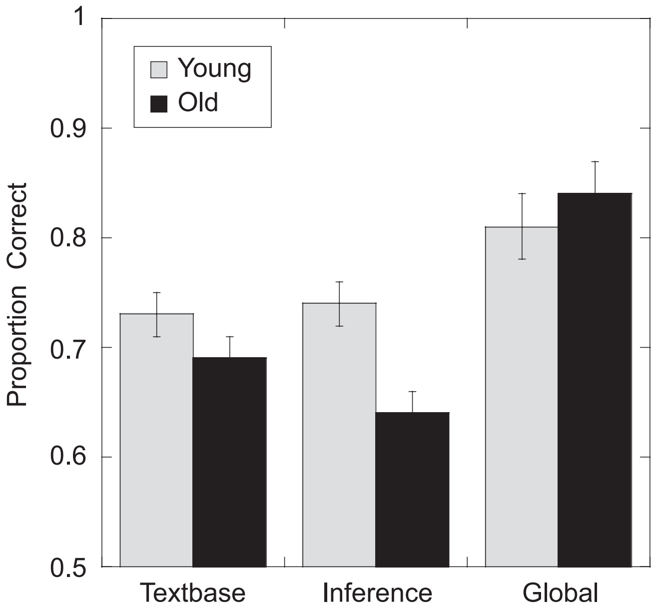

Figure 3. Proportion correct comprehension questions as a function of age and question type.

contrast to which we will return in the Discussion. None of remaining interactions reached significance.

Problem solving

Scoring. Problem-solving protocols were scored for the presence of: (a) the number of animal names from the text mentioned in the solution; (b) the number of dimensions considered when designing the zoo (e.g., environment, feeding, display, animal welfare); (c) the number of specific examples provided for each dimension (e.g., for the display dimension, water tank and cage); and (d) specificity of the solution which was the elaboration of targeted solutions. The specificity was scored using a 1 to 7 scale (1, *very general*, 7, *very specific*).

For scoring, two members of our research team scored six randomly selected protocols (three young and three old) for training purposes. The two scores showed reliable agreement in identifying the number of animal names, and examples for solution; the correlation between the two scorers for these categories was .82 and 1.00, respectively. However, scoring the number of dimensions (r = .55) and specificity of the solution (Spearman's rho = .46) did not reach reliable agreement. Therefore, the scorers had a follow-up session to clarify rating the specificity and to discuss the superordinate-level categories as dimensions. For these dimensions, the agreement between the two raters using an additional four protocols reached 90% agreement. The final interrater reliabilities were calculated based on four new protocols (two younger and two older adults), and one additional scorer participated to score the specificity category in order to assess adequate reliabilities. The reliability between the two raters ranged from .70 to 1.0 for the number of animal names, the number of dimensions, and the number of examples. Finally, the interrater reliability among the three raters for the specificity of the solution ranged from .83 to .94 (Spearman's rho).

Problem-solving performance. Table 5 shows the means and standard errors for the problem-solving measures as a function of age and preexposure (data from one older adult was lost due to experimenter error). To determine whether readers in the age and preexposure groups differed in quality of their solutions, a 2 (Age: young, old) × 3 (Preexposure: NP, CP, IP) ANOVA was conducted on each measure.

Younger readers tended to include more animal names from the text, although the main effect of age was marginal, $F(1, 55) = 3.09$, $p = .085$, $MSE = 11.52$, $\eta^2 = .05$. Neither the main effect of preexposure, $F(2, 55) = 1.37$, $p = .262$, $MSE = 5.13$, $\eta^2 = .05$, nor the Age × Preexposure interaction, $F < 1$, reached significance. Younger readers were also more likely to use text information to provide a detailed rationale for their solution than did older readers, $F(1, 55) = 3.85$, $p = .055$, $MSE = 8.34$, $\eta^2 = .07$. This age effect on specificity did not vary as a function of condition, $F(2, 55) = 1.03$, $p = .364$, $MSE = 2.24$, $\eta^2 = .04$, nor interaction, $F < 1$. There was no

Table 5
Means and standard errors of problem-solving performance measures as a function of age and preexposure condition

	Young				*Old*			
Measure type	*NP*	*IP*	*CP*	*Total*	*NP*	*IP*	*CP*	*Total*
Animals								
M	1.50	2.10	1.26	1.61	1.00	1.18	0.06	0.75
SE	0.58	0.66	0.40	0.31	1.00	0.64	0.60	0.38
Dimensions								
M	3.60	2.90	3.64	3.93	3.78	3.27	3.20	3.40
SE	0.48	0.35	0.36	0.24	0.49	0.38	0.29	0.23
Examples								
M	6.70	5.70	5.64	6.00	8.89	6.18	7.50	7.43
SE	0.88	1.15	1.09	0.58	1.67	1.28	1.19	0.78
Specificity								
M	4.20	3.90	3.73	3.39	3.67	2.64	3.30	3.17
SE	0.49	0.46	0.33	0.23	0.53	0.51	0.45	0.29

Note. NP = the no preexposure group; IP = the inconsistent preexposure group; CP = the consistent preexposure group; Dimensions = the number of dimensions for solution; Example = the number of examples for dimensions; Specificity = rating for specificity of solution.

age difference on the number of dimensions, $F < 1$. Neither the condition nor the Age × Preexposure interaction was significant, $F(2, 55) = 1.15$, $p = .325$, $MSE = 1.82$, $\eta^2 = .04$, for condition, $F < 1$ for the interaction. Finally, age groups did not differ in examples for solutions, $F(1, 55) = 2.41$, $p = .126$, $MSE = 34.68$, $\eta^2 = .04$. There was neither a condition effect, $F(2, 55) = 1.22$, $p = .304$, $MSE = 17.53$, $\eta^2 = .04$, nor an Age × Preexposure interaction, $F < 1$. These results suggest that relative to the young, older adults were able to generate solutions that were of high quality (i.e., considered the same number of dimensions) even though they were less likely to include specific information to provide reasons for their solutions.

We further examined the age effect on problem-solving performance in terms of the efficiency in generating dimensional complexity. To examine this, a ratio of dimensions to problem protocol length (the number of total words) in the subject's responses was calculated and analyzed using a 2 (Age) × 3 (Preexposure) ANOVA. A significant age effect was obtained for this efficiency measure, $F(1, 55) = 7.39$, $p < .01$, $MSE = .06$, $\eta^2 = .12$, supporting the observation that older adults considered multiple dimensions of solutions without articulating much information from the text. These findings provide additional support for previous research showing that older adults tend to engage in more direct strategies during problem solving to find solutions than younger adults do (Blanchard-Fields, Chen, & Norris, 1997; Meyer, Russo, & Talbot, 1995). Table 6 provides examples of problem-solving solutions from one younger and one older adult to illustrate this difference. Neither the condition nor the Age × Preexposure interaction was significant, $F < 1$, for condition, $F(2, 55) = 2.07$, $p = .137$, $MSE = .02$, $\eta^2 = .07$, for the interaction.

Table 6
Examples of the problem -solving solutions

Younger	"To see its activity, forests would be needed for the birds, Helmeted Honeyeater and White Winged Chough. The Aquatic creatures would obviously need water. A night-time like setting for the Tasmanian Thylacine would be advantageous obviously need water. The Leafy Sea Dragon would need seaweed to blend in The Tasmanian Thylacine would need lots of area to run, considering it only attacks its predators once it has exhausted them out. It would be preferable to have natural type settings for these animals, especially with natural food sources and possibly even predators. The marsupials' young would have to be watched carefully because they must stay with the mother, either in her pouch or in her fur. A large space for the Helmeted Honeyeater is preferable because they live only with their partner, but on the whole live as a community defending each other."
Older	"What type of animals to choose and what type of environment would be necessary. What type of food and water sources. Lighting nocturnal or not for some animals. What type of water necessary – salt or freshwater. Area of exhibit necessary. Climatic-temperature conditions necessary. Effect of people on the animals being shown. Also effect of noise on the animals."

Discussion

This research investigated the effects of age and preexposure on reading time allocation and performance. Our data speak to both age differences in the way in which expository text is engaged by readers, as well as the usefulness of introducing "desired difficulty" into text as a way of augmenting engagement among older readers.

Several aspects of our findings were consistent with the notion that older adults are relatively more oriented toward situation-model construction (Radvansky et al., 2001; Stine, Soederberg, & Morrow, 1996; Stine-Morrow et al., 2004). Older adults showed exaggerated resource allocation to the establishment of new discourse entities as well as an exaggerated serial position effect, both of which have been interpreted as indicators of situation construction (Gernsbacher, 1990; Haberlandt, 1984; Stine-Morrow et al., 1996). More attention to the situation model among older readers may have enabled them to produce more elaborated inferences at retrieval, than did the younger readers, by relying on general knowledge. It may also have helped older readers to generate problem solutions that were similar in dimensional complexity to those generated by the young (even though lacking in specific details). Younger adults allocated relatively less time in analysis of the situation-model features, and produced more textbase information at retrieval as well as more text-specific solutions to solve a problem.

Interestingly, when comprehension questions required inferences based on deduction from specific text information, older adults were at a relative disadvantage. Thus, even though older adults may be more likely to produce elaborated inferences based on their knowledge or personal experiences (Adams et al., 1997; Gould et al., 1991; Miller et al., 2004), such a situation-based approach did not guarantee effective performance when inference was constrained by textbase retrieval. The fact that older adults produced more elaborative inferences during recall and yet performed more poorly on inference questions that probed specific content may appear on the surface to be contradictory. However, both of these effects [i.e., age deficits in answering inference questions that require retrieval, synthesis or manipulation of textbase content (Cohen, 1979), and an age advantage in elaborative inference based on pre-existing knowledge (Gould et al., 1991; Miller et al., 2004)] have been demonstrated in the literature. This apparent contradiction speaks to the fact that "inference" can occur in very different contexts and draw on very different processing mechanisms; our findings are not contradictory at all, but are unique (as far as we know) in demonstrating these effects within a single study.

We found somewhat weak evidence for an organizational "mismatch effect" on text processing among younger readers (Mannes & Hoyes, 1996). When younger adults read a target text that was organized differently from the preexposure materials, their reading times were more strongly predicted by text features relative to when they either read materials with a familiar organization or when they were encountering the text for the first time. Also, when the organization across encounters was mismatched, younger adults also showed serial-position and new-discourse-entity effects that were comparable with when they were encountering the material for the first time, suggesting that the mismatch may have encouraged more situation-model processing relative to simple repetition. Older adults did not differ from the young in the way condition moderated the effect of serial position on resource allocation, but otherwise, they showed no mismatch effect. However, to the extent that this "desired difficulty" augmented resource allocation to component processes, we found no evidence that this improved their memory, comprehension, or problem-solving performance, though other researchers have found such an effect (Mannes, 1994; Mannes & Hoyes, 1996). In any case, there was virtually no evidence that this manipulation was effective for older readers. It is surprising that by mismatching the topic structure we did not enhance older adults' situation-model processing relative to simple repetition. One plausible explanation of why our "desired difficulty" manipulation did not benefit older adults is that the IP condition was simply too difficult, with the change in organization across the two presentations taxing attentional resources so that older readers could not take advantage of it (Hess, 1995; Smith, Rebok, Smith, Hall, & Alvin, 1983). Considering that older adults showed disproportionate allocation of their time toward creating discourse-level representations when reading a text for the first time, integrating the new discourse structure into the previously established structure during rereading would be much more resource-consuming for them. Miles and Stine-Morrow (2004) have suggested that older adults may effectively regulate their allocation of effort to maximize their learning within their region of proximal learning (e.g., selectively allocating effort to texts of intermediate difficulty when they were less well learned initially). The "mismatch" manipulation may have been outside that region, and so our results suggest that there may be boundary conditions for the effect of content preexposure on text memory and learning for older adults.

More generally, our data suggest that older readers can learn from text, even though their representation may contain less detail from the textbase. Aging does not seem to compromise the ability to extract broader principles to use the information productively in a novel context.

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Appendix

Outlines

Wildlife in Australia: Types of animals (consistent preexposure)

There are different types of Australian animals with different kinds of adaptations to their environments.

I. Mammals
- A) Tasmanian Thylacine
  - Camouflage: stripes blend into forest
  - Feeding: jaws open wide for prey
  - Endangered: extinct after arrival of Europeans
- B) Spotted-tailed Quoll
  - Feeding: agility enables it to hunt on the ground and in trees
  - Breeding: develops a pouch after mating
  - Endangered: endangered by forest destruction
- C) Red-tailed Phascogale
  - Feeding: nests in trees, but hunts on the ground
  - Breeding: male dies after mating due to exertion
  - Defensive: immune to toxin that eliminates predators

II. Birds
- A) Helmeted Honeyeater
  - Feeding: protrudes a tongue beyond a beak to soak up fluids
  - Defensive: sharp calls to protect a territory or to signal distress
  - Social behavior: forms neighborhoods
- B) White-winged Chough
  - Breeding: communal breeding to raise the young

III. Reptiles
- A) Blue-tongued Skink
  - Defensive: dramatic displays to threaten enemies
  - Feeding: ingests stones to digest food
- B) Thorny Devil
  - Camouflage: coloration to match soil
  - Defensive: creates a false head at predators
  - Feeding: absorbs water through skin

IV. Aquatic creatures
- A) Leafy Sea Dragon
  - Camouflage: seaweed-like appendage
  - Feeding: sucks seaweed while sitting still
  - Breeding: males carry and incubate eggs
  - Endangered: threatened from pollution and excessive fertilizing
- B) Giant Cuttlefish
  - Defensive: ejects ink to disorient enemies
  - Feeding: stretches tentacles far to gather food
  - Camouflage: coloration to match surrounding
  - Breeding: tangles tentacles together during mating

Wildlife in Australia: Adaptations (inconsistent preexposure)

There are different types of Australian animals with different kinds of adaptations to their environment.

I. Camouflage
- A) Mammal
  - Tasmanian Thylacine: stripes blend into forest
- B) Reptile
  - Thorny Devil: coloration to match soil
- C) Aquatic creatures
  - Leafy Sea Dragon: seaweed-like appendage
  - Giant Cuttlefish: coloration to match surrounding

II. Feeding
- A) Mammal
  - Tasmanian Thylacine: jaws open wide for prey
  - Spotted-tailed Quoll: agility enables it to hunt on the ground and in trees
  - Red-tailed Phascogale: nest in trees, but hunts on the ground
- B) Bird
  - Helmeted Honeyeater: protrudes a tongue beyond a beak to soak up fluids
- C) Reptiles
  - Blue-tongued Skink: ingests stones to digest food
  - Thorny Devil: absorbs water through skin
- D) Aquatic creatures
  - Leafy Sea Dragon: sucks seaweed while sitting still
  - Giant Cuttlefish: stretch tentacles far to gather food

III. Breeding and social behavior
- A) Mammals
  - Spotted-tailed Quoll: develops a pouch after mating
  - Red-tailed Phascogale: male dies after mating due to exertion
- B) Aquatic creatures
  - Leafy Sea Dragon: males carry and incubate eggs
  - Giant Cuttlefish: tangles tentacles together during mating
- C) Birds
  - White-winged Chough: communal breeding to raise the young
  - Helmeted Honeyeater: forms neighborhoods

IV. Defensive behavior
- A) Mammal
  - Red-tailed Phascogale: immune to toxin that eliminates predators
- B) Bird
  - Helmeted Honeyeater: sharp calls to protect a territory or to signal distress
- C) Aquatic creature
  - Giant Cuttlefish: ejects ink to disorient enemies
- D) Reptiles
  - Blue-tongued Skink: dramatic displays to threaten enemies
  - Thorny Devil: creates a false head at predators

V. Consequence of not adapting
- A) Mammals
  - Tasmanian Thylacine: extinct after arrival of Europeans
  - Spotted-tailed Quoll: endangered by forest destruction
- B) Aquatic creature
  - Leafy Sea Dragon: threatened from pollution and excessive fertilizer

Target text

Wildlife in Australia

A variety of unique animals live on the island-continent of Australia. This wildlife is especially adapted to the environment and is found nowhere else in the world.

The mammals in Australia are particularly interesting. Even though now extinct, the Tasmanian Thylacine is still one of the best-known animals outside of Australia. This mammal is often called the Tasmanian Tiger, or the "Dog Pouched-Wolf", because it had the shape of a dog as well as stripes covering the length of its back. These stripes allowed the Thylacine to blend into forests. Interestingly, the male also had a pouch to protect his testicles. The Thylacine was a hunter that only ate fresh meat, killing wallabies and kangaroos for food. They were nocturnal hunters, stalking their prey at dusk and using their speed and stamina to pursue the prey until it collapsed from exhaustion. They became extinct because of the arrival of the Europeans. They hunted the Thylacine, which they thought would kill their sheep, and also brought dingoes to Australia, which hunted the same prey as the Thylacine, leading to their starvation.

Another meat-eating marsupial is the Spotted-tailed Quoll. The Quoll, found in East Australia's forests, is about the size of a cat. Its fur ranges in color from reddish to dark brown, with white spots on its body and tail. They are distinct from typical marsupials because the females do not have pouches until they mate. Only after having babies will folds of skin on the mother's belly develop into a pouch. Quolls are becoming endangered as they face the destruction of their forest habitat.

The Red-tailed Phascogale is a rare marsupial in that it lacks a pouch to nurture its young. Instead, the young simply secure themselves in the mother's fur and attach to her teats for about 40 days. It is named for its partially red, long-brushed tail. Though these creatures are skilled climbers and actually build their nests in trees, they look for most of their food (e.g., small insects, birds, and rodents) on the ground. The mating season takes place in May and June, and shortly afterwards, the male dies. The female will live for about one or more years and give birth to 6 to 8 young. Phascogales live in lush vegetation that provides nest sites and protection.

Australia is also home to many rare and surprising birds. The Helmeted Honeyeater is named for its bright yellow crest, which resembles a helmet. It is a nectar-feeding bird with a long, brush-tipped tongue that sucks up fluids by capillary action. They lap up fluids at rates of 10 or more licks per second and can empty a flower in less than a second. This bird has many different calls that sound like "tsup" and "weet". Each breeding pair has a territory of its own, about an acre in size, which is an exclusive feeding area. These territories are usually clustered into neighborhoods. If a predator enters one of the territories, other Honeyeaters from nearby territories will come to help drive out the predator.

The White-winged Chough is a large black, mud-nesting bird, often mistaken for a crow. Choughs are well known for their communal breeding system, which means all family members help to raise the young. They all take turns nesting, incubating, preening, feeding, and defending the young against predators. Large groups also have greater breeding success because the baby Choughs must learn to search for food in the dry Australian bush. Choughs have even been known to kidnap the young of other groups to ensure large numbers. Adult birds dance and show off their acrobatic talents in front of the young birds, as a way of enticing them to join their group. If a young one is thoroughly impressed, it will leave its family to become a member of the new group.

Australia's reptiles are also unique and have characteristics not shared by their non-Australian relations. One of these, the Blue-tongued Skink, is two feet long and has miniature appendages attached to its large body. Their coloring is distinct with dark brown and cream-colored bars in the back, but brown and orange stripes on the side. One of their most prominent features is a bright cobalt blue tongue. If the Skink is threatened, it will stick out its tongue. Even more dramatic, it will expand its body and hiss. Skinks are omnivorous, eating a variety of insects, snails, carrion, flowers, and fruits. Their teeth are large and they have strong jaw muscles so they can crush snails and beetles.

The Thorny Devil is found in the outback. It is a lizard covered with soft spines, even though it is not naturally aggressive. One interesting characteristic of the Thorny Devil is its ability to rapidly change skin color to match the soil it is crossing. If threatened, it can also hide its head between its front legs. This creates a bump giving the appearance of a false head. This bump is not as vulnerable to attack as a real head, providing it with added protection from attackers. Thorny Devils are distributed throughout inland Australia. On the exterior of their body they have small grooves leading to the corners of their mouth, allowing them to drink any water that falls on their body.

Australia is also home to curious aquatic life. For example, the Leafy Sea Dragon becomes invisible among floating seaweed or kelp beds because of leaf-like appendages on its head and body. These appendages, which give the creature its name, are not used for movement at all. Instead, it steers using pectoral fins, and propels itself with dorsal fins, but their movements are slow. Extraordinarily, the male Sea Dragon carries and incubates the eggs until they hatch. The female lays up to 250 eggs into the "brood patch" on the underside of the male's tail, where they attach and are fertilized. After about six weeks, the male gives birth to little Sea Dragons.

Another Australian fish with fascinating features is the Giant Cuttlefish. Like an octopus, it ejects ink from an ink sac to confuse and disorient enemies. A Cuttlefish not only acts like an octopus, but actually looks more like an octopus than a fish. It has a flat head and eight tentacles including two that are needed for feeding. These creatures get their shape from their internal shell, called a cuttlebone. They have the ability to change their color to match their surroundings for hunting. Giant Cuttlefish move slowly through the water using different mechanisms for propulsion. Small fins on their sides enable swimming. They also take water into their bodies and shoot it out the back for propulsion. Their tentacles are also used in courtship. Cuttlefish will tangle their tentacles with those of a potential mate to attract its attention. After mating, hundreds of eggs are quickly laid on rocky reefs.

Australian mammals, birds, reptiles, and aquatic creatures are unique with curious physical features and habits. These features and habits become particularly interesting when considering their functions in enabling the animals to adapt to their surroundings.

Examples of comprehension questions

Textbase

The red-tailed phascogale eats the poisonous vegetation in its habitat. (T)

The white-winged chough is a large, white bird similar to a dove. (F)

Inference

The yellow crest on the helmeted honeyeater is used to ward off predators. (F)

The thorny devil is well suited for a dry environment. (T)

Global

The pouches of Australian animals have different functions. (T)

Australian reptiles often have visual displays that alarm their enemies. (T)