Aging and the Representation of Spatial Situations in Narrative Understanding


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Age differences in the construction of the situation model during text understanding were investigated. Situation model processing was measured in terms of the distance effect, the tendency for readers to process information about objects in a narrative more quickly when the objects are spatially closer to the protagonist than when they are farther away. To examine readers' ability to construct the model directly from the text, the distance effect was contrasted for objects that were either presented in a layout of the narrative setting prior to reading (learned objects) or introduced in the narrative itself (new objects). Both younger and older readers showed strong distance effects for learned objects. When objects had not been learned but were only introduced in the text, however, younger adults did not show a reliable distance effect. Older adults with high levels of comprehension did, lending support to the position that older readers differentially rely on the situation model for effective narrative understanding.

Most contemporary theories of narrative understanding posit that readers construct not only a proposition-based representation of content called the textbase, but also a situation model or mental model of what the text is about that is constructed by elaborating on the textbase with world or domain knowledge (e.g., Kintsch, 1994, 1998; Zwaan & Radvansky, 1998). There is now a substantial literature suggesting that aging brings declines in the ability to process discourse (see Kemper, 1992, and Wingfield & Stine-Morrow, 2000, for reviews). Until very recently, however, this work has for the most part focused on memory for the textbase, neglecting the situation model. This is unfortunate for three reasons. First, many theorists argue that situation model construction involves the elaboration of text content based on world knowledge (Gerrig, 1993; van Dijk & Kintsch, 1983). Because cognitive aging is often described as a dissociation between fluid abilities (i.e., mental mechanics) that decline, and crystallized abilities (i.e., knowledge- and culture-based products) that are preserved or enhanced, the knowledge-driven aspect of situation model theory makes it an especially appealing construct for cognitive aging research. Second, reliance on textbase measures perhaps underestimates the capabilities for encoding information from text among elderly readers, who may adopt more holistic approaches to text (Adams, 1991; Adams, Smith, Nyquist, & Perlmutter, 1997; Radvansky, 1999). Finally, and perhaps most importantly from a phenomenological perspective, much reading in everyday life serves the function of transporting us to another world in which we become vicarious participants (Gerrig, 1993; Pavel, 1986; Zwaan, 1999), and it is important to know whether aging brings any change in the ability to participate in this “narrative world.”

The situation model of a story is thought to be a multidimensional representation of the narrative world (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998), including a sense of place (i.e., existing at the “here–now” point with a character inhabiting the discourse world; e.g., Glenberg, Meyer, & Lindem, 1987; Morrow, Greenspan, & Bower, 1987), as well as a representation of characters’ goals (Radvansky & Curiel, 1998), likely actions of a protagonist (Albrecht & O’Brien, 1993), and characters’ emotional reactions (Gernsbacher, Goldsmith, & Robertson, 1992). Although the textbase representation appears to be inefficiently (Hartley, Stojack, Moshaney, Annon, & Lee, 1994; Stine & Hindman, 1994) and fragilely (Cohen & Faulkner, 1981; Light & Capps, 1986) constructed among older adults, the mental model has been found to be fairly resilient to the effects of aging (Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997; Radvansky & Curiel, 1998; Radvansky, Gerard, Zacks, & Hasher, 1990; Soederberg & Stine, 1995). There is even some evidence that older adults particularly depend on situation-based processing (Miller & Stine-Morrow, 1998; Morrow et al., 1997; Radvansky, Zwaan, Curiel, & Copeland, 2001; Stine-Morrow, Loveless, & Soederberg, 1996), perhaps in some cases as a way of compensating for declines in textbase processes.

The Spatial Situation Model

According to some theorists, the sense of place is critical to narrative comprehension, and this was the focus of our research. The empirical basis of this proposal rests in part on the distance effect, the facilitated processing of objects and events in close spatial proximity to the protagonist (Bower & Morrow, 1990; Morrow et al., 1987; Rinck, Hähnel, Bower, & Glowalla, 1997). In the prototypical version of this paradigm, participants first study a spatial layout, or map, representing the setting in which the to-be-read narrative will take place. In the narrative, there are periodically descriptions of the protagonist moving from one location (the source) to another (the goal) through an unmentioned room (the path). This motion sentence is followed by a target sentence in which the protagonist thinks about an object in one of these locations. The interesting finding is that verification times for objects following the motion sentence...
Achieving referential coherence. As in the classic paradigm, issues were not supported by prior learning or required to be resolved. This pattern suggests that readers “move with” the protagonist through the narrative setting, so as to make locations closer to the protagonist more accessible.

Aging and Situation Model Updating

As noted above, the research done with elders generally suggests a large measure of age constancy in situation model processing (e.g., Radvansky et al., 2001). Older readers demonstrate a distance effect at least as great as that of the young (Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Morrow et al., 1997) and show sensitivity to location information denoted by prepositions comparable to that of the young (Radvansky et al., 1990). As in the case of younger readers, older readers are facilitated in their reading by consistency of emotional tone (Soederberg & Stine, 1995) and by completion of protagonist goals (Radvansky & Curiel, 1998).

There is even some evidence that successful older readers may differentially rely on situation model processing. Morrow and colleagues (1997) manipulated whether or not the location of the object was mentioned in the target sentence. Both younger and older readers slowed down when critical sentences did not explicitly mention the location relative to the case when the object’s location was mentioned, suggesting that readers took time to draw this inference. Interestingly, this effect was exaggerated for older adults who were above average in a subsequent measure of comprehension (relative to both the young and below-average elder readers; cf. Morrow et al., 1997, Figure 3), suggesting that more effective elder readers allocated attentional resources (as measured by the increment in reading time) to instantiate objects in the situation model.

Rationale for the Current Study

Many investigations into the spatial situation model rely on paradigms in which participants are provided with a visual presentation of the narrative setting before reading, which they must be able to reproduce from memory before the text is presented. Some research suggests that virtually identical representations of spatial information can be constructed from visual and verbal descriptions (Denis & Zimmer, 1992; Taylor & Tversky, 1992). Not surprisingly then, the distance effect has been shown to hold even when participants learn the layout from a verbal text description prior to reading the narrative (Rinck, Williams, Bower, & Becker, 1996). Although there is some evidence that readers create spatial models under a variety of task conditions (e.g., Glenberg et al., 1987; Zwaan et al., 1995), it has been argued that readers are likely to monitor and update spatial information only when supported by prior knowledge or when spatial inferences are prompted by referential coherence (de Vega, 1995; McKoon & Ratcliff, 1992; Zwaan & van Oostendorp, 1993). We examined whether older and younger adults would update the spatial model spontaneously when updating was not supported by prior learning or required to achieve referential coherence. As in the classic paradigm, participants read narratives that took place in a previously learned layout. However, some of the objects that the protagonist encountered were not present in the original layout, but were newly introduced in the text. Target sentences always referred to objects but not locations, so there was never any need to activate the location to establish coherence. If readers integrate these newly presented objects into their representations of the layout (i.e., the spatial situation model), then these objects should show the same distance effect in subsequent reading as do the objects that had been learned in the layout a priori.

Developmental hypotheses are also suggested. First, to the extent that situation model processing is preserved with aging, we would expect older adults to show the same or an exaggerated distance effect compared with young adults (e.g., Morrow et al., 1997). Some literature has shown that older adults may have difficulty integrating information across the textbase (e.g., Light & Capps, 1986). If this principle is applicable to situation model updating, we would expect older adults to show a diminished distance effect for new objects because they would be less likely, or less able, to integrate the new objects with the previously learned situation model of the narrative setting. However, if older adults are relatively more oriented toward the situation model, it may be that the failure-to-integrate principle does not apply to situation model processing, and older adults may show an exaggerated distance effect for objects whose spatial location is verbally conveyed in the course of ordinary reading.

Methods

Participants

Participants were 53 college students (18 to 38 years of age; M = 19.9) and 47 community-dwelling elders from the New Hampshire Seacoast (56 to 79 years of age; M = 65.6). An additional two elderly participants were tested but eliminated from the analysis because their overall reading times were greater than 2.5 standard deviations from the mean of their group (the remaining participants showed average reading times within ±2.1 SDs of their age groups). On average, our older group was highly educated and had an advantage over the young in terms of years of formal education completed (where subscript Y = young and subscript O = older participants, M_Y = 12.95, SD = .90; M_O = 16.50, SD = 2.05), t(94) = 11.08, p < .001, and Weschler Adult Intelligence Scale vocabulary scores (M_Y = 48.26, SD = 7.17; M_O = 60.43, SD = 6.00), t(94) = 9.13, p < .001. On a working memory (WM) span task developed by Stine and Hindman (1994) and modeled on that of Daneman and Carpenter (1980), younger adults had an advantage over the older ones (average reading and listening span: M_Y = 5.17, SD = 1.06; M_O = 4.50, SD = 1.19), t(97) = 3.00, p < .01.

Stimulus Materials

The setting for all of the narratives was a 10-room research center, similar to that used by Morrow and colleagues (1987). Six narratives were developed for this experiment. They averaged 920 words in length (SD = 81), and contained a mean of 60.3 sentences (SD = 4.1). Mean Flesch-Kincaid grade level was 6.4 (SD = 0.4). In each one,
the plot revolved around a different protagonist, providing some motivation for him or her to move about the research center. In the first few paragraphs of each narrative, three new objects were introduced. Each object was initially presented with a modifier and location, then mentioned again explicitly, and finally mentioned implicitly a third time propositionally. Over the course of the rest of the narrative, there were six critical motion sentences, which described a protagonist moving from one room (the source room) to another (the goal room) through an unmentioned (path) room (across the narratives the direction of protagonist movement was varied). Following the motion sentence was a target sentence in which the protagonist was described as mentally interacting with (e.g., remembering, thinking about, wondering about) an object from one of these three locations.

There were two versions of the layout with identical rooms but different objects to allow us to counterbalance the objects across the Learned and New conditions. In the printed layout that the participants memorized, three objects were placed in each room, and during the course of each narrative three new objects were “placed” in three different rooms, so that the maximum number of objects in each room was four. Each participant saw only one version of the layout. An abbreviated sample narrative is presented in Appendix A (see Appendix B, Note 1). Half of the objects in the target sentences were from the layout as originally memorized (i.e., Learned objects) and half were those introduced in the text (i.e., New objects). Thus, there were six cells in the within-subject design created by factorially combining two levels of Object Type (learned, new) and three levels of Distance from the protagonist (goal, path, source). Each narrative contained one object in each of the six conditions, and across the six narratives, each of the six types of objects appeared in each serial position of the target sentences within the narrative. In this way, target sentences in the different conditions were matched for length, as well as for propositional and syntactic complexity.

Procedure

The entire experimental session lasted about 2 hr. Participants first memorized the layout in which the narrative would take place. They did this by studying the layout for 2 min and then reproducing the names of rooms and objects in their correct locations on a blank copy of the layout. Study-retrieval trials continued until the participant could correctly position all of the rooms and all of the objects. It took older adults to memorize the layout in which the narrative was described as mentally interacting with (e.g., remembering, thinking about, wondering about) an object from one of these three locations.

After learning the layout, participants read each of the narratives on a Macintosh computer with presentation controlled by MacLaboratory software (Chute, 1994). Reading was self-paced using a sentence-by-sentence presentation. Participants advanced to each sentence with a keypress and were asked to read each story with the goal of answering a series of questions about it. Immediately after each narrative, participants were presented a series of yes/no comprehension questions on the computer that probed understanding of the protagonist’s goals, subgoals organized to achieve goals, and emotional tone and location of the protagonist at

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Young</th>
<th>SE</th>
<th>Old</th>
<th>SE</th>
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<tbody>
<tr>
<td>Protagonist Goals</td>
<td>85.7</td>
<td>1.7</td>
<td>83.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Protagonist Subgoals</td>
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<td>1.9</td>
<td>81.9</td>
<td>1.7</td>
</tr>
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<td>1.6</td>
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<td>2.0</td>
<td>79.6</td>
<td>1.9</td>
</tr>
<tr>
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<td>80.0</td>
<td>1.1</td>
<td>78.1</td>
<td>.9</td>
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</table>
vs. 3,848 ms) relative to younger readers (3,642 vs. 3,551 ms), $F(1,98) = 7.91, p < .01$. This suggests that information about objects learned from the map prior to reading was somewhat less accessible than was information encoded during reading and that this was particularly true for older readers. This difference in accessibility may be due to the different temporal relationships between when learned and new objects were encoded and their use in the narrative (i.e., relative to the target sentences, new objects had been encountered more recently). In other words, only the new objects were mentioned in the text prior to the target sentence, giving them an advantage in terms of activation in the text-base representation. Alternatively, this may reflect the fact that the integration of new information with established knowledge can demand attentional resources (as measured by increased reading time allocation to conceptual integration, Miller, 2001, and by increased time required on a secondary task, Britton & Tesser, 1982), which simply takes more time.

There was also a significant effect of distance (3,643, 3,909, and 4,038 ms, for goal, path, and source, respectively), $F(2,196) = 20.71, p < .001$. This distance effect was apparent for the learned objects among both younger (goal = 3,398, path = 3,599, source = 3,928 ms) and older (goal = 4,131, path = 4,439, source = 4,574 ms) readers. Although this effect for new objects appeared to be somewhat more robust among the older (goal = 3,673, path = 4,118, source = 4,051) than the young adults (goal = 3,429, path = 3,564, source = 3,660), none of the interactions with distance reached significance.

Note, however, that this analysis grouped together participants regardless of their effectiveness as readers. Ineffective readers are often less responsive to the demands of the text (which may in part account for why they are ineffective) and essentially add noise to any analysis of strategies used by readers that are engaged by the text (e.g., Miller & Stine-Morrow, 1998; Stine-Morrow, Miller, & Leno, 2001). Thus, to get a more sensitive estimate of reading strategy, we repeated the analysis for participants showing good comprehension accuracy (at least 75%).

The Distance Effect as a Predictor of Comprehension

To further explore the relationship between the distance effect (as an index of the representation and updating of the spatial situation model), we calculated a proportion distance effect [(reading time source – reading time goal)/reading time source] for both learned objects and new objects, as well as an average. Table 3 presents the correlations of these indices with ability measures, as well as with measures of comprehension accuracy. We report relationships with overall accuracy as well as with performance on location questions. Whereas location questions were the only categories of questions to show individual relationships with the distance effect, we should note that accuracy on location questions was correlated with accuracy on nonlocation questions (goal, subgoal, emotional tone), $r = .35, p < .001$, and that location and nonlocation questions were similarly predictive of the overall comprehension score ($r = .85$ for location; $r = .80$ for nonlocation).
Overall, there was a modest relationship between comprehension accuracy and the distance effect ($r = .23$). In a stepwise regression to predict overall comprehension accuracy, average WM span ($\beta = .23$), explaining 4.7% of the variance, and the distance effect ($\beta = .21$), explaining an additional 3.4%, were significant predictors, $F(2,90) = 5.07, p < .01$; with these in the equation, vocabulary added no explanatory power.

The correlational analysis within each age group showed that the distance effect (collapsing across condition) was a more reliable predictor of performance among the old than the young. This effect among the old was most strongly driven by the distance effect for new objects. Interestingly, to the extent that younger adults’ performance was predicted from the distance effect, this was due only to that for learned objects. It is important to note that while younger and older adults showed similar accuracy for questions about location (cf. Table 1), it was the relationships between question accuracy and the distance effect that differed for the two age groups. Again, these data are consistent with the notion that younger readers relied relatively more on the textbase to retrieve this information, while older adults may have relied on the situation model.

**DISCUSSION**

Although the optimum representation of text for flexible use in the face of various retrieval demands probably includes the representation of both the propositional textbase and the situation model (Kintsch, 1994, 1998), the evidence suggests that these two different facets of text representation compete for resources such that readers may focus on one aspect or the other depending on current task demands (Millis, Simon, & tenBroek, 1998; Zwaan & Radvansky, 1998). It is certainly the case that readers can sometimes answer questions about a text without being able to draw inferences or effectively use the information; such results have been taken as evidence for the psychological reality for the distinction between the textbase and the situation model (Perri & Kintsch, 1985). Our data revealed this sort of dissociation: whereas there were no age differences in the ability to answer questions about the locations of objects that had been described in the text (see Table 1), effective older readers, but not effective younger readers, showed a distance effect for these objects. Both younger and older readers, on the other hand, showed reliable distance effects for the objects that had been learned in the map before reading.

Before describing our interpretation of these findings in more detail, we wish to make clear that the differential effects of situation model processing across age were statistically reliable only among those who showed good comprehension performance. It is not unusual for less effective readers to show relatively less sensitivity in their allocation patterns to text (e.g., Miller & Stine-Morrow, 1998; Stine-Morrow et al., 2001). The implication here is that our conclusions are most clearly generalizable to engaged readers, those readers who allocate resources as demanded by the text and (presumably as a consequence) show relatively good levels of comprehension and memory performance. Thus, in drawing conclusions about age differences in reading strategy, our findings most clearly address the cognitive events leading up to successful performance (Baltes & Baltes, 1990).

Within these boundaries, our data suggest that when updating can be based on established knowledge (as when object locations were learned prior to reading), both younger and older readers spontaneously update the situation model in narrative comprehension. However, only older readers were reliable in spontaneously updating the situation when its initial construction depended on integrating information from the text into the representation. In other words, memo-

ization of the layout of the narrative setting before reading appears to have engendered situation model updating regardless of age.

Without this a priori knowledge of the layout, readers encountering new objects in the narrative setting were free to choose whether to encode these into the textbase or into the situation model. Effective older readers demonstrated a distance effect for these objects, suggesting that they made the choice to encode these objects into the situation model. They apparently did this even though this type of spatial processing was not necessary for referential coherence and additional resources may be required to integrate text-introduced objects into the layout (e.g., de Vega, 1995). Younger readers, however, showed no such distance effect in this condition. There are two reasons why they may not have shown this effect. Either they did not encode the new objects into the situation model when these objects were introduced into the text, or they did not update the situation model (i.e., access the locations of these objects relative to the protagonist as she or he moved through the narrative setting). Our data do not clearly discriminate between these

<table>
<thead>
<tr>
<th>Variable</th>
<th>Learned Objects</th>
<th>New Objects</th>
<th>Overall</th>
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<tr>
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<td>.14</td>
<td>.23</td>
</tr>
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<td>.26*</td>
<td>.35**</td>
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<td>.21*</td>
<td>.22*</td>
<td>.30**</td>
</tr>
<tr>
<td>Location New Objects</td>
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<td>.27*</td>
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<tr>
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<td>.08</td>
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<td>Average WM Span</td>
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<tr>
<td>Vocabulary</td>
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<td>.20*</td>
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<td>.13</td>
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<td>Location Learned Objects</td>
<td>.18*</td>
<td>- .17</td>
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</tr>
<tr>
<td>Location New Objects</td>
<td>.21*</td>
<td>.22*</td>
<td>.30**</td>
</tr>
</tbody>
</table>

**Note:** Distance effect = (reading time source – reading time goal)/reading time source. WM = working memory.

$p < .1; * p < .05; ** p < .01.$

**Table 3. Correlations Between the Proportion Distance Effect and Individual Differences in Ability and Comprehension Accuracy**
two explanations. However, we prefer the former explanation and believe that it is unlikely that objects were fully encoded into the situation model but then somehow tagged as distinctive from the learned objects in situation model updating. It is clearly not the case that younger adults ignored the introduction of the new objects. Their ability to answer questions about the locations of these new objects was at least as good as that of the old, suggesting that they incorporated this information propositionally into the textbase. This made the information accessible for answering questions, but not necessarily part of the working situation model of the discourse world. This finding is consistent with that of Radvansky and colleagues (2001), who showed that younger adults are more likely than older adults to retain the textbase representation. The finding that the new objects were part of the discourse world in on-line reading for older adults showing good comprehension (in the absence of an environmental press to do so) provides evidence for the proposal that successful elderly readers show greater reliance on the situation model.

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References


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**Appendix A**

Sample Passage and Probe Questions

Howard was the staff electrician. Known to everyone at the center as a real sweetheart, he was also known to have a weakness for gambling. On this particular day, Howard had been trying to rewire some equipment in the laboratory for over an hour, but he just couldn’t get it to work properly. Before that he’d spent close to an hour working on the four-slot toaster in the lounge which had been burning bread for days. The lab technicians had been pressuring him to fix the toaster all morning. Without it they were not able to warm their bagels in the lounge, and they claimed their lunches had not been the same.

[Introduction of two more objects]

[Development of plot: Howard has gambling debt and learns that some shady characters are coming to collect. He frantically roams the center trying to find someone to lend him money before the thugs find him.]

**Motion Sentence**: Then he walked from the conference room into the reception room.

**Target Sentence (Learned Goal)**: He wondered if there were any loose change near the magazine rack.

[Additional narrative]

**Motion Sentence**: He walked from the experiment room into the repair shop.

**Target Sentence (New Path)**: He remembered that he had seen his office mate near the toaster.

[Additional narrative]

Just then the secretary grabbed him, shook him a bit, and told him that they had a check for him on the condition that he start attending Gamblers Anonymous meetings.

**Questions**

**Protagonist Goals**
Was Howard determined to pay off his debt to the loan sharks on his own? (n)

**Protagonist Subgoals**
In trying to get some money, did Howard think of selling his VCR? (n)

**Emotional Tone**
Were the center’s employees sympathetic to Howard’s situation? (y)

**Location of Protagonist**
Was it in the reception room that Howard first asked for money? (y)

**Location of Learned Objects**
Was the magazine rack in the library? (n)

**Location of New Objects**
Was the toaster located in the conference room? (n)

**Note**: n = no; y = yes. Answers were not seen by participants.

**Appendix B**

**Notes**
1. Copies of the complete narratives are available on request.
2. The reading time measure used here is corrected for sentence length, as the sentences introducing new objects were not controlled for this variable (unlike the target sentences, which were).