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BRIEF REPORT

Aging and Functional Spatial Relations in Comprehension and Memory

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Previous research has suggested that, relative to younger adults, older adults devote a greater proportion of their discourse processing to the situation model level. The current experiment assessed whether this is due, in part, to a preserved ability to focus on functionally appropriate information. The focus here was on spatial relations. Both reading time and recognition data showed superior performance for functional over nonfunctional information, and this functional effect was similar in younger and older adults. This is consistent with the idea that older adults' ability to process information at the situation model level is relatively well preserved.

There are a number of studies showing declines in comprehension and memory as a result of natural aging (e.g., Cohen, 1979; Kemper, 1987; Kemtes & Kemper, 1997; Light & Capps, 1986; Meyer & Rice, 1981; Stine & Wingfield, 1988, 1990). That research has focused primarily on memory for information stated in the text, the textbase, rather than for the described state of affairs, the situation model. A *situation model* is a mental representation of a situation or event (Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). In other words, a situation model is a referential representation that captures both the information in the discourse itself as well as inferences generated by the comprehender to form an integrated and coherent representation that serves as an impoverished analogue to a real or possible world. Research focusing more on situation models suggests that age-related changes have less of an impact than on other levels of representation.

Research has often found little to no differences in how younger and older adults use situation models. For example, Radvansky, Gerard, Zacks, and Hasher (1990) found that younger and older adults used situation models similarly to make recognition decisions. Also, Radvansky, Zacks, and Hasher (1996) found that the degree to which people integrated information into situation models to reduce retrieval interference was unaffected by age (although difficulty managing interference was more prominent for older adults). Studies by Morrow and colleagues (e.g., Morrow, Leirer, & Altieri, 1992; Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997) have shown that younger and older adults are similarly able to update their situation models during comprehension. Finally, Gilinsky and Judd (1994) reported that older and younger adults similarly use situation models to solve categorical reasoning problems.

Of particular importance here is a study by Radvansky, Zwaan, Curiel, and Copeland (2001). They used a recognition paradigm developed by Schmalhofer and Glavanov (1986) to assess the strength of verbatim, propositional, and model representations. The upshot of these experiments was that, although there were age-related deficits at the surface or propositional level, there was no age-related decline at the situation model level. If anything, there was at least a nominal advantage for the older adults over the younger adults. This study is important because it assessed all three levels concurrently using the same texts and the same participants (see also Stine-Morrow, Loveless, & Soederberg, 1996).

Radvansky et al. (2001) offered a number of ideas for why this might be the case. Two of them are relevant here. One idea was that younger adults exerted more effort toward maintaining the propositional textbase, perhaps reflecting the demands of their current schooling. In contrast, the older adults used the textbase more as scaffolding to create their situation models and then did not maintain it, leaving propositional memory poorer. Another idea was that older adults have well-preserved abilities at the situation model level because, compared with younger adults, they are more expert comprehenders who are better able to focus on information that is more pertinent to situation model construction and memory (cf. Chase & Ericsson, 1982). Thus, although they have fewer processing resources overall, those resources that are available can be better directed to the end product of comprehension, which is the construction of a coherent situation model. As such, preserved situation model processing is a compensatory strategy for losses at lower levels. It should be noted that these hypotheses are not mutually exclusive.

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We tested whether younger and older adults differed in the degree to which they processed and remembered information that varied in its situational importance. Importance was defined here as the role the information played in the described situation. That is, whether the information referred to a functional interaction between two entities. Thus, we focus on one situation model processing component rather than the text as a whole. For our purposes, the term *functionality* refers to the actual or likely interaction between two or more entities in a situation in which the state of one entity would be affected by a second entity in a meaningful way (see Radvansky & Copeland, 2000). Thus, functionality is defined by the structure of the situation and involves some causal relation between entities as they are perceived by the comprehender. More generally, functionality can be thought of in terms of what objects are used for, or roles people play. The current study focuses more on situational functionality.

Our idea of functionality is consistent with Michotte's (1946/1963) idea that knowing what objects are for and how they interact provides the basis for understanding. Radvansky and Copeland observed an influence of functionality on spatial relation processing. Previous research on spatial relations has shown that if they are not the focus of the text or task, they may not be effectively encoded (Langston, Kramer, & Glenberg, 1998; Wilson, Rinck, McNamara, Bower, & Morrow, 1993; Zwaan, Radvansky, Hilliard, & Curiel, 1998; Zwaan & van Oostendorp, 1993). In the Radvansky and Copeland study people read texts with an embedded spatial relation. This spatial relation either played a functional role in the described situation (e.g., a person standing under a bridge would avoid the rain) or did not (e.g., a person standing under a street lamp would not avoid the rain). Functional spatial relations were read faster and remembered better than nonfunctional relations. We refer to these differences as functionality effects.

If older adults process information effectively at the situation model level, then they will show similar functionality effects as the younger adults. That is, relative to nonfunctional information, functional information will be read more quickly (reflecting greater ease of comprehension) and remembered better (reflecting better encoding). This difference should be similar for the older and younger adults.

Experiment

Our aim was to test whether younger and older adults' functionality effects meaningfully differ. If older adults retain the ability to process situation model information, then they will show functionality effects similar to those of the younger adults. We measured functionality in two ways. First, we used reading times for sentences in which a spatial relation was embedded. Functional information should be relatively easy to integrate into the situation model, and so should be read faster than nonfunctional information. Second, because functional information is more important to the described situation, it is more likely to be encoded and remembered. Thus, functional relations should be recognized more often than nonfunctional ones.

Method

Participants. Forty-eight people were tested in each of the two age groups. The younger adults ranged from 18 to 22 years of age ($M = 19.3$), were recruited from the University of Notre Dame, and received partial course credit. The older adults ranged from 60 to 94 years of age ($M = 73.7$), were recruited from the community, and were paid. The younger adults had less education (range = 12–15 years; $M = 13.1$) than did the older adults (range = 10–20 years; $M = 14.6$), $t(94) = 3.68$, and the younger adults scored lower on the Shipley Vocabulary test (Zachary, 1986; range = 25–39; $M = 30.7$) than did the older adults (range = 25–39; $M = 33.6$), $t(94) = 4.07$. However, the younger adults scored higher on the Salthouse and Babcock (1991) Figure Comparison test, which serves as a processing speed measure (range = 11–30; $M = 19.5$), than did the older adults (range = 5–17; $M = 11.0$), $t(94) = 12.20$, and the younger adults scored higher on the Daneman and Carpenter (1980) Working Memory Span test (range = 2–5.5; $M = 3.3$) than did the older adults (range = 1.5–4.5; $M = 2.5$), $t(94) = 4.69$ (all $ps < .05$). All participants were native English speakers.

Materials. The eight stories (adapted from Radvansky & Copeland, 2000) were written so that each contained two critical sentences that conveyed a functional spatial relation when one object was used, but a nonfunctional relation when a different object was used.[1] The analyses were based on sentence functionality. Thus, the experiment was a 2 (age) × 2 (condition: functional vs. nonfunctional) design. To counterbalance the incidence of functional and nonfunctional sentences, there were four versions of each story. For example, for the story in the Appendix, in the first critical sentence the nonfunctional version was "David was standing below a *lamp-post.*" In contrast, the functional version was "David was standing below an *old bridge.*" Each participant read two stories containing two functional objects, two stories containing two nonfunctional objects, and four stories containing one functional and one nonfunctional object. Across all stories, for a given reader, each condition occurred equally often at each position. All four text versions were rotated across participants. The stories were 31–45 sentences long, with the critical sentence at approximately one third and two thirds of the way through each story. In addition, there were two practice stories that were used to familiarize people with the procedure.

Two comprehension questions were created for each story. For the story in the Appendix, the questions were "Was it raining?" and "Was David's wallet stolen?" These questions were used to ensure that the people had read the stories. Overall, half of the questions were true and half were not. None of these questions asked about information in the critical sentences.

Procedure

Reading. People were tested individually. The texts were presented on a PC-compatible computer. The text was white on a black background in 40-column mode. People read the two practice stories first, followed by the experimental texts. The experimental stories were read in a different random order for each person. Reading was self-paced. The texts were presented one clause at a time. Each of the critical items was a single clause sentence. After reading a clause, the space bar was pressed with the left hand and the next clause appeared. The computer recorded reading times. After each story, two comprehension questions, presented in red, were answered by clicking one of the two buttons on the mouse with the right hand. The left mouse button was pressed for "yes, this is true", and the right mouse button for "no, this is false". There were equal numbers of "yes" and "no" answers.

[1] Radvansky and Copeland (2000) found similar functionality effects when the target object remained the same but the context was varied (thus making an object functional or nonfunctional).

Recognition. Immediately after reading all of the stories, people were given two recognition tests. The first was a spatial recognition test that probed for the critical spatial relation sentences. For this test, four versions of each critical sentence were presented in a forced choice format. One of these was the functional version (e.g., "David was standing below an old bridge"). There were three other versions. The nonfunctional-object version altered the object from the critical sentence (e.g., "David was standing below a lamppost"). The nonfunctional-spatial term version altered the spatial relation (e.g., "David was standing in front of an old bridge"). Finally, the nonfunctional-both version altered both of these (e.g., "David was standing in front of a lamppost"). Readers made their responses by circling the letter corresponding to the sentence they remembered reading earlier.

After the spatial recognition test, people were given a recognition test based on the methodology developed by Schmalhofer and Glavanov (1986) and used by Radvansky et al. (2001). This was the representational levels test. For this test, six sentences were selected from each text to serve as the test items. These test items were never the spatial relation sentences. There were four versions of each item. One was the verbatim sentence from the text (e.g., "If he stayed out much longer, he would get soaked"). The second was a paraphrase that retained the propositional content of the original, but which had its wording altered either by using synonyms, rewording, or both (e.g., "He would get soaked if he stayed out any longer"). The third was an inference that was information that was likely to be inferred during the reading, but which was never actually mentioned (e.g., "It was raining really hard"). Finally, the fourth was a wrong sentence that contained information that was thematically consistent with the text, but which was inconsistent with what had been stated (e.g., "It looked like it would clear up soon"). For this test, a brief title was provided for each set of six sentences to remind people to which story the items referred. The task was to indicate whether each of the sentences had actually appeared in the story. People were warned that some items might differ in only their wording. Next to each item was a "Y" or "N" for people to circle to indicate whether the sentence had actually occurred in the story. An equal number of verbatim, paraphrase, inference, and wrong items appeared across all of the stories for each participant, and the items were rotated across participants.

Analysis. Reading times were converted to milliseconds per syllable. The slowest and fastest reading times per participant per condition were excluded to remove any outliers. For the levels of representation recognition test, the data were analyzed using a signal-detection approach. A' scores (following Donaldson, 1992), a nonparametric signal-detection measure, were calculated as a discrimination measure. For the surface form measure, verbatims were considered hits and paraphrases were considered false alarms. For the textbase measure, paraphrases were considered hits and inferences were considered false alarms. Finally, for the situation model measure, inferences were considered hits and incorrects were considered false alarms. In addition to A' scores, B'' bias scores were also calculated, although the central focus was on the A' scores. A criterion of $p < .05$ was used for all analyses.

Results and Discussion

Reading times. The reading time results are summarized in Table 1. There was a significant main effect of age, with the younger adults reading faster (174 ms/syllable) than the older adults (268 ms/syllable), $F(1, 94) = 63.44$, $MSE = 6{,}591$. The critical sentences were read faster when they contained the functional object (203 ms/syllable) than when they contained the nonfunctional object (238 ms/syllable), $F(1, 94) = 53.46$, $MSE = 1{,}089$. Also, the interaction was significant, $F(1, 94) = 4.46$, $MSE = 1{,}089$. As can be seen in Table 1, a functionality effect was observed for both the younger, $F(1, 47) = 25.59$, $MSE = 575$, and older adults, $F(1, 47) = 30.17$, $MSE = 1{,}603$, although it was slightly larger for the older adults. Overall, these data are consistent with the idea that older adults are as sensitive as younger adults, if not more so, to aspects of a text that play a more important role in the structure of the situation being described.

Table 1
Reading Times (in ms/Syllable), and Recognition for the Critical Sentences

Condition	Reading time *M*	Reading time *SD*	Recognition *M* (%)	Recognition *SD*
Young				
Functional	162	40	83	16
Nonfunctional	186	50	60	22
Old				
Functional	245	61	79	20
Nonfunctional	290	87	52	23

Spatial recognition. The spatial recognition results are also summarized in Table 1. As a reminder, chance would be 25%. There was a marginally significant main effect of age, with younger adults recognizing more critical sentences (72%) than older adults (66%), $F(1, 94) = 3.88$, $MSE = 0.052$, $p = .05$. There was also a significant main effect of condition, with critical sentences being recognized more often when they were functional (81%) than nonfunctional (56%), $F(1, 94) = 95.00$, $MSE = 0.032$. The interaction was not significant ($F < 1$). This is consistent with the idea that the ability to retain functionally important aspects is relatively unchanged as a result of the natural aging process, but that information that is not as critical to understanding the operation of the described situation is more likely to be lost. There is no age-related deficit with regard to this distinction, and, if anything, the older adults show a nominally larger effect than the younger adults. The general loss of the ability to retain propositional textbase information would account for the overall lower recognition rate for the older adults relative to the younger adults.

Representational levels. The results for this test are summarized in Table 2. All of the A' values were significantly different from chance (.5), all Bonferroni-corrected ps $< .01$, except for the older adults' performance on the surface form measure, $t(47) = 1.24$, $p = .22$. Consistent with Radvansky et al. (2001), younger adults outperformed the older adults on the surface form, $F(1, 94) = 11.94$, $MSE = 0.026$, and textbase measures, $F(1, 94) = 4.37$, $MSE = 0.031$. In contrast, the older adults outperformed the younger adults on the situation model measure, $F(1, 94) = 4.75$, $MSE = 0.008$. This pattern is in line with previous research (Radvansky et al., 2001) in showing that older adults have poorer memory at lower levels of processing and that there is no deficit for the older adults at the situation model level.

Although of less direct interest, we also looked at the bias measure. As can be seen in Table 2, people responded most liberally on the surface form measure, and most conservatively for the situation model measure. In all cases, the older adults responded more liberally than the younger adults (all ps $\leq .06$). This pattern is consistent with previous research (e.g., Koutstaal & Schacter, 1997; Radvansky et al., 2001).

Table 2
Recognition Discrimination Scores (A′) and Bias Scores (B″)

Condition	Surface form *M*	Surface form *SD*	Textbase *M*	Textbase *SD*	Situation model *M*	Situation model *SD*
A′ scores						
Young	.64	.16	.67	.17	.84	.10
Old	.53	.16	.60	.19	.88	.08
B″ scores						
Young	−.75	.29	−.12	.65	.93	.21
Old	−.85	.23	−.70	.39	.54	.56

Note. For A′, a score of .5 indicates chance discrimination and 1 indicates perfect discrimination. For B″, negative numbers indicate more liberal responding, and positive numbers indicate more conservative responding.

General Discussion

Our findings are consistent with the idea that older adults devote greater effort in text comprehension and memory to processing at the situation model level relative to the other levels. This was assessed by looking at how spatial information was processed during reading and memory. This spatial information is either functional in the described situation or not.

Our results showed that both the younger and older adults found it easier to comprehend functional spatial relations than nonfunctional ones. Moreover, during memory testing, both younger and older adults showed superior memory for functional over nonfunctional spatial relations. The older adults showed a nominally larger effect, making it unlikely that there is any age-related deficit. These findings are consistent with the idea that situation model processing is largely preserved with aging.

We also looked at younger and older adults' memory for information at the surface form, textbase, and situation model levels. Consistent with previous research (Radvansky et al., 2001), younger adults outperformed the older adults at the surface form and textbase levels, whereas the older adults outperformed the younger adults at the situation model level. Older adults may not remember exactly what the text was, but they remember what it was about.

Overall, the findings from this study are consistent with the idea that there is relatively little age-related change in processing at the situation model level in comprehension and memory, although there are changes at lower levels of processing. Our results show that younger and older adults are sensitive to functional information in a text. This is consistent with both of the possibilities outlined in the introduction. First, it may be that younger adults are making efforts to maintain the textbase, whereas the older adults are less likely to maintain whatever textbase they have created after the completion of their situation models. This is most strongly supported by the signal-detection data. Second, older adults may process information at the situation model level by better selecting out those pieces of information that are more pertinent to understanding the described situation. This is hinted at in the reading time data, and to a somewhat lesser degree by the spatial recognition data. This idea is also consistent with research showing that older adults are better at selecting information that is more diagnostic for making trait inferences (Hess & Auman, 2001). Overall, this study opens the door to continue to explore both of these possibilities. Future research will be further aimed at understanding situation model processing and how it is related to age-related changes in cognition.

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Appendix

Sample Story Used in the Experiment

David walked along the banks of the river in town. Although the days were unbearably hot, the nights could be bitterly cold. He hugged his thin dust-covered coat around him as he thought about how the travel agent had lied to him. Two months ago, David went to see the travel agent. She told him that North African Sahara towns were friendly and romantic. Now, everything so far suggested the opposite. David walked further down the river. A steady cold rain began to pour from the sky. If he stayed out much longer he would get soaked.

Critical sentence: *David was standing below an old bridge.*

He listened to the rain falling on the road as he took stock of their misfortunes so far. The townfolk treated you with contempt if you didn't speak the native Arabic or French. His wallet and passport had been stolen. Maureen and he were shocked to find out how decrepit and dirty their hotel was. Even the coffee they were served was bad. David was sure that this trip would bring his troubled marriage to an end. Twenty minutes later, David saw a taxi and hailed it. The driver stopped and David got in. As he was scanning the drab city he saw an object that could free him. While driving through the merchant district, he saw an old black Ford. Although it was far from perfect, he thought that he could use it to escape this cursed place. David couldn't take his eyes off that car. The driver had just pulled into a gas station.

Critical Sentence: *The old car was sitting to the left of a slick new gas pump.*

The contrast was striking. The driver filled up the gas tank. David wished he had his wallet so that he could offer to buy that car. Maybe he would just steal it. How liberating it would be to cruise out of this town in that car. He didn't know where he would drive to, he just wanted out of here. Even sitting in a gas station it seemed to command his attention.

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