

BRIEF REPORTS

The Role of Age and Perceptual Symbols in Language Comprehension

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Older and younger participants read sentences about objects and were then shown a picture of an object that either matched or mismatched the implied shape of the object in the sentence. Participants' response times were recorded when they judged whether the object had been mentioned in the sentence. Responses were faster in the shape-matching condition for all participants, but the mismatch effect was stronger for older than for younger adults, even when the larger variability of the older group's response times was controlled for. These results suggest that older adults may construct stronger situation models than younger adults.

Results of several studies indicate an absence of age-related differences with respect to the construction of the situation model (Radvansky, 1999; Radvansky & Curiel, 1998; Radvansky, Zwaan, Curiel, & Copeland, 2001). Compared with younger adults, older adults have been found to have equally elaborate comprehension of the spatial situation of the protagonist in the text (Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997) and a similar higher performance for functional over nonfunctional information (Radvansky, Copeland, & Zwaan, 2003). Older adults also showed patterns in inference construction similar to those of younger adults (Graesser & Bertus, 1998).

Findings suggest that older adults' text comprehension abilities are quite robust. If anything, older adults show a nominal advantage over younger adults with regard to constructing situation models (Radvansky, Copeland, & Zwaan, 2003). For instance, a study was recently conducted to examine the updating of temporal information in situation models of younger and older readers. Not only did this study show longer response times to probes from narratives with larger rather than shorter time shifts for both younger and older adults, it also showed an Age Group \times Condition interaction, suggesting stronger updating effects in the situation model for older than for younger readers when time shifts in the narratives were large (Radvansky, Copeland, Berish, & Dijkstra, 2003).

Constructing and updating situation models are the result of mental representations formed by the reader during the text comprehension process. Recent research suggests that people routinely activate perceptual symbols during language comprehension (Pecher, Zeelenberg, & Barsalou, 2003; Stanfield & Zwaan, 2001; Zwaan, Stanfield, & Yaxley, 2002; Zwaan & Yaxley, 2003).

Zwaan et al. (2002) examined whether comprehenders routinely represent the implied shape of entities. Participants were presented with sentences describing an object in a given location (i.e., "The ranger saw an eagle in the sky/nest"), followed by a line drawing of an object (e.g., an eagle). The implied shape of the object changed as a function of the object's location; for example, when in the sky, an eagle had its wings outstretched, but when in a nest, its wings were folded. Once presented with the pictured object, participants judged whether the object had been mentioned in the sentence. Response times were slower when the picture mismatched the implied shape (the mismatch condition) than when the picture matched the implied shape (the match condition). For example, when participants read a sentence about an eagle in the sky, they responded more slowly to a picture of an eagle with folded wings than to a picture of an eagle with outstretched wings. The reverse occurred when the sentence described an eagle in its nest.

Because the activation of perceptual representations during language comprehension has been documented for younger adults only (e.g., Stanfield & Zwaan, 2001; Zwaan et al., 2002; Zwaan & Yaxley, 2003), the question addressed in this article is whether, and to what extent, perceptual representations are used by older adults when they comprehend sentences. If perceptual symbols are routinely used during text comprehension, an analogue representation of the text could help explain how subtle components of the situation, such as the orientation and implied shape of objects in the situation, contribute to an understanding of the text (Zwaan, 2004). On the basis of research on language comprehension in older adults (Graesser & Bertus, 1998; Morrow et al., 1997; Radvansky, Copeland, Berish, & Dijkstra, 2003; Radvansky, Copeland, & Zwaan, 2003), we can predict that older adults show a mismatch effect comparable to that of younger adults (Stanfield & Zwaan, 2001; Zwaan et al., 2002).

An additional prediction to be considered is that older adults may produce a larger mismatch effect than younger adults. Because older adults have had more experience with reading, seem to focus more on the end product of comprehension than on the surface structure, and are affected more by changes in the text that require updating of the situation model (Morrow et al., 1997;

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Radvansky, Copeland, Berish, & Dijkstra, 2003), it is possible that older adults will build a stronger situation model before responding to a probe than younger adults. This may result in a longer response time for a pictured object that mismatches the implied shape of the object presented in the previous sentence. In other words, the older adult's stronger situation model would be more difficult to override than the younger adult's relatively weaker situation model when inconsistent shape information is contained in the picture.

Method

Participants

Twenty-three younger (mean age = 18.25 years, $SD = 0.64$) and 22 older (mean age = 74.40 years, $SD = 7.39$) adults participated in the experiment. The younger adults were undergraduate students participating for course credit; the older adults were healthy, community-dwelling adults. The data for 7 participants were removed from the data set. Of these, 6 were removed before the analyses were run, for the following reasons: 2 younger and 2 older adults were removed because of extremely low accuracy on the recognition task (< 70%), 2 younger adults were removed because of their earlier participation in a similar experiment, and 1 older adult had extremely slow response (> 3,000 ms) and reading times. Results are reported for the remaining 38 participants.

Materials

Eighty-four black-and-white drawings were obtained from a clip-art package and a study by Snodgrass and Vanderwart (1980) or were created from photographs that had a similar level of detail as line drawings. Of the 84 pictures, 56 served as filler items. The remaining 28 experimental items consisted of object pairs, with each member of a pair denoting a different shape of the object. For example, one member of a pair could be a picture of an eagle with its wings outstretched as if in flight, and the other member could be a picture of an eagle with its wings drawn in, as if perched. Other items included an egg (in a carton vs. in a pan) and a lemon (in a tree vs. in a drink). Each picture was scaled to occupy a square of about 3 in. on a computer screen. Picture pairs were on the same scale and had the same amount of detail with respect to shape. A few line drawings were paired with photos. Examples of pictures and photos and the sentences they followed are presented in the Appendix.

Eighty-four sentences were created to accompany the pictures: 56 filler sentences and 28 experimental sentences (14 sentences implying one shape of a given object and 14 sentences implying the alternate shape). The filler sentences all mentioned a concrete noun other than the subsequently pictured object and thus required a "no" response on the recognition task. Examples of the filler items are presented in the Appendix. The experiment was run on a PC using the E-Prime 1.0 software (Schneider, Eschman, & Zuccolotto, 2002). Responses were recorded via the keyboard, using the *j* key for yes and the *f* key for no responses.

Before the item analysis was conducted, two items were removed from both older and younger participants' data owing to extremely low response accuracy scores. These pictures, which may have been difficult for participants to recognize, were of chewed gum and a cigarette butt.

Design and Procedure

A 2 (match vs. mismatch) \times 2 (shape version: 1 vs. 2) \times 2 (age group: older vs. younger) mixed design was used. To reduce error variance associated with the particular pairing of experimental items (Pollatsek & Well, 1995), all items and conditions were counterbalanced across lists. Specifically, each participant saw all items but only one shape version of each item in one list. Across these lists, matching and mismatching pictures

and the different shape versions (e.g., eagle with wings outstretched vs. eagle with wings drawn in) were counterbalanced. This procedure resulted in a 2 (match vs. mismatch) \times 4 (counterbalanced list versions) \times 2 (older vs. younger) design. In the participant analysis, the match–mismatch conditions were compared as within-participant variables, and age group and lists as between-participant variables. In the item analysis, the match–mismatch conditions, list, and age groups were all compared as within-item variables. Because the list variable was included only to reduce error variance, significant effects involving list are provided separately in footnotes but are not discussed in further detail. When effects involving list were not significant, data were collapsed across lists.

Participants received verbal and written instructions to read each sentence presented on the computer screen, to press the space bar when they had finished reading, and then to judge whether the subsequently pictured object had been mentioned in the sentence by pressing the "yes" or "no" labeled key ("yes" and "no" stickers were placed on top of the *j* and *f* keys, respectively) as quickly and accurately as possible. During the experiment, comprehension questions appeared after 24 of the filler items. (An example of a comprehension question is listed in the Appendix.) Participants had to press the "yes" or "no" key to answer this question. This task was included to ensure that participants were reading for comprehension. There were an equal number of questions requiring yes and no responses. The experiment took about 20 min to complete.

Results

Response Times

Table 1 displays the mean response latencies and standard deviations for each condition per age group. A 2 (match vs. mismatch) \times 2 (age group) analysis of variance (ANOVA) was conducted on response latencies. There was a significant mismatch effect: The responses to the pictured object were faster when they matched the implied shape of the object in the sentence, compared with when they mismatched, $F_1(1, 36) = 33.30$, $MSE = 187,706$, $p < .001$; $F_2(1, 50) = 13.71$, $MSE = 415,327$, $p < .01$. There was also an effect of age, with younger adults having shorter response latencies than older adults, $F_1(1, 36) = 48.64$, $MSE = 4,730,520$, $p < .001$; $F_2(1, 50) = 568$, $MSE = 13,544,610$, $p < .001$, and a match condition by age group interaction, $F_1(1, 36) = 6.42$, $MSE = 36,214$, $p < .05$; $F_2(1, 50) = 4.00$, $MSE = 98,814$, $p = .051$, with the mismatch effect being larger for the older adults than for the younger adults.¹

The results showed the predicted main effect of sentence–picture match. There was also a main effect of age, with longer response latencies for older than for younger adults, and there was an interaction between match condition and age, suggesting that the mismatch effect was more pronounced in the older adults than in the younger adults. This Match Condition \times Age interaction should be interpreted with caution, however, as the performance of older adults typically is more variable than that of younger adults (Hultsch, MacDonald, & Dixon, 2002; Perfect & Maylor, 2000; Ratcliff, Spieler, & McKoon, 2000; Stine-Morrow, Milinder,

¹ There were significant interactions between match condition and list and between age and list, and a three-way Condition \times List \times Age interaction, for the item analysis only, $F_2(3, 50) = 2.99$, $MSE = 90,818$, $p < .05$; $F_2(3, 50) = 4.84$, $MSE = 115,506$, $p < .05$; $F_2(1, 3, 50) = 25.72$, $MSE = 635,772$, $p < .001$, indicating mismatch effects for some but not all lists and differences between age groups for some list effects. List was used to reduce error variance (Pollatsek & Well, 1995).

Table 1
Means (and Standard Deviations) for Response Latency (in Milliseconds) and Response Accuracy (Proportion Correct)

Age group	Response latency		Response accuracy	
	Match	Mismatch	Match	Mismatch
Young	809 (146.5)	864 (173.5)	.98 (.06)	.96 (.06)
Old	1,264 (264.0)	1,407 (290.7)	.93 (.09)	.92 (.10)

Pullara, & Herman, 2001), although this phenomenon is not observed for all tasks (Shammi, Bosman, & Stuss, 1998). Similarly, a wider range of response times for older adults (young: match = 533–1,062, mismatch = 471–1,165; old: match = 835–1,671, mismatch = 930–2,029) also occurred in our data set, suggesting that the interaction observed in the current study could be caused by such differences in variance.

To more accurately compare the mismatch effect for younger and older adults, we used a z -score transformation to control for variability in response times, following a procedure proposed by Faust and colleagues (Faust, Balota, Spieler, & Ferraro, 1999; for a description, see Hummert, Garstka, O'Brien, Greenwald, & Mellott, 2002). Specifically, we transformed the response time for each trial to a z score using the participant's mean and standard deviation across all trials for both conditions. After this transformation, we computed condition means across trials for each participant and conducted ANOVAs on the z -transformed means. Figure 1 shows the results. The analysis yielded a main effect of match condition, $F_1(1, 36) = 19.85$, $MSE = 1.90$, $p < .001$; no main effect of age; but again a Match Condition \times Age interaction, $F_1(1, 36) = 4.99$, $MSE = 0.477$, $p < .05$. Thus, even when interindividual variability was taken into account, the interaction remained, indicating a stronger mismatch effect for the older than for the younger adults.

To assess the mismatch effect further, we conducted ANOVAs on response time for younger and older adults separately. The participant analysis for the younger group, including list, yielded a significant difference between match and mismatch conditions,² $F_1(1, 15) = 7.37$, $MSE = 30,874$, $p < .05$. The item analysis for the younger group yielded a marginal difference between match and mismatch conditions,³ $F_2(1, 50) = 3.58$, $MSE = 54,486$, $p = .064$. The participant and item analyses for the older group also yielded a significant difference between match and mismatch conditions, $F_1(1, 15) = 29.47$, $MSE = 176,166$, $p < .001$; $F_2(1, 50) = 11.55$, $MSE = 459,654$, $p < .001$.⁴

Accuracy

Table 1 presents the accuracy of responses, that is, whether the object in the picture had been mentioned in the preceding sentences, for younger and older adults. A 2 (match vs. mismatch) \times 2 (age group) ANOVA was conducted to assess differences in accuracy between the match and mismatch conditions. The participant and item analyses on accuracy of response yielded a main effect of age group, $F_1(1, 36) = 4.78$, $MSE = 0.038$, $p < .05$; $F_2(1, 50) = 24.11$, $MSE = 0.186$, $p < .001$, indicating greater accuracy for younger than older adults, but no main effect of match condition or an Age Group \times Match Condition interaction ($F_s < 2.60$).⁵

No differences in accuracy for the responses were found for the match–mismatch conditions in the participant analyses when performed for the different age groups separately ($F_s < 2.40$).⁶

Individual Differences

Sentence reading speed and comprehension were assessed to address individual differences. Table 2 presents the means and standard deviations for sentence reading time and sentence comprehension accuracy for younger and older adults. A 2 (match vs. mismatch) \times 2 (age group) ANOVA was performed to assess age differences for sentence reading speed. There was no effect for match condition, nor was there an Age Group \times Match Condition interaction ($F_s < 1.50$), but there was a main effect of age, with older adults being slower than younger adults, $F(1, 35) = 4.20$, $MSE = 5,318,020$, $p < .05$. Independent sample t tests were conducted for comprehension accuracy, but there were no differences in comprehension accuracy between the two age groups ($t > 1.50$).

Discussion

The present results suggest that, like younger adults (Zwaan et al., 2002), older adults use perceptual information in sentence comprehension. In this study, both younger and older adults were slower when responding to probes about pictures that mismatched rather than matched the implied shape of objects in the preceding sentence. The results also showed a larger mismatch effect in older than in younger adults, even when the variability in response time was controlled for. This finding is in line with other aging studies that have demonstrated similar age differences in performance during the construction and updating of situation models and in the text comprehension of younger and older adults, as well as stronger updating processes in older adults (Radvansky & Curiel, 1998; Radvansky, Copeland, Berish, & Dijkstra, 2003; Stine-Morrow et al., 2001). Lower response accuracy for older adults has been documented in other studies as well (Radvansky, Copeland, Berish, & Dijkstra, 2003; Radvansky & Curiel, 1998) and has been explained as part of older adults' general cognitive decline in aging—a process that does not seem to affect their comprehension abilities. In our study, older adults' accuracy rates were over 90% in both match and mismatch conditions, which can be considered extremely high.

What explains the stronger mismatch effect in older compared with younger adults? One explanation could be that longer sentence-reading times would give older adults more time to build a context-rich situation model that would be more difficult to

² A main effect of list was found as well, $F_1(1, 3) = 3.44$, $MSE = 116,964$, $p < .05$.

³ A List \times Condition interaction was found, $F_2(3, 50) = 22.63$, $MSE = 344,259$, $p < .001$.

⁴ A List \times Condition interaction was found for the item analysis, $F_2(3, 50) = 9.59$, $MSE = 381,831$, $p < .001$.

⁵ There was a Factor \times List interaction in the item analysis only, $F_2(3, 50) = 4.78$, $MSE = 0.052$, $p \leq .01$.

⁶ For the item analyses, there was a significant Match Condition \times List interaction for the younger group, $F_2(3, 50) = 3.27$, $MSE = 0.019$, $p < .05$, but not the older group ($F_2 < 2.60$).

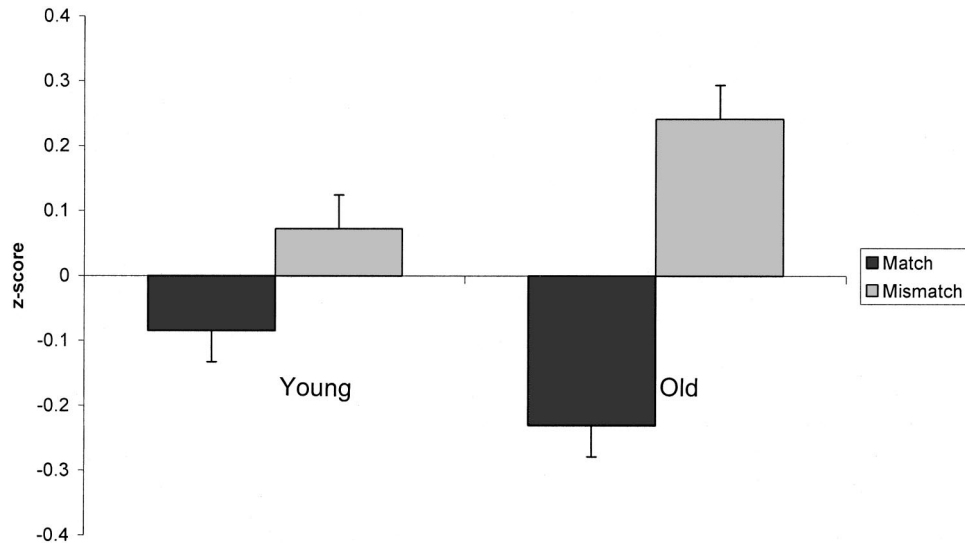


Figure 1. Z scores for match and mismatch reading times in younger and older adults.

override with a mismatching picture than younger readers, who spend less time building this situation model. This explanation is contradicted, however, by data from a similar experiment involving spoken presentations of sentences in which a larger mismatch effect was found for older than for younger adults even though sentences were presented at the same rate (Madden & Dijkstra, 2004). Obviously, because the presentation time of the prerecorded sentences was the same for both age groups, older adults had had no extra time to build more elaborate situation models in that study.

A more plausible explanation could be that older adults emphasize online situation model construction as the situation in the sentence unfolds word by word, whereas younger adults focus more on the surface structure, or the meaning of each individual word, while reading the sentences. In both cases, younger and older readers activate perceptual representations while reading. Younger adults may abide by the experimental demands of the task more closely and focus on the words in the sentence. In this experiment, constructing a situation model based on the whole sentence is irrelevant to the task, because the only criterion for response is whether the object in the picture was mentioned in the preceding sentence, matching its implied shape or not. Responses could in principle be based on two sources of information, the (perceptual) situation model that compares the object in the picture with that in the sentence and the surface structure that does or does

not state the object that is presented later in the picture. Our data suggest that the older adults relied more on the situation model whereas younger adults seemed to rely on the surface structure more, a finding that is consistent with other studies on situation models (Morrow et al., 1997; Radvansky, Copeland, Berish, & Dijkstra, 2003; Radvansky et al., 2001).

This study adds to the accumulating support for the assumption that language comprehenders routinely represent the shapes of objects when reading sentences (Zwaan, 2004; Zwaan et al., 2002). The findings of these representations are now confirmed with an older age group. An additional finding is the stronger mismatch effect in older adults. This finding suggests that the construction of mental representations may vary in strength depending on reader characteristics and task demands. The larger mismatch effect in older adults, controlled for variability in response, seems to reflect a difference in emphasis on the text when constructing situation models between younger and older adults.

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Table 2
Means (and Standard Deviations) for Sentence Reading Times (in Milliseconds) and Comprehension Accuracy (Proportion Correct)

Age group	Reading time		Comprehension
	Match	Mismatch	
Young	1,606 (372.4)	1,559 (314.8)	.72 (.16)
Old	2,074 (970.3)	2,164 (1,237.9)	.63 (.21)

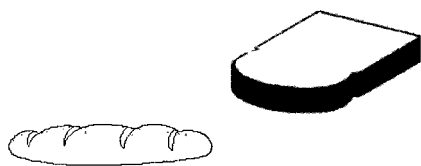
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Appendix

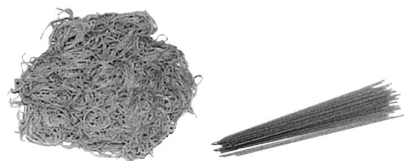
Examples of Experimental and Filler Items

Experimental Items

There was bread in the [bakery window/toaster].

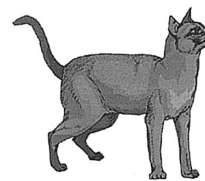


There was spaghetti in the [bowl/box].



Filler Items

There was a cat on the blanket.



Comprehension question: Was the blanket under the cat?
There was film in the camera.



Comprehension question: Could the camera be used to take pictures?

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