Situation Model Updating in Young and Older Adults: Global versus Incremental Mechanisms

Heather R. Bailey[1,2] and **Jeffrey M. Zacks**[2]

[1]Kansas State University

[2]Washington University St. Louis

Abstract

Readers construct mental models of situations described by text. Activity in narrative text is dynamic, so readers must frequently update their situation models when dimensions of the situation change. Updating can be incremental, such that a change leads to updating just the dimension that changed, or global, such that the entire model is updated. Here, we asked whether older and young adults make differential use of incremental and global updating. Participants read narratives containing changes in characters and spatial location and responded to recognition probes throughout the texts. Responses were slower when probes followed a change, suggesting that situation models were updated at changes. When either dimension changed, responses to probes for both dimensions were slowed; this provides evidence for global updating. Moreover, older adults showed stronger evidence of global updating than did young adults. One possibility is that older adults perform more global updating to offset reduced ability to manipulate information in working memory.

During narrative comprehension, readers construct *situation models*, which are working memory representations of the situation described in the text. Situation models are thought to represent information along various dimensions such as the characters, their goals, space, and time (Zwaan & Radvansky, 1998). Information relevant to these dimensions often changes throughout the story: New characters are introduced, goals are accomplished, the story moves into a new spatial location. Situation models presumably are updated at these changes to reflect the new state of affairs. Updating involves altering the contents of a situation model to capture these changes readers encounter during a story. One of the main goals of the current experiment is to evaluate how situation models are updated.

Some theories of text comprehension propose an *incremental updating* mechanism in which only information relevant to the changing dimension is updated in the situation model (Bower & Rinck, 2001; Zwaan, Langston, & Graesser, 1995). One model that proposes incremental updating is the Event Indexing Model (Zwaan et al., 1995). This model claims that people track the dimensions of the situation such as characters and space as they read narrative texts. When information along one of these dimensions changes (e.g., the spatial location in a story changes), readers update their situation model to represent this new

Correspondence concerning this article should be addressed to: Heather Bailey, 414 Bluemont Hall, Kansas State University, Manhattan, KS 66506, hbailey@ksu.edu, Phone: (785) 532-0807, Fax: (785) 532-5401.

spatial location but information relevant to other dimensions is not updated. Presumably, changed information is less likely to be maintained in the current situation model. Thus, if a reader was queried about this information, responses should take longer and be less accurate compared to responses about information that is still maintained in the situation model. Assuming that the changed information is less likely being actively maintained in working memory, responses will require retrieval from long-term memory, which should produce slower and less accurate responses.

For example, suppose you read about a character named Elvira who had a beehive hairdo and was watching movies on a large-screen TV in a basement room. If you read that Elvira walked up to the kitchen for a glass of milk, theories supporting an incremental updating mechanism would predict that information regarding the basement would no longer be accessible in the current situation model because Elvira is now in the kitchen. Thus, responses to probes about the location of the TV should be slower or less accurate (or both). Importantly, though, incremental updating should not affect responses to information about information that remains unchanged in the story because it is presumably still accessible in the situation model: Responses to probes about Elvira's hairdo should not be slower or less accurate, compared to a no shift control.

Curiel and Radvansky (2014) reported evidence that supports an incremental updating mechanism. They manipulated whether a character shift immediately followed a spatial shift (or vice versa) and found that, although both character and spatial shifts triggered situation model updating, they did not interact with one another. That is, reading times slowed down at a spatial shift even when it immediately followed a character shift and vice versa. Curiel and Radvansky (2014) describe these results in terms of incremental updating because each situational shift is being updated independently of one another.

Other accounts have described a *global updating* process (Gernsbacher, 1990; Zacks, Speer, Swallow, Braver, & Reynolds, 2007). Event Segmentation Theory (Zacks et al., 2007) is one such account. According to this theory, dynamic activity is segmented into discrete events that are represented in the situation model. An event is "a segment of time that is conceived by an observer to have a beginning and an end" (Zacks & Tversky, 2001, p. 17). When one event ends, the activity is segmented and an *event boundary* is perceived. An event boundary is a breakpoint between the end of one event and the beginning of another, and Event Segmentation Theory proposes that these boundaries are perceived when the dynamic activity is changing and future activity becomes less predictable. It is at these boundaries that the entire situation model is updated—including information relevant to dimensions on which no change has occurred. Put differently, when readers come across a situational change that is perceived as an event boundary, the current model is flushed and a new model is constituted. Thus, *all* information that occurred prior to the event boundary is less likely to be accessible and more likely needs be retrieved from long-term memory. If a reader were asked about any of this information—i.e., both the changed and the unchanged information—then responses should be slower and less accurate compared to a no shift control.

Using the previous example, suppose one read that Elvira with the beehive hairdo was watching movies on a large-screen TV in a basement room and then walked upstairs to the

kitchen for a glass of milk. Theories that incorporate global updating mechanisms would predict that the change in spatial locations should render information from the previous location as well as attributes of the character less accurate and slower to a recognition probe. Specifically, global updating should cause information about the TV's location as well as information about Elvira to be cleared from the situation model.

Evidence for global updating includes a study conducted by Speer and Zacks (2005), in which spatial information from previous events was less available following a time shift (e.g., "An hour later…"). A variety of studies have shown that responses are slower to verify objects that had been mentioned before a time shift (e.g., Ditman, Holcomb, & Kuperberg, 2008) or a spatial shift (e.g., Glenberg, Meyer, & Lindem, 1987; Rinck & Bower, 2000). Results from these studies support global updating, because they suggest that readers update not only the dimension that changed (space or time) but also the inventory of objects in the situation. There is evidence for global updating in the experience of interactive events as well as in narrative comprehension: Radvansky and Copeland (2006) probed people for objects they were carrying in a virtual-reality environment when they were either in the middle of a room (i.e., no shift) or after they had just walked into another room (i.e., spatial shift). They found that an object's availability was reduced after a spatial shift even when people were still carrying it. That is, a change in spatial location rendered an object less accessible in the mental representation even though it was unchanged (i.e., it still remained in the person's possession).

These data are consistent with a global updating mechanism because they suggest that when one situational dimension changes, the likelihood of updating *other* situational dimensions increases. However, to provide strong evidence it is necessary to control shifts on both the tested and untested dimensions. None of these studies did this. Changes related to multiple dimensions may have occurred at event boundaries. For instance, in the narratives used by Speer and Zacks (2005), time shifts sometimes were accompanied by stated or implied spatial shifts. Thus, such designs do not distinguish between global updating of spatial information in response to a time change and incremental updating of spatial information in response to a change in spatial change.

To directly evaluate incremental and global updating mechanisms, the current experiment used narratives that systematically controlled shifts along one dimension at a time. These narratives included shift sentences that contained only a change in characters or a change in spatial locations. We chose the character and spatial dimensions for both theoretical and practical reasons. For theoretical purposes, the character dimension is important for comprehension (Zwaan & Radvanksy, 1998) and readers track characters closely (e.g., Albrecht & O' Brien, 1993; Glenberg, et al., 1987; Rapp, Gerrig, & Prentice, 2001; Rinck & Weber, 2003; Zwaan et al., 1995), whereas although readers can track space (e.g., Therriault, Rinck, & Zwaan, 2006), they do not always do so (Zwaan & Radvansky, 1998). Further, previous work on incremental and global updating has focused on these two dimensions (Curiel & Radvansky, 2014). For practical purposes, we wanted to create moderately long narrative texts that maintained global coherence and were enjoyable to read. Manipulating the character and spatial dimensions was easier in this context as opposed to other situational dimensions, such as time. For instance, multiple time shifts

(e.g., "a day later...") within one narrative might have disrupted global coherence and overall comprehension. Using carefully constructed sentences that contained only one change along the character or spatial dimensions allowed us to evaluate whether the changed information, unchanged information, or both types of information were updated after a shift.

Incremental and global updating are very different memory updating mechanisms; however, they are not mutually exclusive. Situation models may be updated incrementally in response to some dimension changes, but updated globally in response to other changes. For instance, the entire model may be updated when people reach an event boundary, whereas only the changing information may be updated when they read about a change that occurs within the middle of an event. The Structure Building framework (Gernsbacher, 1990) is a theory that accommodates both incremental and global updating. It proposes a *mapping* process that is a form of incremental updating, and a *shifting* process that is a form of global updating. Mapping occurs when readers modify their situation model to represent new information described in the story. Shifting, on the other hand, occurs when incoming information does not overlap with previous information. Readers shift and build an entirely new "substructure." Kurby and Zacks (2012) used a think-aloud paradigm during narrative comprehension and reported a pattern of results supporting the Structure Building framework. They found that readers were more likely to mention the changing dimension in the middle of an event, whereas they were likely to mention multiple dimensions at event boundaries. That is, situation models were updated incrementally as information was changing within an event, but updated globally when a new event began[1].

Given some evidence that young adults use both incremental and global updating mechanisms, the goal of the current experiment was to evaluate how older adults update their situation models. The construction and updating of situation models are important for comprehension because they help maintain the structure of a story. Despite the fact that older adults typically show declines in processing speed (Salthouse, 1991; 1994) and working memory capacity (Zacks, Hasher, & Li, 2000), their situation model processing shows patterns similar to that of young adults. (e.g., Radvansky, 1999; Radvansky & Dijkstra, 2007; Radvansky, Zwaan, Curiel, & Copeland, 2001; Stine-Morrow, Gagne, Morrow, & DeWall, 2004). Older adults may rely upon situation models disproportionately for comprehension to compensate for these other cognitive impairments (Radvansky et al., 2001; Stine-Morrow, Morrow & Leno, 2002).

However, this reliance on situation models does not indicate that older adults use situation models as effectively as do young adults. In fact, some studies demonstrated that, although older adults are able to update their situation models, they do so more slowly than young adults (Morrow, Leirer, Alteiri, & Fitzsimmons, 1994; Morrow, Stine-Morrow, Leirer, Andrassy, & Kahn, 1997). Further, physiological measures (parafoveal preview benefit) have revealed that older adults experience more cognitive load at a sentence boundary as compared to young adults (Payne & Stine-Morrow, 2012). Together these results suggest

---

[1]Although the Event Indexing Model proposes an incremental updating mechanism, it does not state that global updating *cannot* occur. Conversely, Event Segmentation Theory proposes a global updating mechanism, but it does not claim that incremental updating *cannot* occur. However, neither theory includes both incremental and global updating as an integral component.

that the updating process is more resource demanding for older adults. Given that situation model updating may be more difficult for older adults than for young adults, we wanted to evaluate whether these age groups update in fundamentally differ ways.

We predicted that older adults will engage in incremental updating because they tend to keep no-longer-relevant information activated in working memory (Hasher & Zacks, 1988) and bind it with the task-relevant information (Campbell, Hasher, & Thomas, 2010). In fact, this retention of irrelevant information may help older adults identify associations and improve memory in future situations (Campbell et al., 2010; Thomas & Hasher, 2011). Rather than clearing all information from the previous event, older adults may incrementally update only the changed information and maintain activation of the unchanged information.

However, older adults may demonstrate stronger global updating effects than young adults. Previous work has found that older adults are slower to update their situation model than are young adults (Morrow et al., 1994; 1997), and this may be due to global updating. In other words, situation model updating may be slower and more demanding for older adults because they are building a new situation after each major situational change, whereas young adults are not.

Another possibility is that there are no age-related differences in updating mechanisms. That is, it is possible that both young and older readers update their situation models in a global fashion, in an incremental fashion, or they may use both types of updating mechanisms (see Kurby & Zacks, 2012).

To evaluate situation model updating in the current experiment, young and older adults read narrative texts that systematically controlled for changes in characters (i.e., *character shifts*) and changes in spatial locations (i.e., *spatial shifts*). Following a shift, participants were presented with a probe phrase from the previous situation that was related either to the changed or unchanged situational dimension. Probe phrases were also tested following control sentences that contained *no shift*.

Response time and accuracy to the probe phrases were used as outcome measures on the assumption that responses would be relatively fast and accurate if the information was still represented in the situation model, whereas responses would be relatively slower and less accurate if the information was removed from the situation model during updating. In this paradigm, the effects of incremental updating should be seen only for the changed dimension (i.e., information related to Elvira's basement) but the effects of global updating should be seen for both the changed and unchanged information (i.e., information related to Elvira's basement and her hairdo). Thus, global updating should slow responses to memory probes for both the unchanged and changed dimension, whereas incremental updating should slow responses only for the changed dimension. A pure global updating mechanism should produce this pattern in response times: no shift < unchanged dimension = changed dimension. A pure incremental updating mechanism should produce this pattern: no shift = unchanged dimension < changed dimension. If both global and incremental updating occurred, we would expect to see this pattern: no shift < unchanged dimension < changed dimension.

Method

Participants

Forty older adults (25 females; age range = 61 – 79 years; mean age = 68.9 years; *SD* = 5.2; mean years of education = 15.3 years; *SD* = 2.9[2]) were recruited from the St. Louis community using the Volunteers for Health participant pool maintained at the Washington University in St. Louis School of Medicine. Thirty-seven young adults (27 females; age range = 18 – 23 years; mean age = 19.9 years; *SD* = 1.5) were recruited from introductory psychology courses at Washington University St. Louis to complete a course requirement. Older adults were excluded on the basis of a wide range of neurological disorders (e.g., Parkinson's disease, Huntington's disease) and neurological damage (e.g., due to stroke, seizures, or head trauma). Further, these older participants were screened for dementia using the Short Blessed dementia screen (Short Blessed score < 7; Katzman et al., 1983). Each older adult was paid $10 per hour and each young adult received course credit for their participation.

Materials

All participants were given one practice story about two children on a playground and 8 experimental texts about (1) a camping trip, (2) touring a castle, (3) a family getting ready in the morning, (4) visiting a relative in the hospital, (5) Christmas shopping, (6) visiting an aquarium, (7) employees in an office, and (8) a trip to the zoo. The practice story consisted of 23 sentences (264 words) and the 8 experimental texts ranged from 90–118 sentences (1046–1405 words) in length. (The experimental stories used in this experiment can be found online at http://dcl.wustl.edu/DCL/Stimuli.html, and an example is given in Appendix A.)

All of the experimental texts contained 12 trials, each of which was made up of a sentence containing a probe phrase (e.g., "baby-blue eyes", "dimly lit room"), 3 filler sentences, a target sentence, and a recognition probe phrase (for an example, see Figure 1). The sentence containing the probe phrase were near the beginning of a new event (presented in either sentence 1, 2, 3 or 4 of a new event) and included a phrase either related to the characters in the story (e.g., "baby-blue eyes") or to the spatial locations in the story (e.g., "dimly lit room"). The 3 filler sentences contained information relevant to storyline but no major changes along the dimensions represented in situation models such characters, space, goals, objects, and time. The target sentences could contain either a character shift, spatial shift, or no shift. The recognition probe phrases were presented immediately after the target sentences and were either targets (e.g., "dimly lit room") or situationally plausible foils (e.g., "spacious office"). Target and foil probe phrases were matched on syllable length according to the MRC Psycholinguistic Database (Wilson, 1988). All probe phrases were either 3 or 4 syllables in length.

---

[2]We were unable to obtain educational information for our entire older adult sample. The descriptive statistics reported here are for 26 of our older adult participants.

Design and Procedure

Participants were instructed to read the texts for comprehension so that they could summarize each story. The texts presented one sentence at a time, and reading was self-paced. Participants pressed the spacebar to advance to the next sentence. Each story contained 12 target sentences: 4 contained no shifts, 4 contained a character shift, and 4 contained a spatial shift. After they read a shift sentence, participants were presented with a warning signal (#####) in the center of the screen for 500 ms followed by a probe phrase. The practice story contained four probe phrases and the 8 experimental texts each contained 12 probe phrases. Of the 12 probe phrases in the experimental texts, 6 were character probe phrases and 6 were spatial probe phrases. The type of shift sentence (no shift, character shift, or spatial shift) was crossed with the type of probe phrase (character probe or spatial probe) resulting in 6 trial types. Thus, we manipulated whether the recognition probe phrase was presented prior to or after the updating process. That is, some probe phrases were presented within the same event as they were introduced (labeled "Event Middle" in Appendix A), such as after no shift (character or spatial probes after no shift). These trials presumably assess responses prior to situation model updating. Other probe phrases were presented following an event boundary (labeled "Event Boundary" in Appendix A), such as a shift on the probed dimension (character probes after character shifts or spatial probes after spatial shifts), or a shift on the *other* dimension (character probes after spatial shifts or spatial shifts after character probes). This design is illustrated in Appendix A.

Probe phrases remained onscreen until a response was recorded. Participants were instructed to press the "Y" key as quickly as possible if they had read the probe phrase in a recent sentence and to press the "N" as quickly as possible if they had not read the phrase. Response times were recorded and no feedback was provided. Immediately after a button was pressed, the next sentence in the story was presented onscreen. Text order was counterbalanced using reverse counterbalancing, and assignment of probe phrase to the target or foil condition was counterbalanced. Thus, within each of the age groups (young and older) there were four groups that varied on text order (1 vs. 2) and probe phrase assignment (A vs. B), with approximately 10 participants in each group.

Participants were seated at a desktop computer, read the practice text and then provided a short summary of the story. The experimenter answered their questions and then participants read the experimental texts. Following each text, participants wrote a paragraph summarizing the story. After summarizing the final text, all participants completed a demographics questionnaire, and the older adults completed the Short Blessed Test (Katzman et al., 1983) to screen for dementia.

Data Preparation

Three older adults were excluded for failing to meet criteria on the Short Blessed Test dementia screen (scores > 5). For the remaining 37 older adults and 37 young adults, sentence reading times and response times to the probe phrases were z-scored within participants. Z-scores more than 3.5 standard deviations different from the participant's mean were removed from the analyses. For the sentence reading times, 50 values (1.4% of the data) for the young adults and 75 values (2.1% of the data) for the older adults met this

criterion. Mean accuracy and trimmed response time scores were calculated for each participant for each condition. There were no participants with outlying mean accuracy or mean trimmed response time. Both variables were approximately normally distributed (|skewness| < 2.0, |kurtosis| < 2.0).

To control for the large effect of sentence length and any effect of probe phrase length on response time, we fit two linear regressions for each participant (Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). One regression predicted reading time for each sentence from the number of words in the sentence. We examined the raw per-word reading rates to investigate age differences in reading rate, and used the residuals (in standardized units) from these regressions to analyze the effects of situational changes on reading time to the target sentences. The other regression predicted response time for each probe phrase from the number of syllables in the phrase. Residuals from these regressions were used to analyze the probe phrase response times.

Results

Sentence Reading Times

Figure 2 shows raw per-word reading times for young and older adults. Overall, older adults' per-word reading rate on the target sentences ($M = 315$ ms, $SD = 90.16$) was significantly slower than the young adults' reading rate ($M = 172$ ms, $SD = 58.03$), $t(70) = 7.92$, $p < .001$, $d = 1.88$. To evaluate the effects of updating situation models during reading, the mean residual reading times for the target sentences were calculated. These residuals are shown separately for young and older adults in Figure 3. The residuals were subjected to a linear mixed model that included random effects of participants and items as well as fixed effects of age (young vs. older) and Shift Type (no shift vs. character shift vs. spatial shift).

There was a significant fixed effect of Shift Type, $F(2, 93) = 5.60$, $p = .005$. Follow-up pairwise comparisons with Fisher's LSD post hoc test revealed that participants read character shift sentences ($M = 0.171$, $SE = 0.76$) significantly slower than spatial shift sentences ($M = -0.144$, $SE = 0.76$), adjusted $p = .001$ and marginally slower than the no shift sentences ($M = −0.014$, $SE = 0.75$), adjusted $p = .053$. Contrary to our predictions, spatial shift sentences did not differ from no shift sentences, adjusted $p = .174$. The Age x Shift Type interaction was not significant. (The main effect of Age was not tested because the z-scoring eliminated overall age differences by design.) The fixed effect of Shift Type was significant for young adults, $F(2,93) = 5.51$, $p = .005$. Follow-up pairwise comparisons with Fisher's LSD post hoc test indicated that young adults read character shift sentences ($M = 0.18$, $SE = 0.09$) significantly slower than spatial shift sentences ($M = −0.17$, $SE = 0.09$), adjusted $p = .001$, and marginally slower than no shift sentences ($M = −0.01$, $SE = 0.09$), adjusted $p = .072$; however, young adult reading times on spatial shift and no shift sentences did not differ, adjusted $p = .137$. Similarly, older adults demonstrated a fixed effect of Shift Type, $F(2,93) = 4.14$, $p = .019$. Follow-up pairwise comparisons revealed that older adults read character shift sentences ($M = 0.15$, $SE = 0.09$) significantly slower than spatial shift sentences ($M = −0.12$, $SE = 0.09$), adjusted $p = .005$, and marginally slower than no shift sentences ($M = −0.02$, $SE = 0.09$), adjusted $p = .075$. Older adult reading times for spatial shift and no shift sentences did not differ, adjusted $p = .298$. Thus, both young and older

participants demonstrated the same reading time patterns: Both groups slowed down while reading character shift sentences but not while reading spatial shift sentences.

Recognition Probe Responses

To evaluate whether readers updated their situation models incrementally or globally, we compared probe phrase accuracy and response times when the probe phrases followed no shift, when the probe phrase was from the *unchanged dimension* (i.e., character probes following spatial shifts and spatial probes following character shifts), and when the probe phrase was from the *changed dimension* (i.e., character probes following character shifts and spatial probes following spatial shifts). Mean raw response times for young and older adults are presented in Figure 4.

Response time—We used an accuracy threshold of 70% to ensure that only responses from those individuals who were engaged in the task were analyzed. This resulted in excluding 1 young adult and 4 older adults from further analyses. For the remaining participants, the mean residual response times to character and spatial probes are plotted by no shift, unchanged dimension, and changed dimension sentences and by age in Figure 5. To evaluate the effects of age, probe type, and updating condition on probe response times, we conducted a linear mixed model. The model included random effects of participants and items and fixed effects of Age (young vs. older), Updating Condition (no shift vs. unchanged dimension vs. changed condition), and Probe Type (character vs. spatial).

The fixed effect of Updating Condition was significant, $F(2,263) = 3.56$, $p = .030$. The Age x Updating Condition interaction was significant, $F(2,5650) = 3.86$, $p = .021$, such that response times from the older adults but not the young adults showed a global updating pattern. The older adults demonstrated a significant fixed effect of Updating, $F(2,247) = 3.15$, $p = .045$. Follow-up pairwise comparisons with Fisher's LSD post hoc test revealed that older adults' response times to probes following no shift ($M = -0.07$, $SE = 0.04$) were significantly faster than their response times to the unchanged probes following a change ($M = 0.05$, $SE = 0.04$), $p = .041$, and to the changed probes ($M = 0.05$, $SE = 0.04$), $p = .028$. The older adults' response times to the unchanged and changed probes did not differ, $p = .888$. For the young adults, the fixed effect of Updating was not significant, $p = .234$. However, the pairwise comparisons with Fisher's LSD post hoc test approached significance. Young adults' response times to changed probes ($M = 0.06$, $SE = 0.07$) were marginally slower than their response times to probes following no shift ($M = -0.02$, $SE = 0.07$), $p = .074$, and to unchanged probes ($M = -0.02$, $SE = 0.07$), $p = .074$. Young adults' response times to probes following no shift and to unchanged probes did not differ, $p = .978$. The remaining interactions were not significant. (Again, the main effect of Age was not tested because the z-scoring eliminated overall age differences by design.)

As shown in Figure 5, there was a large difference between response times to character and spatial probes following a no shift sentence for young adults. Given that previous work has shown that readers may be less likely to track the spatial dimension than the character dimension (e.g., Therriault et al., 2006; Zwaan, Radvansky, Hilliard, & Curiel, 1998), we

conducted a follow-up mixed modeling analysis only on the character probes for the young adults. However, the fixed effect of Updating was not significant, $F < 1.0$, $p = .549$.

Accuracy—Figure 6 presents mean accuracy for character and spatial probes following no shift, the unchanged dimension, and the changed dimension sentences separately for young and older adults. To evaluate the effects of age, probe type, and updating condition on probe response times, we conducted a logistic mixed model because, for each trial, accuracy was a dichotomous variable (i.e. correct vs. incorrect). Random effects for participants and items were added separately to the model and a likelihood ratio test was performed to assess significance. The random effects of participants and items were significant, $\chi^2(1) = 121.34$, $p < .001$ for participants; $\chi^2(1) = 662.54$, p < .001 for items. The final model retained both the random effects of participants and items as well as the fixed effects of Age (young vs. older), Updating Condition (no shift vs. unchanged dimension vs. changed condition), and Probe Type (character vs. spatial).

The fixed effect of Age was significant, $z = 2.08$, $p = .038$, odds ratio = 0.65, with young adults ($M = 0.82$, $SE = 0.01$) responding more accurately than older adults ($M = 0.79$, $SD = 0.01$). The Age x Probe Type interaction was also significant, $z = 2.11$, $p = .035$, odds ratio = 1.62, such that young adults responded more accurately to character probes ($M = 0.83$, $SE = 0.01$) than spatial probes ($M = 0.81$, $SE = 0.01$), whereas older adults responded more accurately to spatial probe ($M = 0.80$, $SE = 0.01$) than character probes ($M = 0.78$, $SE = 0.01$). However, the fixed effects of Updating Condition, Probe Type, and the remaining interactions were not significant.

Discussion

Young and older adults read narrative texts that systematically manipulated changes in situational dimensions and responded throughout the texts to information from dimensions that changed, dimensions that remained unchanged while a different dimension changed, and no-change controls. The main goals of the current experiment were to evaluate (1) whether readers update their situation models in an incremental or a global fashion, or both, at these dimension changes, and (2) whether young and older adults make differential use of incremental and global updating. Incremental updating involves only updating information relevant to the changing dimension in the situation model, whereas global updating involves updating the entire situation model when a situational dimension changes.

Results from the current experiment provided evidence that older adults depend more on global updating than do young adults (see Figure 5). When older adults read about a change in spatial location—for example, Elvira moving from the basement to the kitchen – they were slower to respond not only to probes related to the basement but also to probes related to Elvira in comparison to control probes. These findings suggest that older adults update their entire situation model – not just the changing information – when they encounter a change. However, young adults did not show the same pattern of updating. Their response times were significantly different from those of older adults: they showed a pattern that was consistent with a mix of global and incremental updating, and statistically quite weak. Only the condition promoting both global and incremental updating (probes of a changed

dimension) approached differing significantly from the condition in which no updating was hypothesized (probes on no change trials).

Young and older adults showed no updating effects in accuracy (see Figure 6). That is, readers' accuracy did not differ significantly across the three updating conditions. The lack of an updating effect in the accuracy data was unexpected; however, even if information has been updated (i.e., cleared from working memory), it presumably can be retrieved from long-term memory – perhaps even activated long-term memory (Cowan, 2001). Thus, even though information is no longer active in working memory, readers may be able to retrieve the information from long-term memory and accurately respond to the recognition probes. However, responses would take longer if retrieval requires a cue-driven search through long-term memory as opposed to output from working memory.

The lack of strong evidence for updating effects in young adults' response times and accuracy rates is inconsistent with the existing literature. One possibility for this discrepancy is methodological differences between previous studies and the current one. The narratives used in the current experiment were tightly controlled such that each target sentence only contained one shift. Previous work has demonstrated cumulative effects of situational shifts such that updating—as measured by event segmentation (e.g., Magliano, Miller, & Zwaan, 2001) and sentence reading times (e.g., Zwaan et al., 1998)—is more likely to occur as the number of changing situational dimensions increases. Perhaps the strict control of changing only one situational dimension at a time may have reduced updating effects. Another methodological difference is that, in the current study, several filler sentences separated the introduction of the probe phrase and the shift sentence. That is, the probe phrase was mentioned towards the beginning of an event followed by several filler sentences that contained no changes and finally the target shift sentence. In contrast, Zwaan (1996), for example, presented probe words in sentences that immediately preceded the time shifts. The stories used in the current study were constructed carefully so as not to create any situational discontinuities (along the time, space, character, goal, and causality dimensions) between the introduction of the probe phrase and the target sentence. However, participants read 3 filler sentences containing new information, which may have caused the probe-related information to be backgrounded and, thus, reduced any updating effects.

Further, the recognition probes in the current experiment were phrases (e.g., "baby blue eyes", "dimly lit room") as opposed to single word probes (e.g., "creek", "beaming") used in earlier work, and our narratives (84–118 sentences) were considerably longer than all of the texts used in previous studies (Curiel & Radvansky, 2014: 41–65 sentences; Rinck & Bower, 2000: 20 sentences; Speer & Zacks, 2005: 28 sentences; Zwaan, 1996: 13 sentences). Although these may be minor discrepancies, any of these methodological differences may have contributed to the weak updating effects in young adults. Older adults showed a larger updating effect than younger adults, which was statistically reliable in the current paradigm.

Interestingly, we found an interaction between age and the type of recognition probe such that older adults were less accurate on the character probes than were the young adults. Further, we found a significant interaction between age and type of shift for character probes

only, $F(1,72) = 4.69$, $p = .034$, $\eta^2 = .05$, which indicates that older adults were less accurate when responding to character probes following a change in characters compared to when the character information remained unchanged, whereas young adults showed no difference in accuracy. This finding is consistent with those reported by Noh and Stine-Morrow (2009) who hypothesized that older adults have difficulty tracking multiple characters due to reduced working memory capacity. They found that older adults were able to track characters while they were the focus of the story, but had difficulty when a new character was introduced.

Another measure of situation model updating is the time spent reading the shift sentences. The narratives used in the current experiment were carefully written so as to introduce a shift along one situational dimension while controlling shifts along other dimensions. We expected that shifts in the spatial and character target sentences were important enough to the narrative to cause situation model updating. To evaluate updating, reading time for sentences that contained shifts was compared to reading time for those that did not contain shifts with the assumption that slower reading times indicate readers perceived the change and updated accordingly. Surprisingly, we found that readers did not significantly slow down at sentences containing character or spatial shifts as compared to no shifts. In fact, young and older adults read sentences containing a spatial shift numerically faster than they read sentences containing no shift and significantly faster than they read sentences with character shifts. These reading times may indicate that readers did not perceive spatial changes or did not perceive them as important enough to constitute updating. Some research has shown that readers do not track spatial location in a narrative as closely as they track other dimensions such as characters and goals (e.g., Zwaan, Radvansky, Hilliard, & Curiel, 1998; but see Zwaan & Radvansky, 1998 for a review). However, the probe response time data suggest that readers updated situation models at spatial shifts: Probe responses were at least as slow following spatial changes and following character changes, and older adults were slower for both types of change than for no-change probe responses. Thus, the probe response time data indicate that situation models are updated at spatial shifts, but this is not reflected in reading times. Further, Bailey, Kurby, Sargent, and Zacks (under review) asked young adults to read these narratives and identify the points at which one event ended and another began (i.e., identify event boundaries). Readers were significantly more likely to identify sentences containing a character or spatial shift as event boundaries than sentences containing no shift.

Situation Model Updating & Aging

These results indicate that young and older adults make differential use of incremental and global updating during narrative comprehension. In fact, young adults' responses showed little effect of situation model updating on recognition probe response time The young adults' reading time data did show indirect evidence of updating such that they slowed down when they encountered a sentence containing a character shift; however similar to the older adults, they did not slow down when reading a spatial shift sentence. Perhaps the young readers did not perceive the shifts as changes important enough to require situation model updating. However, previous work has demonstrated that readers believe the shift sentences in these narratives contain important changes (Bailey et al., under review), and as

Radvansky and Copeland (2010) discuss, situation model updating can occur even in the absence of increased sentence reading times. Thus, it seems unlikely that the young adults in the current experiment did not perceive the shift sentences as important changes.

The memory probe results provide evidence that older adults updated their situation models in a global fashion. This provides support for comprehension theories such as Event Segmentation Theory and the Structure Building framework. Other work has provided evidence of incremental updating (e.g., Kurby & Zacks, 2012) and the current results do not rule out the occurrence of this updating mechanism, but they do entail that theories that only specify an incremental updating mechanism (for example, the Event Indexing Model) need to be modified to include a global updating mechanism.

We predicted that older adults would rely more upon incremental mechanisms than would young adults given previous work evaluating reading time at the sentence level (Stine et al., 1995) and given older adults' reduced inhibitory process (e.g., Hasher & Zacks, 1988). However, we found the opposite pattern: Older adults showed more evidence of global updating mechanisms than did young adults. Older adults' use of global updating may explain why previous work has found that older adults are slower to update their situation model than are young adults (Morrow et al., 1994; 1997): Situation model updating may be slower and more demanding for older adults because they are building a new situation after each major situational change, whereas young adults are not. Thus, one possibility is that older adults may use global updating as a strategy to compensate for reduced working memory abilities. With diminished working memory processing abilities and capacity, older adults may update their situation models in a global manner to remove no-longer relevant information and prepare for upcoming events. Another possibility is that, with increased experience in text processing and comprehension, older adults are more successful than are young adults at removing no-longer relevant information from their situation models. Although the current study cannot distinguish between these two possibilities, the evidence demonstrates that older adults create a new situation model following important situational changes that occur while reading narrative texts.

Acknowledgements

References

Albrecht JE, O'Brien EJ. Updating a mental model: Maintaining both local and global coherence. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1993; 19:1061–1070.

Bailey HR, Kurby CA, Sargent JQ, Zacks JM. (under review). Attentional focus affects how events are segmented and updated in narrative text.

Bower GH, Rinck M. Selecting one among many referents in spatial situation models. Journal of Experimental Psychology: Learning, Memory, & Cognition. 2001; 27:81–98.

Campbell KL, Hasher L, Thomas RC. Hyper-binding: A unique age effect. Psychological Science. 2010; 21:399–405. [PubMed: 20424077]

Cowan N. The magical number 4 in short-term memory: A reconsideration of mental storage capacity. Behavioral and Brain Sciences. 2001; 24:87–185. [PubMed: 11515286]

Curiel JM, Radvansky GA. Spatial and character situation model updating. Journal of Cognitive Psychology. 2014; 26:205–212.

Ditman T, Holcomb PJ, Kuperberg GR. Time travel through language: Temporal shifts rapidly decrease information accessibility during reading. Psychonomic Bulletin & Review. 2008; 15:750–756. [PubMed: 18792500]

Ferreira F, Clifton C Jr. The independence of syntactic processing. Journal of Memory and Language. 1986; 25:348–368.

Gernsbacher. Language comprehension as structure building. Hillsdale, NJ: Lawrence Erlbaum Associates; 1990.

Glenberg AM, Meyer M, Lindem K. Mental models contribute to foregrounding during text comprehension. Journal of Memory and Language. 1987; 26:69–83.

Hasher, L.; Zacks, RT. Working memory, comprehension, and aging: A review and a new view. In: Bower, GH., editor. The Psychology of Learning and Motivation. Vol. 22. New York, NY: Academic Press; 1988. p. 193-225.

Katzman R, Brown T, Fuld P, Peck A, Schechter R, Schimmel H. Validation of a short orientation-memory concentration test of cognitive impairment. American Journal of Psychiatry. 1983; 140:734–739. [PubMed: 6846631]

Kurby CA, Zacks JM. Starting from scratch and building brick by brick in comprehension. Memory and Cognition. 2012; 40:812–826. [PubMed: 22282158]

Magliano JP, Miller J, Zwaan RA. Indexing space and time in film understanding. Applied Cognitive Psychology. 2001; 15:533–545.

Morrow DG, Leirer VO, Altieri PA, Fitzsimmons C. Age differences in creating spatial mental models from narratives. Language and Cognitive Processes. 1994; 9:203–220.

Morrow DG, Stine-Morrow EAL, Leirer VO, Andrassy JM, Kahn J. The role of reader age and focus of attention in creating situation models from narratives. Journal of Gerontology: Psychological Sciences. 1997; 52B:73–80.

Noh SR, Stine-Morrow EAL. Age differences in tracking characters during narrative comprehension. Memory & Cognition. 2009; 37:769–778. [PubMed: 19679857]

Payne BR, Stine-Morrow EAL. Aging, parafoveal preview, and semantic integration in sentence processing: Testing the cognitive workload of wrap-up. Psychology and Aging. 2012; 27:638–649. [PubMed: 22229390]

Radvansky GA. Aging, memory, and comprehension. Current Directions in Psychological Science. 1999; 8:49–53.

Radvansky GA, Copeland DE. Walking through doorways causes forgetting: Situation models and experienced space. Memory & Cognition. 2006; 34:1150–1156. [PubMed: 17128613]

Radvansky GA, Copeland DE. Reading times and the detection of event shift processing. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2010; 36:210–216.

Radvansky GA, Dijkstra K. Aging and situation model processing. Psychonomic Bulletin & Review. 2007; 14:1027–1042. [PubMed: 18229472]

Radvansky GA, Zwaan RA, Curiel JM, Copeland DE. Situation models and aging. Psychology and Aging. 2001; 16:145–160. [PubMed: 11302363]

Rapp DN, Gerrig RJ, Prentice DA. Readers' trait-based models of characters in narrative comprehension. Journal of Memory & Language. 2001; 45:737–750.

Rinck M, Bower GH. Temporal and spatial distance in situation models. Memory & Cognition. 2000; 28:1310–1320. [PubMed: 11219959]

Rinck M, Weber U. Who when where: An experimental test of the event-indexing model. Memory and Cognition. 2003; 31:1284–1292. [PubMed: 15058689]

Salthouse TA. Mediation of adult age differences in cognition by reductions in working memory and speed of processing. Psychological Science. 1991; 2:179–183.

Salthouse TA. The aging of working memory. Neuropsychology. 1994; 8:535–543.

Speer NK, Zacks JM. Temporal changes as event boundaries: Processing and memory consequences of narrative time shifts. Journal of Memory and Language. 2005; 53:125–140.

Stine-Morrow EAL, Gagne DD, Morrow DG, DeWall BH. Age differences in rereading. Memory & Cognition. 2004; 32:696–710. [PubMed: 15552347]

Stine-Morrow EAL, Morrow DG, Leno R III. Aging and the representation of spatial situations in narrative understanding. Journal of Gerontology: Psychological Sciences. 2002; 57B:P291–P297.

Therriault DJ, Rinck M, Zwaan RA. Assessing the influence of dimensional focus during situation model construction. Memory & Cognition. 2006; 34:78–89. [PubMed: 16686108]

Thomas RC, Hasher L. Reflections of distraction in memory: Transfer of previous distraction improves recall in younger and older adults. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2012; 38:30–39.

Trueswell JC, Tanenhaus MK, Garnsey SM. Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. Journal of Memory and Language. 1994; 33:285–318.

Wilson M. MRC Psycholinguistic Database: Machineusable dictionary, version 2.00. Behavior Research Methods, Instruments, and Computers. 1988; 20:6–10.

Zacks JM, Speer NK, Swallow KM, Braver TS, Reynolds JR. Event perception: A mind/brain perspective. Psychological Bulletin. 2007; 133:273–293. [PubMed: 17338600]

Zacks JM, Tversky B. Event structure in perception and conception. Psychological Bulletin. 2001; 127:3–21. [PubMed: 11271755]

Zacks, JM.; Hasher, L.; Li, KZH. Salthouse, TA.; Craik, FIM. The handbook of aging and cognition. 2nd ed. Mahwah, NJ: Erlbaum; 2000. Human memory; p. 293-357.

Zwaan RA. Processing narrative time shifts. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1996; 22:1196–1207.

Zwaan RA, Langston MC, Graesser AC. The construction of situation models in narrative comprehension: An event-indexing model. Psychological Science. 1995; 6:292–297.

Zwaan RA, Radvansky GA. Situation models in language comprehension and memory. Psychological Bulletin. 1998; 123:162–185. [PubMed: 9522683]

Zwaan RA, Radvansky GA, Hilliard AE, Curiel JM. Constructing multidimensional situation models during reading. Scientific Studies of Reading. 1998; 2:199–220.

Appendix A

Example of a narrative text

SET UP SENTENCES	Jim and Kathy were preparing to take their kids on their first camping trip, and they were a little nervous.
	They had waited longer than their friends to have children.
	Most of the time they were very happy with this decision; they relished the thought of being retired by the kids' late adolescence and having the time to take long trips with them.
	They felt they were wiser, more patient parents than they would have been twenty years ago.
	Both had been workaholics in their joint law practice, and it had paid off in a level of financial security.
	They could afford to slow down, to take time to really enjoy the kids.
	But they felt a distance from the other parents, and they were at times self-conscious about being perhaps a little less active.
	Camping was important.
SENTENCE WITH PROBE PHRASE	Jim picked up his keys from the basket by the front door and paused.
FILLER SENTENCE 1	The basket was supposed to be a place for just keys, but his were always buried under everything else in there.

FILLER SENTENCE 2	Jim hated how it became a place to keep junk.	
FILLER SENTENCE 3	From now on he would keep it clean, he vowed.	
SPATIAL SHIFT	He found his keys and walked into the garage.	**EVENT BOUNDARY**
SPATIAL PROBE	BY THE FRONT DOOR (**TARGET**); BY THE BIG TREE (**FOIL**)	
FILLER SENTENCE A	"I don't like the look of those clouds," Jim thought.	
FILLER SENTENCE B	He remembered that the forecast said it would be in the upper seventies and sunny the rest of the weekend, so he felt the weather would improve.	
SENTENCE WITH PROBE PHRASE	As soon as he entered the garage Jim spotted the tent he had stored in the rafters.	
FILLER SENTENCE 1	He loved getting out into nature and was excited about getting everything ready for the trip.	
FILLER SENTENCE 2	He knew he wasn't very organized about this, but he figured he would find everything if he just looked around.	
FILLER SENTENCE 3	Unfortunately he already had a nagging feeling that he'd probably forget something.	
NO SHIFT	He looked around for other things one would need for a camping trip.	**EVENT MIDDLE**
SPATIAL PROBE	IN THE RAFTERS (**TARGET**); ABOVE THE SHELF (**FOIL**)	
FILLER SENTENCE A	"Ah ha! There it is," he exclaimed.	
SENTENCE WITH PROBE PHRASE	On the top shelf in the corner, Jim saw the box that his wife had conveniently labeled "Camping Gear".	
FILLER SENTENCE 1	As he pulled it down, the sleeping bags that had been piled on top fell down around him.	
FILLER SENTENCE 2	"At least I won't forget those," he muttered as the last one bounced off his shoulder.	
FILLER SENTENCE 3	Opening the tote, he found matches, fire starter, flashlights, camping dishes, and some random pieces of rope.	
CHARACTER SHIFT	Walking into the garage, Kathy laughed at the pile of stuff surrounding her husband.	**EVENT BOUNDARY**
SPATIAL PROBE	IN THE CORNER (**TARGET**); IN THE DOORWAY (**FOIL**)	
FILLER SENTENCE A	He was sitting on the floor, digging through the tote.	
FILLER SENTENCE B	"Jackpot," he thought to himself.	
FILLER SENTENCE C	Kathy looked up at the rafters.	
SENTENCE WITH PROBE PHRASE	Pulling back her short black hair, she asked, "Need some help?"	
FILLER SENTENCE 1	Taking a step stool, she pulled the tent down from the rafters and handed it to her husband to load into the car.	
FILLER SENTENCE 2	Putting the stool back, she walked over to the shelves in the corner.	
FILLER SENTENCE 3	She pulled out the other box of camping gear that she herself had packed and labeled.	
NO SHIFT	Inside the box, on top of everything else, was a packing list for camping trips that she had made.	**EVENT MIDDLE**
CHARACTER PROBE	SHORT BLACK HAIR (**TARGET**); OUTSTRETCHED ARMS (**FOIL**)	
FILLER SENTENCE A	The list was neatly arranged by category.	
SENTENCE WITH PROBE PHRASE	Kathy was glad she was so much more organized than her husband.	

FILLER SENTENCE 1	She pulled out the list and passed the box to her husband to put in the car.	
FILLER SENTENCE 2	She quickly scanned the list and, satisfied, put it into her pocket.	
FILLER SENTENCE 3	"That's everything from out here—I'll go get the kids," Kathy said.	
CHARACTER SHIFT	Jim leaned against his workbench to wait.	**EVENT BOUNDARY**
CHARACTER PROBE	ORGANIZED (**TARGET**); EFFICIENT (**FOIL**)	
FILLER SENTENCE A	Kathy thought the boys were probably downstairs playing.	
FILLER SENTENCE B	Jim heard her call to them as the screen door closed behind her.	
SENTENCE WITH PROBE PHRASE	Jim scratched his graying beard as he waited.	
FILLER SENTENCE 1	He was excited about taking the kids on this trip.	
FILLER SENTENCE 2	They were going to the same place he had gone camping as a kid.	
FILLER SENTENCE 3	It was halfway up the mountain that their town was named for.	
NO SHIFT	The drive would take them about two hours today because it was Memorial Day weekend and Jim knew traffic would be bad.	**EVENT MIDDLE**
CHARACTER PROBE	GRAYING BEARD (**TARGET**); SHORT MUSTACHE (**FOIL**)	
FILLER SENTENCE A	He wondered what time it was.	
SENTENCE WITH PROBE PHRASE	Jim drummed his fingers on the workbench as he began to become impatient.	
FILLER SENTENCE 1	They still had to stop for gas, groceries, and breakfast at McDonald's before they could even leave town!	
FILLER SENTENCE 2	He was glad when his family came out, and he began loading their camping supplies into the car.	
FILLER SENTENCE 3	"Let's go!" he said	
SPATIAL SHIFT	They pulled out of the driveway and, five minutes later, pulled up to a gas pump.	**EVENT BOUNDARY**
SPATIAL PROBE	ON THE WORKBENCH (**TARGET**); ON THE BOOKSHELF (**FOIL**)	
FILLER SENTENCE A	Jim ran his credit card at the pump and took the nozzle to start filling the car.	
FILLER SENTENCE B	As the gas pumped, Jim watched the numbers whizzing higher.	
FILLER SENTENCE C	He was a little worried about sleeping on the ground tonight.	
SENTENCE WITH PROBE PHRASE	He had been standing for five minutes and already his achy back was bothering him.	
FILLER SENTENCE 1	He mentally added aspirin to the grocery list.	
FILLER SENTENCE 2	The list was getting longer, and he hoped it wouldn't take too long at the store.	
FILLER SENTENCE 3	Fortunately, the gas had just finished pumping.	
SPATIAL SHIFT	Jim took his receipt and they drove to the grocery store.	**EVENT BOUNDARY**
CHARACTER PROBE	ACHY BACK (**TARGET**); STIFF ANKLES (**FOIL**)	
FILLER SENTENCE A	Jim grabbed a cart as he and Kathy walked into the store.	
FILLER SENTENCE B	He followed behind with it as they walked through the store.	
SENTENCE WITH PROBE PHRASE	He paused to clean his bifocals.	

FILLER SENTENCE 1	He was embarrassed that his eyesight was so bad already.	
FILLER SENTENCE 2	Looking at the groceries on the shelf, he sometimes had to squint to read the brand names.	
FILLER SENTENCE 3	"I hope the kids don't inherit my terrible eyesight," he thought as he grabbed the aspirin for his back.	
CHARACTER SHIFT	Kathy expertly led the way through the store, taking the things they needed from the shelves.	**EVENT BOUNDARY**
CHARACTER PROBE	BIFOCALS (**TARGET**); OLD GLASSES (**FOIL**)	
FILLER SENTENCE A	She had her list organized by type of food and section of the store.	
SENTENCE WITH PROBE PHRASE	It helped that it was summer and all the standard camping food was at the front of the store.	
FILLER SENTENCE 1	Kathy was very proud of what an efficient shopper she was.	
FILLER SENTENCE 2	In addition to the hot dogs and hamburgers, Kathy picked up a bunch of snacks.	
FILLER SENTENCE 3	She chose granola bars and trail mix, because she tried hard to keep her family healthy.	
CHARACTER SHIFT	Jim didn't like that there wasn't any candy going into the cart.	**EVENT BOUNDARY**
SPATIAL PROBE	AT THE FRONT (**TARGET**); ON THE GROUND (**FOIL**)	
FILLER SENTENCE A	Jim appreciated Kathy's attempts to make them eat well, but he was on vacation now and really just wanted some sugar.	
FILLER SENTENCE B	He knew the kids would agree.	
FILLER SENTENCE C	He liked to spoil them.	
SENTENCE WITH PROBE PHRASE	They passed the candy aisle, and Jim took advantage of the opportunity.	
FILLER SENTENCE 1	He grabbed a giant bag of M&Ms, plus a few other treats.	
FILLER SENTENCE 2	He buried them in the cart beneath Kathy's bag of carrots.	
FILLER SENTENCE 3	"We're getting stuff for s'mores, right?" he asked.	
NO SHIFT	Jim knew you couldn't have a camping trip without s'mores.	**EVENT MIDDLE**
SPATIAL PROBE	CANDY AISLE (**TARGET**); CHECKOUT LINE (**FOIL**)	
FILLER SENTENCE A	"I guess we can," Kathy conceded.	
FILLER SENTENCE B	Jim grinned and threw the ingredients into the cart: marshmallows, chocolate bars, and graham crackers.	
SENTENCE WITH PROBE PHRASE	He considered himself a devoted father, and was determined to give his kids the full childhood camping experience.	
FILLER SENTENCE 1	He checked the cart; it seemed that they had everything they needed.	
FILLER SENTENCE 2	"Let's check out and get out of here," Jim said.	
FILLER SENTENCE 3	He paid for the groceries in the self-checkout to save time.	
SPATIAL SHIFT	He grabbed the bags, took them out and loaded them in the car, and they drove away.	**EVENT BOUNDARY**
CHARACTER PROBE	DEVOTED (**TARGET**); CHILDISH GRIN (**FOIL**)	
CONCLUDING SENTENCES	The drive up the mountainside towards the campgrounds was beautiful.	
	The kids really seemed to enjoy the idea of camping on the mountain.	
	They pulled up to their camp spot and began to unpack.	
	Jim told the boys that if they helped him put the tent up that he would take them to check out the nearby stream.	

The tent went up easier than Jim and Kathy thought it would.

"Just in time," they thought, because they were getting hungry again.

Kathy set up the grill and started getting some burgers ready.

She told Jim to take the kids to the stream and that the food would probably ready in half an hour or so.

As she watched them walk off, she happily thought to herself that this was going to be a rewarding trip.

She began cooking and soaked in every second of being outside and on vacation.

SENTENCE WITH PROBE PHRASE	Linda's **baby-blue eyes** widened when she saw how expensive the tickets were.
FILLER 1	She hadn't been to the aquarium in years and was surprised at how the prices had gone up.
FILLER 2	She was a single mom, so money could have been tight.
FILLER 3	She was glad she had such a great job.
CHARACTER SHIFT	Linda paid for the tickets, and they walked down the hall and turned left into the jellyfish room.
CHARACTER PROBE	BABY-BLUE EYES (**TARGET**); STIFFENING NECK (FOIL)
…	
SENTENCE WITH PROBE PHRASE	Linda looked around at the tanks of all sizes lining the walls in the **dimly lit room**.
FILLER 1	Some tanks were lit from beneath by colored lights.
FILLER 2	Linda liked how this made the jellyfish glow eerily.
FILLER 3	Linda gazed through the glass of the largest tank.
CHARACTER SHIFT	Jimmy came up to the tank and tapped the glass.
SPATIAL PROBE	DIMLY LIT ROOM (**TARGET**); SPACIOUS OFFICE (**FOIL**)

Figure 1.
Excerpt from a narrative describing a trip to an aquarium. Each event consisted of a sentence containing a probe phrase, three filler sentences, and then a change or no-change sentence. After the sentence, participants were given a probe phrase and indicated whether or not they had read the phrase in a recent sentence.
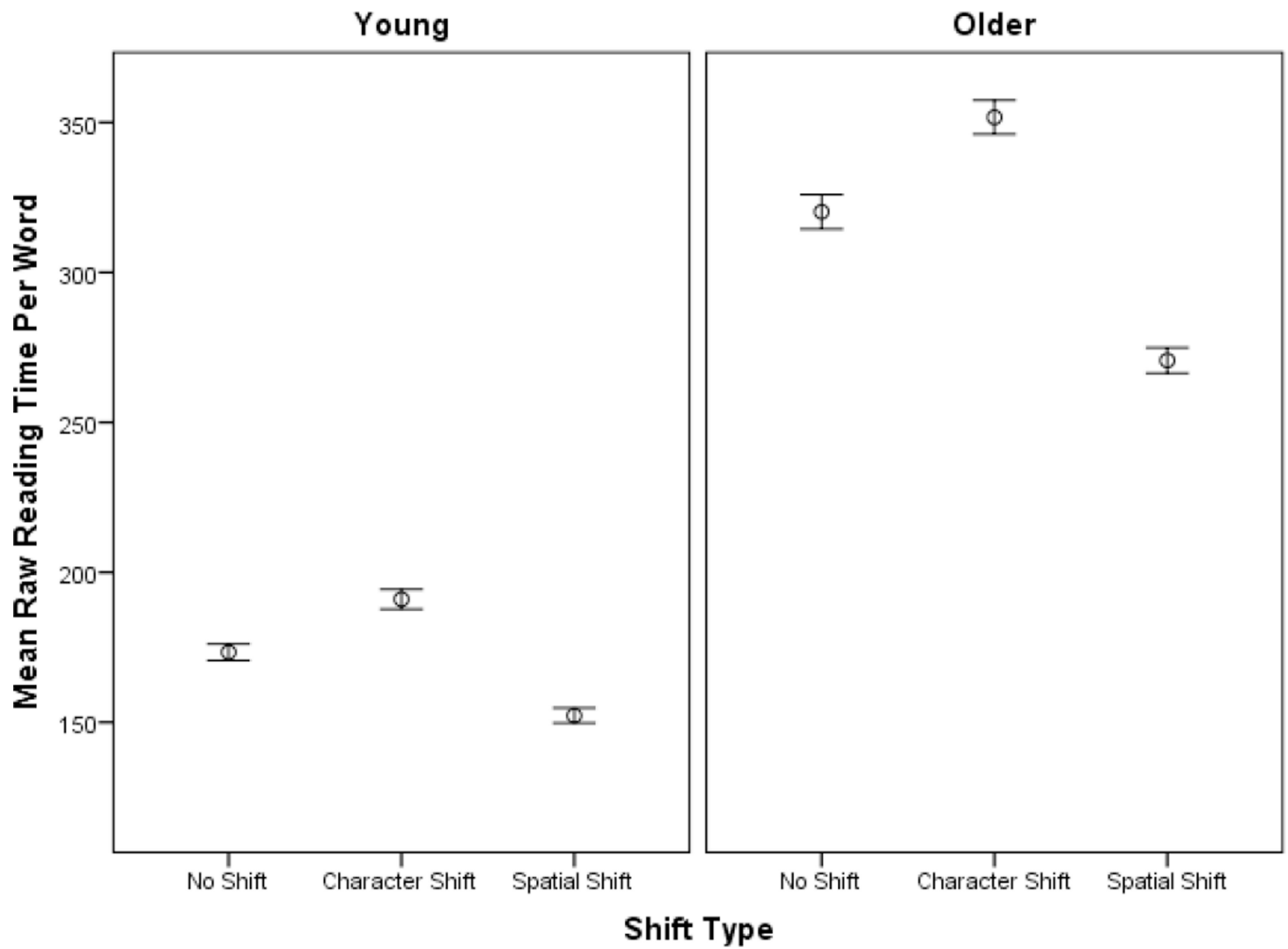
Figure 2.
Mean raw sentence reading time per word for the no shift, character shift, and spatial shift
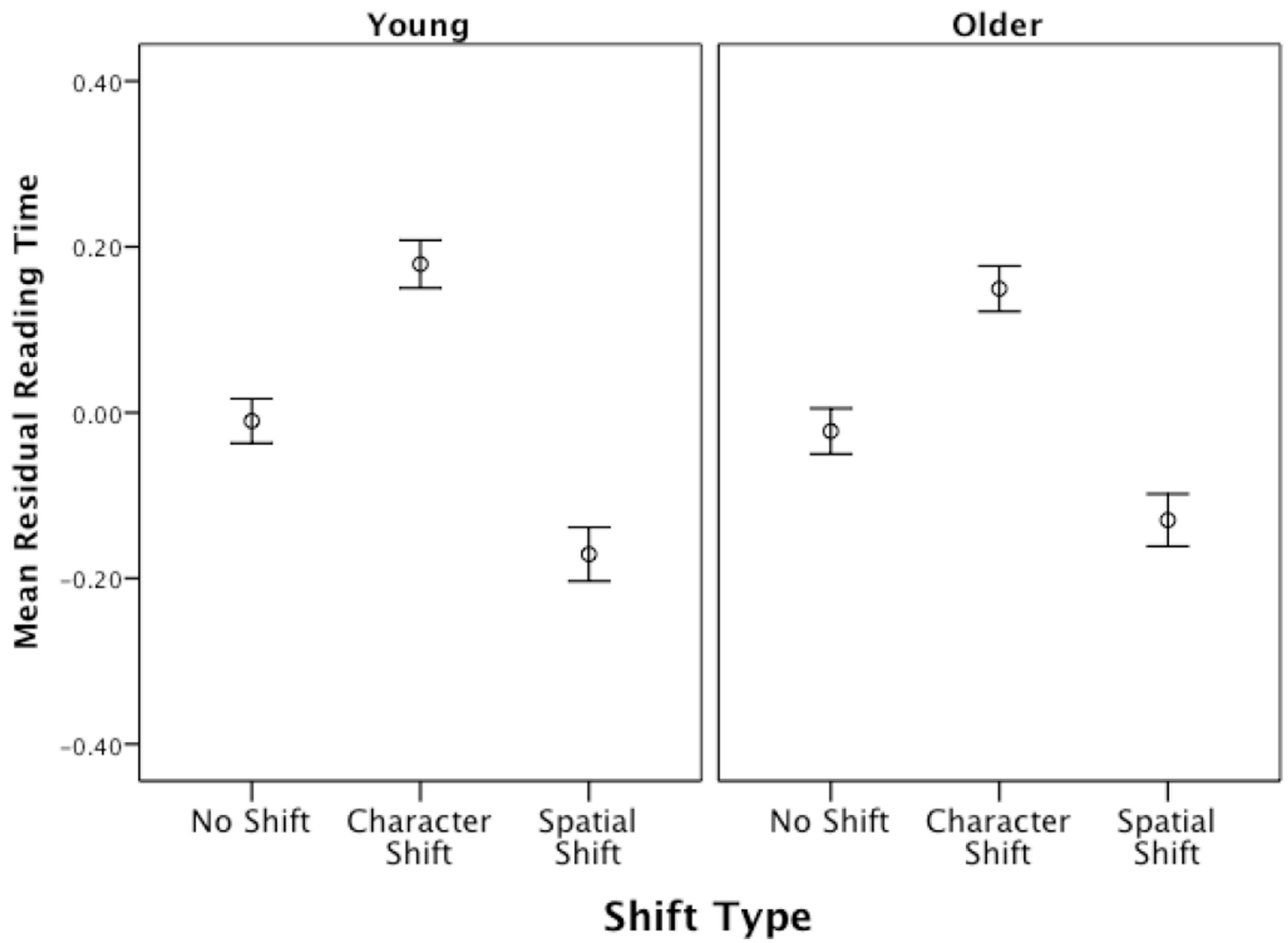sentences for young and older adults. Error bars are standard errors of the mean.

Figure 3.
Mean residual z-scored sentence reading time for the no shift, character shift, and spatial shift sentences for young and older adults. Error bars are standard errors of the mean.
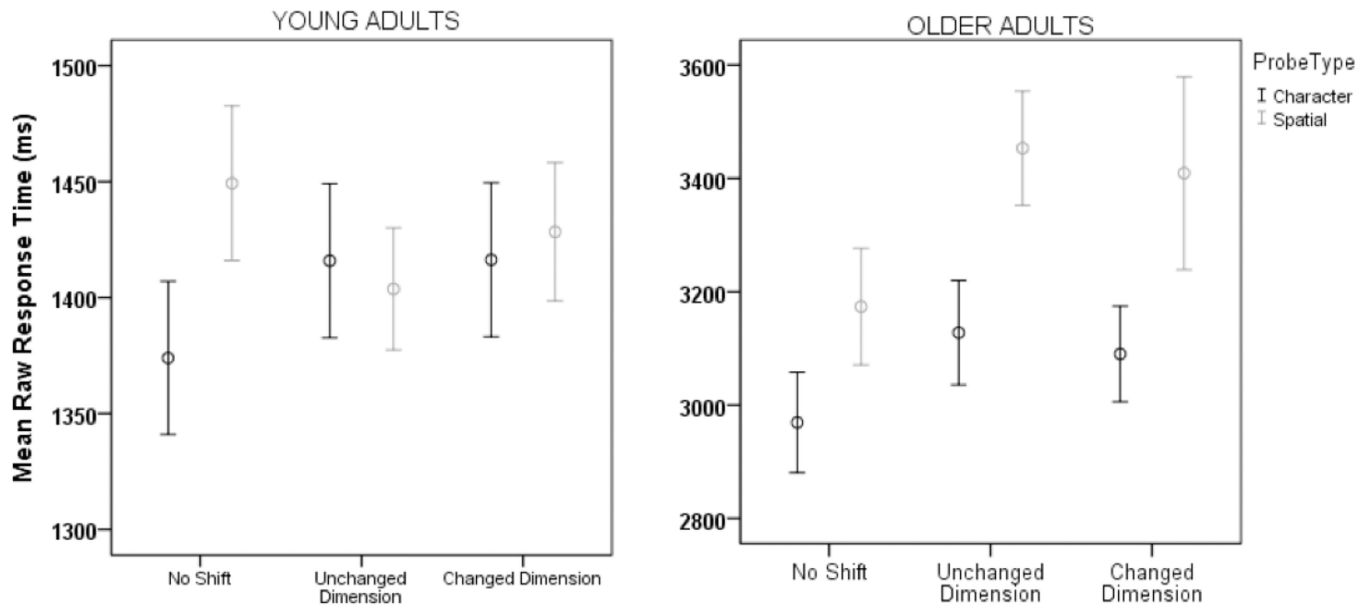
Figure 4.
Mean raw response time to the probe phrases presented after no shift, probe phrases related to unchanged information, and probe phrases related to the changed information for young and older adults. Note that young and older adults mean response times are on different scales. Error bars are standard errors of the mean.
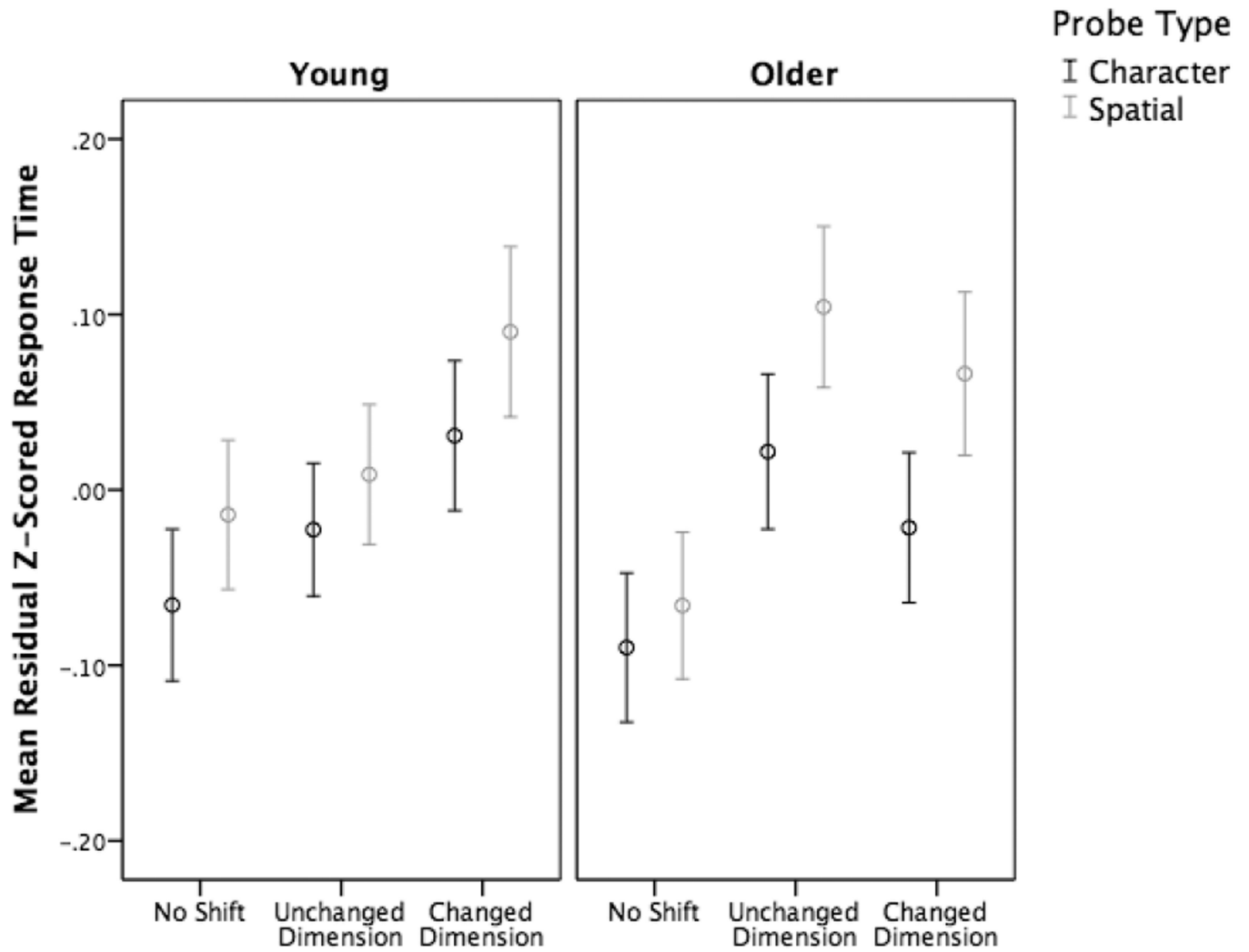
Figure 5.
Mean residual z-scored response time to the probe phrases presented after no shift, probe phrases related to unchanged information, and probe phrases related to the changed information for young and older adults. Error bars are standard errors of the mean.
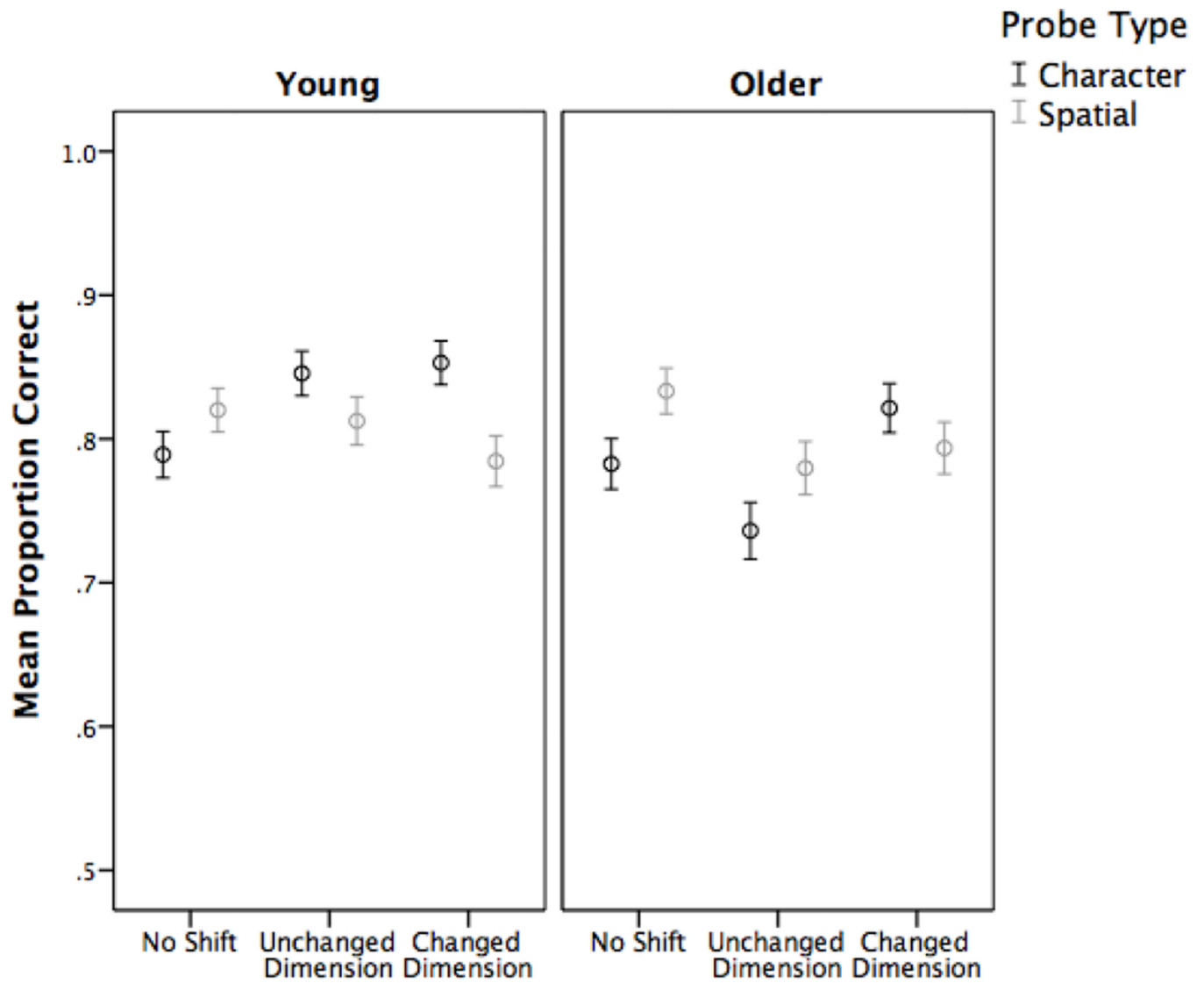
Figure 6.
Mean accuracy to the probe phrases presented after no shift, probe phrases related to unchanged information, and probe phrases related to the changed information for young and older adults. Error bars are standard errors of the mean.