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Spatial and character situation model updating

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During text comprehension, people create situation models to understand the described events. When a change in the situation happens, model updating can occur along multiple dimensions. Prior studies have looked at the separate effects of dimensional shifts finding an increase in processing time when a shift occurs. This reading time study used spatial and character shifts to assess the impact of updating on each other. Specifically, does a prior spatial shift affect character updating and vice versa? This follows recent work exploring the distinction between incremental and global updating. An experiment that manipulated spatial and character shifts as well as their order found influences of both shift types on comprehension, but they did not influence one another. A second experiment revealed that extensive prior knowledge of the spatial environment did not impact the pattern of results. Overall, these results are consistent with the idea that during the comprehension of continuous text event shifts are largely processed separately in a way consistent with incremental updating and may have combined effects.

***Keywords**:* Event cognition; Language comprehension; Situation models; Updating.

Successful narrative comprehension requires coordinating different types of event information to construct a situation model that accurately represents the described events (Zwaan & Radvansky, 1998). Although a number of studies have looked at the processing of individual event dimensions (e.g., Zwaan, Radvansky, Hilliard, & Curiel, 1998), fewer have looked at the influence of different components on one another. Here, we report a study that considers how the processing of one event component can influence the processing of another. We focus on the spatial and character dimensions because, although both are essential elements of an event, their organisational roles in structuring a situation model differ: spatial shifts signal changes in the story's setting whereas character shifts signal changes in the story's agents. We used these shift types to understand how a prior shift along one dimension can influence the effectiveness of updating information along the other.

We used the well-known finding that, as people read, when there is a shift to either a new location or to a new character, there is an increase in reading time which reflects situation model *updating* (e.g., Radvansky & Copeland, 2010; Rinck & Bower, 1995; Zwaan et al., 1998). These increased reading times reflect active situation model processing because they involve changes to the structure of the described events which can in turn influence comprehension and memory (Zwaan & Radvansky, 1998).

Of the two, spatial shifts have been more extensively studied. A number of studies have addressed spatial shifts. In a classic study by Glenberg, Meyer, and Lindem (1987; see also Radvansky & Copeland, 2001), people read stories

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in which a protagonist and an object were either spatially associated or dissociated. Response times to the object names, and reading times of a sentence that contained an anaphoric reference to the object showed increased processing difficulty when the object was spatially dissociated than associated, indicating that readers update spatial information during comprehension.

Morrow, Greenspan, and Bower (1987) and Rinck and Bower (1995), as well as others (Curiel & Radvansky, 2002; Zwaan et al., 1998), further studied spatial shift effects with more complex texts. In these studies, people memorised a map of an environment, such as a research centre, that contained information about rooms and objects in them. Later, people read stories that described a protagonist's movements through the environment. Reading was periodically interrupted with probes about the objects. Response times increased as the distance between the object and the protagonist's current location increased. Rinck and Bower (1995) found a similar effect using reading times for anaphoric sentences. It should be noted that although some research suggest that spatial updating may be difficult to detect (e.g., Zwaan, Magliano, & Graesser, 1995), this may be because people process spatial shifts very well, and the disruption may be slight, although a shift and updating has occurred (Radvansky & Copeland, 2010).

Thus, spatial shifts influence the accessibility of information in memory generally, not just during text processing. For example, when people walk through a doorway, thereby changing locations, memory for objects in the old location becomes less available (Radvansky & Copeland, 2006; Radvansky, Krawietz, & Tamplin, 2011; Radvansky, Tamplin, & Krawietz, 2010). Also, following the Event Segmentation Theory (Swallow, Zacks, & Abrams, 2009; Zacks, Speer, & Reynolds, 2009), when people parse events in text or film, the information that was present prior to an event boundary, such as a shift in location, is less available than the information that crossed such a boundary. In reading, as a story character moves from one location to another, the situation model is updated to include the new spatial framework, and entities that were relevant to the old location, but irrelevant in the new, are removed (Radvansky & Copeland, 2010).

Research on the influence of character shifts has been less studied and has been typically measured using multiple regression analyses of reading times (see Lorch & Myers, 1990) from the perspective of Zwaan's Event Indexing Model (Zwaan & Radvansky, 1998). In general, character shifts result in increased reading times (Zwaan et al., 1995, 1998) as readers update their situation models. The parsing of ongoing narrative activity at places where new characters are introduced is also evident from the event segmentation data (Magliano, Kopp, McNerney, Radvansky, & Zacks, 2012). People who are asked to segment narratives into separate events use the introduction of new characters as one of the bases for doing so.

In sum, where there is a spatial or character shift in the described events, comprehension is disrupted as people update their situation models. However, there are important differences between spatial and character shifts. Conceptually, a spatial shift is a change in the spatial–temporal framework of an event (Wyer & Radvansky, 1999), altering the event setting. In comparison, for character shifts, readers often track a course of events across time by orienting the described situations around a central character (Radvansky, Spieler, & Zacks, 1993), such as when people organise their understanding of a story around a central character. Information about the sequence of events, the causal structure of a story and the goals that drive actions and reactions are understood with reference to that character. As a result, a character shift also brings about major changes in the described situation of a different quality than a location shift.

It is unclear how a shift along one of these dimensions affects the other as they seem to involve different qualities of the described events. Specifically, spatial information refers to the spatial–temporal framework that encapsulates an event, whereas characters would be represented in some way by tokens within the context of a spatial–temporal framework. For shifts that co-occur, the shift that comes first may influence the subsequent shift due to the nature of the primary shift. This may result in updating that is reflected in longer reading times. The aim of the current study was to assess the influence of spatial shifts on character processing and vice versa.

A study by Rinck and Weber (2003) found that the spatial and character shifts interacted. In their study, they experimentally manipulated whether a location, time or character shift occurred in a text, just as we do in the current study, although they did not control the order in which the shifts occurred. The influence of dimension shifts was evaluated in terms of their impact on reading time. What they found was that there was a combined influence of shifts along various dimensions, and

the influence of spatial shifts was weaker than that of the temporal and character shifts. However, it is unclear whether this effect is bidirectional, or if one dimension is influencing the processing of another, but not the reverse.

The relative influence of various event dimensions on situation model updating is also important for Kurby and Zacks' (2012) distinction between incremental and global updating. Incremental updating is when a given situation model is retained but altered to accommodate new information. This is incremental updating because the same situation model is involved, but it has been altered in the light of new information. In comparison, global updating is when a given situation model is entirely removed from processing and is replaced by a different one. Such a new model may share characteristics with the prior one, such as a common time frame, but is best thought of as a separate mental representation. This is global updating because a different situation model is involved, even if it is similar or related to a prior model. Using think-aloud data, Kurby and Zacks suggested that comprehenders engage in both types of updating. One of the predictions that comes out of this distinction is that, for incremental updating, when a text signals updating along the one dimension, then there will be little or no influence on the processing of other dimensions because only the one dimension is updated. In comparison, for global updating, when a text signals updating along one dimension, then this will influence processing along the other dimension because the entire situation model is being replaced.

PREDICTIONS

The issue at hand for the current study is the influence of one type of event shift on the other during the comprehension of narrative text. At the start, we can reject a *single impact hypothesis* that would suggest that if there is updating along one dimension then there would be no additional influence of updating along any other dimension. That is, for this hypothesis, if there is updating on one dimension, further processing cost along any others would be eliminated and not observed. This would be consistent with a strictly global updating process because the updating along one dimension would cause all of the other dimensions to be rebuilt regardless of their relation with the prior event. Research by Zwaan et al. (1998) and others showed that when there are shifts along more than one event dimension, there is a greater disruption in reading time. What we do not know is the nature of this relationship.

The first hypothesis we consider here is a *combined impact hypothesis*, in which event shifts are processed separately. Their combined influence increases updating time as the number of dimensions that are updated increases. This would also be consistent with a strictly incremental updating process. This type of outcome is generally in line with the multiple regression reading time analyses reported by Zwaan et al. (1998). According to this view, the order in which the dimensions are updated has no influence because there are differences in the type of updating.

Second, according to a *spatial impact hypothesis*, spatial shift processing has a larger impact on character shift processing than vice versa. This may occur because location shifts are more effective markers as global event boundaries than are character shifts. New locations mark shifts to new episodes, and so may be more of a signal to a reader to engage in global updating. The occurrence of global updating could then elicit an expectation that there could be a shift in the people involved as well (a point also raised by Rinck & Weber, 2003). As such, a person would be better prepared to process subsequent new character information because there has been global updating of the situation model. In comparison, the introduction of a new character is more incremental and does not strongly imply that new locations are involved and global updating would not occur, but only incremental updating. As such, the prediction is that a prior spatial shift will result in a smaller influence of character shift updating when it followed a location shift, whereas a prior character shift will have little or no impact on the processing of a subsequent location shift.

Finally, a third hypothesis is a *character impact hypothesis*. Work by Rich and Taylor (2000) and Taylor and Tversky (1997) suggests that the character dimension has priority over the spatial dimension. This may be because narratives are often oriented around entities. For example, stories are often about the people, not the places. The locations merely provide the settings for those events. As such, the disruption that occurs following a character shift could be experienced as more dramatic, and so would trigger a global updating process. As such, this would bias a person to be better prepared for a spatial shift (this point is also raised by Rinck & Weber, 2003). In comparison,

the introduction of a new location does not imply that a new character will be involved as there could be a continuation of a course of events oriented around that character. If this was the case, then a location shift would only trigger incremental updating. As such, the prediction is that a prior character shift will result in a smaller influence of a location shift, whereas a prior location shift has little or no impact on the processing of a subsequent character shift.

EXPERIMENT 1

This experiment assessed whether spatial shifts influence the processing of subsequent character shifts and vice versa. People read short stories that took place on an unfamiliar, fictional campus. The experimental texts contained critical target sentences in which the first part either did or did not describe a shift in either the location or the person followed by a description of either the same or different protagonist or location. Of interest here was whether a shift along one dimension would influence the processing of information along the other.

Method

Participants. The participants were 122 University of Notre Dame undergraduates who participated in exchange for partial course credits.

Materials. Eight narratives were written by the first author for the text comprehension task that ranged in length from 41 to 65 sentences ($M = 56$; $SE = 3$). Each narrative contained four critical sentences that contained spatial information and either an anaphoric reference or a character statement. For each story, there was one sentence for each location-shift/character-shift combination, and the ordering of the two types of information was counterbalanced across the stories. The mean length of the critical sentences was 13 words ($SE = 0.7$).

For a given critical sentence, when the spatial shift came first, the first part of the sentence described the protagonist's location in one of two conditions: *no spatial shift* or *a spatial shift*. This was done using a spatial preposition. The location in a no spatial shift condition was the same as in the preceding sentence, whereas for the spatial shift condition, the protagonist had moved to a new location. The second part of the sentence either kept the same character (*no character shift*) or introduced a new one (*character shift*). Both conditions referred to the character with a proper name. Half of these sentences were preceded by a spatial shift and half were not. To assess the influence of character shifts on spatial shifts, the sentences were rewritten to reverse the ordering of the character and spatial elements. As an example, all eight versions of a critical sentence from one of the eight stories are shown later. Prior to this sentence, participants would have read:

> When he (Gene) got back, he went to Tomkin Hall. He wanted to talk to his girlfriend. She had been pretty uncommunicative the past couple of days. He was afraid to talk to her, though. He couldn't handle her rejection.

Note that story versions were counterbalanced across participants.

(1) In Tomkin, Gene was extremely frustrated as he walked around. (location 1st, no spatial shift, no character shift).
(2) In Payne Hall, Gene was extremely frustrated as he walked around. (location 1st, spatial shift, no character shift).
(3) In Tomkin, Liz was extremely frustrated as she walked around. (location 1st, no spatial shift, character shift).
(4) In Payne Hall, Liz was extremely frustrated as she walked around. (location 1st, spatial shift, character shift).
(5) Gene was extremely frustrated as he walked around Tomkin (character 1st, no spatial shift, no character shift).
(6) Gene was extremely frustrated as he walked around Payne Hall (character 1st, spatial shift, no character shift).
(7) Liz was extremely frustrated as she walked around Tomkin (character 1st, no spatial shift, character shift).
(8) Liz was extremely frustrated as she walked around Payne Hall (character 1st, spatial shift, character shift).

Procedure. For the narrative comprehension task, the texts were presented in a random order on a computer. People read each narrative one sentence at a time and controlled the rate of presentation by pressing the spacebar on the keyboard, which recorded reading times to a file and advanced to the next sentence. A practice narrative that was similar to the experimental

narratives in sentence length, number of sentences, story setting and actions of the characters was presented first. At the end of each story, two yes/no comprehension questions were asked about what happened in the story. An example comprehension question is: "Is Frank an MBA student?" People responded by pressing one of two buttons on a computer mouse. If a question was answered incorrectly, the computer buzzed and a message appeared on the screen asking the person to read more carefully.

Results and discussion

Reading times. The reading time data are presented in Table 1. The reading time data were submitted to a 2 (order: spatial or character shift first) × 2 (spatial shift) × 2 (character shift) mixed analysis of variance (ANOVA). A character shift effect was observed, $F(1,121) = 32.97$, $MSE = 10{,}763$, $p < .001$, $\eta^2 = .21$. People were faster when there was no shift (253 ms/syllable) than when there was a character shift (292 ms/syllable). Moreover, a spatial shift effect was also observed, $F(1,121) = 32.73$, $MSE = 6133$, $p < .001$, $\eta^2 = .21$. People were faster when there was no shift (258 ms/syllable) than when there was a shift (287 ms/syllable). These two effects did not interact, $F < 1$, $\beta = .81$. Importantly, the main effect of shift order was not significant, $F(1,121) = 2.41$, $MSE = 5629$, $p = .12$, $\beta = .99$, nor were any of the interactions involving order, all F's ≤ 1.46, $\beta = .99$. Thus, although there were influences of character and location shifts, they did not influence one another, regardless of the order in which they occurred.

Comprehension questions. The average error rate for the comprehension questions was 19% ($SE = 1.1\%$).

So, importantly, the updating effects for characters and locations seem to be largely separate, perhaps because they involve different qualities of events that would be handled separately by cognition. Moreover, when there were shifts along both dimensions, there was an overall increase in reading time. The fact that the amount of disruption is similar both when a shift occurs alone and in the context of the other type of shift suggests that these factors are not processed completely in parallel with one another, but that the amount of cognitive effort that needs to be expended along each of these dimensions was relatively constant.

TABLE 1
Mean reading times (in ms per syllable; standard errors in parentheses) for the critical sentences for Experiment 1

	No character shift	*Character shift*	*Second shift cost*
Spatial shift first			
No spatial shift	243 (9)	271 (11)	28
Spatial shift	262 (10)	299 (14)	37
Change in second shift			9
	No spatial shift	*Spatial shift*	*Second shift cost*
Character shift first			
No character shift	239 (9)	279 (10)	40
Character shift	269 (11)	317 (15)	48
Change in second shift			8

This result is most consistent with a combined impact hypothesis and this idea that the type of updating done in this situation would be incremental updating in both cases.

EXPERIMENT 2

Experiment 2 was similar to Experiment 1 except that the narratives were set at the participants' home college campus. This is relevant because in Experiment 1 readers have no prior knowledge of any of the discourse elements (the locations or characters) prior to reading. As such, readers may have been more likely to engage in incremental updating because they did not have the knowledge base sufficient to draw on in the more extensive effort required to engage in global updating. Previous research by Zwaan et al. (1998) showed that spatial updating effects in reading times are larger when a reader has prior knowledge of the spatial layout in which a narrative set. Thus, it might be that under these circumstances people have the knowledge base to effectively engage in global updating.

It should be noted that in Zwaan et al.'s (1998) study, the absence of prior knowledge resulted in an absence of any significant influence of a spatial shift on reading times. This is in contrast to Experiment 1 in which we did observe an influence of the spatial shifts on reading times. Keep in mind that Radvansky and Copeland (2010) demonstrated that although there may be no updating effect in reading time data, such updating processes may be revealed by other dependent measures, such as memory probes. As such, it may be that in Zwaan et al.'s

(1998) study, readers were updating when they encountered spatial shifts, and that the absence of a reading time effect was due to the lack of a need to draw upon more extensive, newly learned spatial knowledge.

An alternative to the idea that prior knowledge will influence the type of updating that is done is the idea that, although prior knowledge may make it easier to detect spatial updating effects in some research paradigms, it may have no influence of updating along another situation dimension. If this was the case, then it would be the case that prior knowledge will not affect the nature of the updating processes per se, and the same pattern of results will emerge in Experiment 2 as were seen in Experiment 1.

Method

Participants. Seventy University of Notre Dame undergraduates participated in exchange for partial course credits. First-year students were excluded until after the fall break (two months after the start of the fall semester) because of their lower level of familiarity with the campus. One participant was replaced for incorrectly answering more than 30% of the narrative comprehension questions. Four additional participants were replaced because they misidentified more than half the items on the map task.

Materials and procedure. The eight narratives written for Experiment 1 were modified so that the names of the locations corresponded to familiar Notre Dame campus locations. In addition, at the end of the study, participants were presented with a map task. For this task, people were presented with a map of the campus with 24 locations marked on the map. The task was to label each of the marked map locations. This was used to verify whether the participants had extensive prior knowledge of the Notre Dame campus. The remainder of the procedure was like that for Experiment 1.

Results and discussion

Reading times. The reading time data are presented in Table 2. First off, it should be noted that the reading times were quite a bit faster in Experiment 2 than in Experiment 1. This is likely due to the fact that the stories referred to a familiar environment. The reading time data were submitted to a 2 (order: spatial or character shift first) × 2 (spatial shift) × 2 (character shift) mixed ANOVA. A character shift effect was observed, $F(1,69) = 55.70$, $MSE = 2092$, $p < .001$, $\eta^2 = .45$. People were faster when there was no shift (213 ms/syllable) than when there was a character shift (242 ms/syllable). Moreover, a spatial shift effect was also observed, $F(1,69) = 23.87$, $MSE = 1772$, $p < .001$, $\eta^2 = .26$. People were faster when there was no shift (219 ms/syllable) than when there was a shift (236 ms/syllable). These two effects did not interact, $F < 1$, $\beta = 1.00$. Importantly, the main effect of shift order was not significant, $F < 1$, $\beta = .89$, nor were any of the interactions involving order, all F's ≤ 2.08, all p's $> .10$, $\beta = .98$. Thus, paralleling the results of Experiment 1, although there were influences of character and location shifts, they did not influence one another, regardless of the order in which they occurred.

Comprehension questions and map task. The average error rate for the comprehension questions was 12% (SE = 1.0%) For the map task, the average number of incorrectly identified locations was 5 (SE = 0.8), which corresponded to an error rate of 16%. Of these errors, 85% were items that were incorrectly identified and 15% were left blank. Forty-four per cent of the incorrectly identified items were misidentified as adjacent buildings. This indicates that people had fairly good knowledge of the campus layout.

TABLE 2
Mean reading times (in ms per syllable; standard errors in parentheses) for the critical sentences for Experiment 2

	No character shift	*Character shift*	*Second shift cost*
Spatial shift first			
No spatial shift	203 (7)	230 (8)	27
Spatial shift	225 (7)	247 (8)	22
Change in second shift			5
	No spatial shift	*Spatial shift*	*Second shift cost*
Character shift first			
No character shift	204 (7)	237 (9)	33
Character shift	219 (8)	254 (9)	35
Change in second shift			–2

So, consistent with Experiment 1, Experiment 2 showed both spatial and character shift effects and these had no influence on one another. This was true even though in this case there was extensive prior knowledge of the spatial locations. Thus, similar to Experiment 1, these are more consistent with an incremental updating process along both types of event dimensions than a global updating process for either type of event dimension.

GENERAL DISCUSSION

Narrative comprehension involves understanding the events described by a text. Part of this process involves updating one's understanding as the evolving event changes, and people are trying to concurrently process changes of varying qualities. Our study was done with the aim of observing the relationship between spatial and character shifts. Consistent with previous research, our results showed both spatial and character shift effects (e.g., Zwaan & Radvansky, 1998).

Importantly, these two updating effects seem to be largely separate, perhaps because they involve different qualities of events that would be handled separately by cognition. Moreover, when there were shifts along both dimensions, there was an overall increase in reading time. This pattern of influence is more consistent with the idea that, in the context of the current study, people were engaging in incremental updating rather than global updating, for both types of measures, and so is most consistent with a combined impact hypothesis.

Some studies have suggested that prior knowledge of event elements, such prior knowledge of a spatial layout, can influence situation model processing (e.g., Zwaan et al., 1998). Specifically, the effects of situation model updating were only observed in that study when people had extensive prior of a spatial layout prior to the experimental task. However, in Experiment 2, when participants had extensive prior knowledge of the described spatial locations, the pattern of performance was unchanged. Thus, the observed effects are more likely due to general event processing, and not due to such particularities of the task. That said, it should be noted that it is possible that extensive prior knowledge of the story characters could affect the outcome, but actually doing such a study is likely to be very unwieldy.

Looking across the literature, there are a variety of different findings in terms of the influence of one dimension on another. There are some cases where people have found a stronger influence of one event dimension relative to another (Rich & Taylor, 2000; Rinck & Weber, 2003; Taylor & Tversky, 1997). However, the pattern of findings is inconsistent and does not appear to replicate well. In the work by Taylor and colleagues it is also possible that task or text demands may also be driving readers to prefer the processing of one type of event shift over another. Moreover, in the current study, sentence reading times were collected to assess when situational shifts influenced processing. As such, ours is more of an online measure of updating. In contrast, the work by Taylor and colleagues was primarily based on measures taken after a sentence or an entire passage had been read. This involved such tasks as explicitly organising the information, providing a coherence rating after each narrative, or rating how well a sentence fits with the previous sentence. As such, that work may be more a measure of the subjective importance of the different types of information.

In the study by Rinck and Weber (2003), although an interaction was found between spatial and protagonist shifts, they consistently were unable to find basic significant effects of spatial shifts, whereas this was observed in our study. As such, the interaction that they observed may have been due to a weakness in the ability to observe spatial shifts in general, which then made their materials prone to observing an interaction. In addition, the lack of a spatial effect raises the question as to whether any interaction observed in their study was due to spatial updating.

The most consistent finding, observed here as well, is that during continuous narrative comprehension when there are changes along multiple aspects of a described event there is a slow-down in processing as a person exerts the mental effort needed to update their situation model along multiple dimensions. This includes both removing irrelevant information and adding in new components (Radvansky & Copeland, 2010). The type of updating observed here is more consistent with incremental updating processes described by Kurby and Zacks (2012). It should be noted that these data do not indicate that it would not be possible to observe global updating effects. At some level, global updating must occur in cases where the described events have changed so dramatically that an entirely new event model must be created. However, in the context of more continuous narrative descriptions, such as

the ones used here, changes in spatial location or character do not bring about such changes as a matter of course. Instead, during continuous narrative comprehension, these seem to involve a more incremental updating process.

In sum, our results suggest that different event dimensions are updated largely separate from one another, but that there is a combined, incremental influence of the two, suggesting that each compounds the amount of effort needed to successfully update one's understanding of the ongoing events. The more effort that is needed to appropriately update one's understanding, the greater the disruption that is observed in processing time. So, not only are there qualitatively different aspects of events that need to be tracked by readers, but, also, as the shift in the described events, from one event to the next, becomes greater, there is a greater amount of effort that must be extended to modify all of those components of the situation model representation.

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