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Eye Movements Reveal the Influence of Event Structure on Reading Behavior

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Abstract

When we read narrative texts such as novels and newspaper articles, we segment information presented in such texts into discrete events, with distinct boundaries between those events. But do our eyes reflect this event structure while reading? This study examines whether eye movements during the reading of discourse reveal how readers respond online to event structure. Participants read narrative passages as we monitored their eye movements. Several measures revealed that event structure predicted eye movements. In two experiments, we found that both early and overall reading times were longer for event boundaries. We also found that regressive saccades were more likely to land on event boundaries, but that readers were less likely to regress out of an event boundary. Experiment 2 also demonstrated that tracking event structure carries a working memory load. Eye movements provide a rich set of online data to test the cognitive reality of event segmentation during reading.

Keywords: Eye movements; Event cognition; Reading; Working memory; Individual differences

1. Introduction

Frank was an attorney who was heading home from the office one night in his black Lexus, the car's wax job gleaming like a shell of black ice. So Frank's driving, feeling weightless and invincible behind the greenish glow of his dashboard lights, when he senses a tingling on his legs. He sees a strange hint of movement down there by his feet, little ripples in the darkness. So he flips on the dome light and finds thousands of shiny, black palm-sized spiders marching into his lap, spilling over his knees, pushing

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> up inside his pant legs. The things looked like they were bred for war, jagged black bodies with yellow stripes, long spiny legs like needlepoints. His ankles were buried in them, submerged in a boiling pile of arachnids. He freaked, he cranked the wheel, he flipped down an embankment. After they pried him out of the wreckage and after he stopped ranting, the cops assured him there was not a sign of even one spider inside the car.
>
> —Excerpt from *John Dies at the End*, David Wong

As we ride vicariously with Frank in his car, we find ourselves in an event that includes the spatial location of the driver's seat, the sensations of spiders climbing up our legs, and the panic of trying to get them off. As we crash, time jumps forward and we begin to cope with what just happened. Narratives such as this convey a rich set of circumstances, actions, goals, and reactions, and the reader is tasked with developing representations of the implied situations. Readers routinely build these so-called *situation models*, which are structured by events (Kurby & Zacks, 2008; Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zwaan & Radvansky, 1998). The events we refer to here have been described in the past as "... a segment of time at a given location that is perceived by an observer to have a beginning and an end" (Zacks & Tversky, 2001, p. 3). Readers perceive boundaries between events when the spatiotemporal framework changes, as well as when there are changes in other situational dimensions such as a shift in characters; otherwise they perceive continuity of the current event (Zacks, Speer, & Reynolds, 2009; Zwaan & Radvansky, 1998). The situation described before the crash depicted above can be represented in a single event model because it describes actions at a discrete time and place (Zwaan & Radvansky, 1998). As features of an unfolding narrative change, so may our mental representations of the events. For example, when you read the above passage, you likely segmented your situation model at the temporal shift implied by the clause *After they pried him out of the wreckage* and began a new model (Kurby & Zacks, 2012). How do readers build and manage the working memory representations needed for situation model construction? In this study, we aimed to explore the moment-to-moment processing consequences of event cognition during reading, as revealed by eye movements.

Research has suggested that when readers perceive an event shift to occur, they update their working memory representations of "what is happening now" called *event models* (Kurby & Zacks, 2008; Zacks et al., 2007). The event-indexing model (Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998), for example, proposes that readers track a number of situational dimensions, such as characters and goals, and update their representations when they change. Theories of event cognition (Radvansky & Zacks, 2014; Zacks et al., 2007) argue that there are a number of processing consequences that occur when an event boundary is perceived. Processing load increases as event models are reset, attention increases to encode new event information, and event models are updated. Many studies support the existence of the consequences of event shifts on processing. Readers change their reading rate when the situation changes, with most studies showing slower reading (Rinck & Weber, 2003; Therriault, Rinck, & Zwaan, 2006; Zacks et al., 2009; Zwaan et al., 1995), although a recent study showed faster reading for temporal and spatial shifts (McNerney, Goodwin, & Radvansky, 2011). Readers also talk more about the current situation at event boundaries in think-aloud procedures, consistent with an increase in attention to the situation at boundaries (Kurby & Zacks, 2012). Previous event information also becomes less accessible and new information becomes more accessible after a shift in the situation (Gernsbacher, 1985, 1997; Radvansky & Copeland, 2010; Speer & Zacks, 2005; Zwaan, 1996).

Although event segmentation is thought to be an obligatory concomitant of online comprehension (Kurby & Zacks, 2008), methodological limitations of previous research into the nature of event segmentation curb conclusions regarding how segmentation affects ongoing working memory processes. A precursor to this study, for example, used a self-paced reading paradigm during which participants read passages one clause at a time (Zacks et al., 2009), and it found that participants took longer to read the clauses that had been previously marked as "event boundaries." However, the presentation of text with this technique may have induced reading that would not occur during reading of larger blocks of texts presented more naturalistically. With large blocks of text available to inspect while reading, as is the case during most reading circumstances, readers have the option to re-read previous passages. In addition, the collection of just one data point per clause—time taken to read it before pressing a button to continue—provides fairly gross estimates of the time course of event cognition while reading, and it may not be sensitive to the rapidly unfolding comprehension processes that occur in real time (Graesser, Millis, & Zwaan, 1997).

In two experiments reported here, participants read narrative texts presented in large blocks, and we assessed the association between eye movement patterns and perceived event structure. We focused on three main reading time measures of first fixation duration, first pass reading time, and total reading time, as well as regressions (backward saccades to previously read text) into and out of clauses. Assessing eye movements during reading allows for a nuanced way to test hypotheses regarding the role of event structure in comprehension. Event segmentation theory (EST; Zacks et al., 2007) and the event-indexing model (Zwaan et al., 1995) argue that processing load increases as one updates event representations at event shifts, often reflected as a slowdown in reading time at event shifts, and deeper encoding of sentence information (Gernsbacher, 1997). Consistent with most results from self-paced reading paradigms (Rinck & Weber, 2003), we predict that we will replicate this reading slowdown at event boundaries in both first pass reading time (the time taken to read a clause the first time through) and total reading time (including all time the eyes spent gazing at a clause, including the passes after the first). In addition, work in event processing and language comprehension (Otten & Van Berkum, 2008, 2009; Reynolds, Zacks, & Braver, 2007; Zacks, Kurby, Eisenberg, & Haroutunian, 2011) argue for a fast predictive process which anticipates the content of incoming stimuli. As such, we expect first fixation times (the duration of the first fixation after the eyes reach a new clause) to show that readers slow down at new event boundary clauses almost immediately.

Regressive eye movements provide novel tests for event model representation and updating. EST argues that as one builds an event model, the segmentation system flushes away the old event model to create room in working memory for a new event representation (Kurby & Zacks, 2008, 2012; Radvansky & Zacks, in press; Zacks et al., 2007). Research supports this possibility; information contained in the previous event model becomes less accessible when a new event is perceived to begin (Gernsbacher, 1985; Kurby & Zacks, 2008; Speer & Zacks, 2005; Swallow, Zacks, & Abrams, 2009; Zwaan, 1996). Mentally established boundaries between events in a narrative text may correspond to something like physical boundaries in eye movements—once you perceive a new event, you are unlikely to move backwards until you move on to subsequent text. In our opening example, readers may be unlikely to make regressive eye movements back to previous clauses (i.e., regressions *out*) upon building a new model cued by the event shift *After they pried him*.

Regressive eye movements may also provide support for the possibility that event boundaries mark important junctures in the narrative. When we perceive a new event to begin, we may increase attention to the newly incoming event information to build a fresh model (Kurby & Zacks, 2012; Zacks et al., 2007). This should result in more resource-costly processing of event-initial information (Gernsbacher, 1997; Zacks et al., 2007). Some research in situation model construction has shown a first-mention bias; the initial information of a new event is read more slowly and remembered better (Gernsbacher, 1997; Gernsbacher, Hargreaves, & Beeman, 1989; Newtson & Engquist, 1976; Swallow et al., 2009). Regarding eye movements, because event-initial information has privileged status in event models (Gernsbacher, 1997; Kurby & Zacks, 2008) readers are likely to make regressive eye movements into event boundary clauses. Regarding our opening example again, this means that the clause *After they pried him* should garner eye movements to return to it (i.e., regressions *in*) after participants have initially moved past it in their reading.

Experiment 1 tested these potential effects of event structure on eye movements during reading. In Experiment 2, we replicated the procedures of Experiment 1 but also assessed working memory capacity. Although previous research has appealed before to working memory as the substrate in which event representations are built (and from which they are flushed) (Kurby & Zacks, 2008), no previous research has found links between working memory capacity and the real-time costs of event segmentation as revealed by eye movements. The segmentation of events has been proposed to be a spontaneous and obligatory process (Radvansky & Zacks, in press; Reynolds et al., 2007; Speer, Zacks, & Reynolds, 2007; Zacks et al., 2001). In addition, updating working memory at event shifts is commonly thought to cause a working memory load as a constellation of processes is engaged (Zacks et al., 2007). If updating at event shifts incurs a working memory *load*, we should observe that participants with low working memory show larger effects of event boundaries on reading time. Alternatively, it is possible that the ability to structure event models effectively is a characteristic of skilled reading (Gernsbacher, Varner, & Faust, 1990). If updating at event shifts is a *skilled* pursuit, then the eye movements of participants with high working memory will show more sensitivity to event structure while reading. Experiment 2 attempts to distinguish between these two possibilities.

2. Experiment 1

In this experiment, we investigated the role of event structure in eye movement behavior during the reading of extended narratives. As described above, we expect that as the probability of segmentation at a clause increases, reading times will be slower, regressions into the clause will be more likely, and regressions out of the clause will be less likely.

2.1. Participants

Thirty-four individuals participated in this experiment in partial fulfillment of course requirements. All participants were undergraduate students at Grand Valley State University.

2.2. Materials

The stories were four scenes from the book *One Boy's Day* (Barker & Wright, 1951). *One Boy's Day* is an observational record of the activities of a 7-year-old boy, named Raymond, throughout a 12-h period on a day in the 1940s. The texts describe Raymond getting up and eating breakfast, playing in the schoolyard, having a music lesson, and having an English lesson. They were each approximately 1,200 words long (about 180 clauses). The texts have been used in previous studies of event segmentation and text comprehension (Kurby & Zacks, 2012; Speer et al., 2007; Zacks et al., 2009). Zacks et al. (2009) performed a thorough analysis of the relation between event segmentation behavior and the types of situational change described in the introduction (i.e., objects, space, character, goals, causes, and time). This analysis showed that the probability of segmentation at any particular clause increased as the number of situational changes increased (from 0 to more than 3; Zacks et al., 2009). Thus, event boundaries are typically associated with multiple situational changes in the text.

We divided each story into 6–8 blocks for presentation. Block division locations were determined by the number of full sentences we could fit onto a single screen for presentation in Experiment Builder (SR Research). In other words, the between-screen division locations were arbitrary and we did not consider the extent to which a division point from one screen to the next was an "event boundary," but we did ensure that each screen began and ended with a full sentence. To check whether the clauses that ended and began each screen were distributed in an unbiased manner with regard to the event boundary predictor, we conducted an analysis of our division points within the texts based on the segmentation norms from Zacks et al. (2009). This analysis revealed that the clauses we used as page-initial clauses were not more likely to be perceived as event boundaries than non-page-initial clauses according to the norming data (page-initial: $M = .10$, $SD = .13$; non-initial: $M = .10$, $SD = .18$), $t(755) = 0.10$, $p = .921$, nor were page-final clauses more likely to be perceived as boundaries than non-page-final clauses (page-final: $M = .06$, $SD = .13$; non-final: $M = .10$, $SD = .18$), $t(755) = 1.32$, $p = .187$. For the practice phase, we used a short scene about Raymond practicing casting a fishing line with his father. With each text there was an accompanying four-alternative forced-choice test, taken from Speer et al. (2007). We recorded eye movements with an SR Research table-mounted EyeLink 1000.

2.3. Procedure

Participants sat in front of the computer monitor with their chins positioned in a chin-rest to read the stories. Before eye tracking began, we calibrated fixation position and considered an average error of .25 degrees of visual angle (or below) to be acceptable. During an initial practice session, participants were instructed to read a short story about Raymond at their own rate, and to press the space bar to move from one text block to the next. After the practice session and each of the subsequent four stories, the experimenter re-calibrated eye positions to maintain precise eye movement data. Each of the four stories we analyzed were broken into 6–8 blocks and presented on the screen one block at a time (see Fig. 1). Participants pressed the spacebar to move to the next block of text. Participants completed a short comprehension test after each text (including the practice text) to help ensure careful reading.

2.4. Results and discussion

Interest areas for eye movement analysis were defined at the clause level. To establish our predictor variable to indicate the degree to which a clause is considered an event boundary, we used normative event segmentation data from Zacks et al. (2009). In addition to using the same texts as Zacks et al. (2009), we also divided interest areas into clauses in exactly the same manner to preserve the utility of the event segmentation norms. The *event segmentation predictor* variable is the proportion of participants from Zacks et al. (2009) Experiment 1 (visual-continuous condition) that indicated a given clause as a coarse event boundary ($min = 0$, $max = .84$). This variable was left as continuous. We conducted mixed effect models with this event segmentation variable as the main predictor variable.[1] To rule out possible confounds due to a higher proportion of high event boundary clauses that contained punctuation, we included terminal punctuation and non-terminal punctuation as covariates in the models tested. To account for the fact that clause length correlated positively with the event boundary predictor, $r(755) = .24$, $p < .001$, we also included the number of characters in a given clause as a covariate. With these sources of variability partialled out of the mixed effects models tested, no observed effects of the event boundary predictor on reading time could be attributed to the increased presence of punctuation or to the increased length of such clauses. We included the random effects of subject, text, and text embedded in subject. (For the regression behavior dependent variables, we conducted analogous logistic mixed effects models.)

We found that reading rate slowed down as event segmentation probability increased for all three reading time measures of total reading time, first pass reading time, and first fixation duration (Table 1). In addition, regressions into previous clauses were more

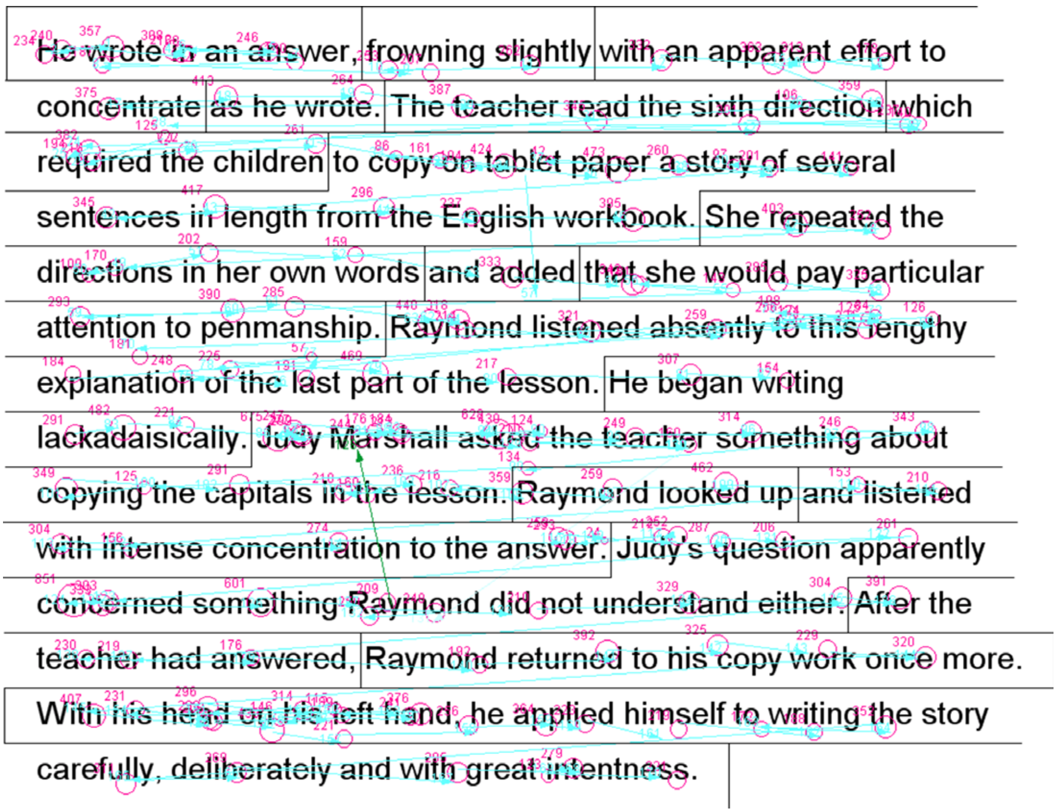

Fig. 1. Example text block presented to participants, overlaid with interest areas (clauses), as well as example fixations (magenta) and saccades (light blue) from one participant. Norming data allowed us to consider each clause on a continuum of "event boundary-ness"; for example, the clause *She repeated the directions in her own words* had a very low probability of segmentation (i.e., not likely to be perceived as an event boundary), whereas the clause beginning with *Judy Marshall asked the teacher* had a high probability of segmentation (i.e., likely to be perceived as an event boundary). The eye movements shown here reflect that difference: This participant spent more time reading the *Judy Marshall* clause overall and made a regressive eye movement into it (green arrow). Such effects persisted after accounting for clause length differences.

likely to land on clauses with high event segmentation probability, and regressions out of a clause currently being read were non-significantly less likely to occur at such clauses (Table 2; see also Fig. 1).

We therefore found evidence for an influence of event structure on reading behavior. Participants fixated on event boundaries (clauses high in event segmentation probability) longer than non-boundaries (clauses low in event segmentation probability), even in the first fixation, and the regressive eye movements into event boundary clauses suggest that event boundaries serve as foundational information in situation models. Although non-significant, the direction of the regressions out data also are consistent with the possibility that attention shifts away from old event information when a new one is perceived to begin (this effect is significant in Experiment 2).

Table 1
Experiment 1: Mixed effects model results for the reading time (fixation) measures

Measure	Regression Weight	SE	95% CI	$t(20558)$	p	d
Total reading time	74 ms	35	3–140	2.11	.035*	0.78
First pass time	90 ms	32	28–152	2.82	.004**	1.05
First fixation	22 ms	4	13–31	4.99	<.001***	1.85

Notes. Coefficients represent effects of the event segmentation predictor. *Total reading time* was defined by the total time spent fixating a clause, including all visits to it beyond the first series of fixations; *first pass reading time* was defined as the total time participants spent fixating a given clause upon entering the clause the first time before moving on to a different clause; *first fixation time* was defined as the average length of the first fixation on a given clause. *$p < .05$; **$p < .01$; ***$p < .001$.

Table 2
Experiment 1: Logistic mixed effects model results for the regressions measures

Measure	Log Odds	SE	Odds Ratio	95% CI	$z(20558)$	p	d
Regressions in	0.30	0.09	1.35	1.14–1.61	3.44	<.001***	1.20
Regressions out	−0.11	0.09	0.90	0.76–1.08	−1.15	.249	−0.44

Notes. Odds ratios represent effects of the event segmentation predictor. *Regressions in* coded whether or not a given participant fixated that clause again after having moved on to other ones. *Regressions out* coded whether or not the participant made a regressive eye movement to a previous clause from the current one. ***$p < .001$.

3. Experiment 2

In Experiment 2, we replicated the paradigm of Experiment 1 and included a task to assess working memory capacity. Although working memory has long been thought to be involved in event segmentation processes while reading, previous research has not found sufficient individual differences evidence to support such a relationship (e.g., Radvansky & Copeland, 2001). It is possible that our naturalistic reading task combined with measurements of eye movements could pick up subtle reading effects that clause-by-clause reading time measures miss. With clause-by-clause reading, a participant does not have the option to inspect previous clauses, even if they were important in establishing a new event. Our task allows for more natural reading strategies, which might reveal a cumulative correlation with working memory capacity. If that is the case, we would expect that first pass reading times will not show any effects of working memory capacity, but total reading time of each clause would show such effects. Furthermore, the nature of the interaction allows for a test between the load and skilled pursuit hypotheses as presented above.

3.1. Participants

Eighty-four individuals participated in this experiment in partial fulfillment of course requirements.

3.2. Materials

We used identical story materials for this experiment as Experiment 1. We used a variant of the reading span test (see Swets, Desmet, Hambrick & Ferreira, 2007 for details), based on procedures described by Turner and Engle (1989), to assess working memory capacity.

3.3. Procedure

We used identical reading and eye tracking procedures as in Experiment 1. After the eye tracking task was complete, we also assessed working memory capacity. Participants were required in this task to judge whether sentences made sense while memorizing three to six words at a time. We assessed working memory on a continuous scale from 0 to 36, reflecting the total number of words correctly recalled in serial order. Finally, participants engaged in an event segmentation task in which they explicitly indicated where they perceived event boundaries in the same four texts from *One Boy's Day*. They did so by marking on a printed sheet of paper where they thought "a large meaningful unit of activity" ended, and another began. These are typical instructions for this task (Kurby & Zacks, 2012; Zacks et al., 2009). The data collected during this event segmentation task provided the basis for the event boundary predictor variable in Experiment 2.

3.4. Results and discussion

In Experiment 2, to more closely link segmentation behavior to eye movement data, we used the event segmentation data from the participants themselves (rather than those from Zacks et al., 2009) as the event boundary predictor variable. This event segmentation variable was represented as the proportion of the 84 participants that segmented at each clause (min = 0, max = .74).[2] This clause-level segmentation proportion/predictor was highly correlated with the segmentation proportion/predictor used in Experiment 1, $r(755) = .87$, $p < .001$. This demonstrates very high intersubject agreement on event boundary locations. To help allay possible concerns about this change in procedure, we note that the results were identical whether we used the Zacks et al. norms or the present norms as the continuous event segmentation predictor variable.

We replicated all of the reading time effects (see Table 3) and the regressive eye movement effects from Experiment 1 (see Table 4), and in addition, we found that regressive eye movements out of clauses high in event segmentation were significantly less likely to occur than at clauses low in event segmentation. In the mixed effects models, we also included the interaction between mean-centered working memory scores and the event boundary predictor. There was a significant interaction between event segmentation probability and working memory capacity for the total reading time variable (see Fig. 2). In this interaction, participants with lower levels of working memory slowed

Table 3
Experiment 2: Mixed effects model results for the reading time (fixation) measures

Measure	Predictor	Regression Weight	SE	95% CI	t(48739)	p	d
Total reading time	Segmentation probability	212 ms	41	129 to 288	5.17	<.001***	1.22
	Working memory (WM)	−29 ms	7	−41 to −16	−3.75	<.001***	−0.88
	Segment prob × WM	−30 ms	6	−41 to −19	−5.23	<.001***	−1.23
First pass time	Segmentation probability	139 ms	38	63 to 209	3.68	<.001***	0.87
	Working memory (WM)	−9 ms	5	−18 to −0.4	−1.90	.044*	−0.45
	Segment prob × WM	−2 ms	5	−12 to 8	−0.30	.771	−0.07
First fixation	Segmentation probability	23 ms	5	13 to 34	4.39	<.001***	1.03
	Working memory (WM)	−1 ms	1	−2 to 0	−1.35	.167	−0.32
	Segment prob × WM	−0.3 ms	1	−2 to 1	−0.35	.735	−0.08

Note. *p < .05; **p < .01; ***p < .001.

Table 4
Experiment 2: Logistic mixed effects model results for the regressions measures

Measure	Predictor	Log Odds	SE	Odds Ratio	95% CI	t(48739)	p	d
Regressions in	Segmentation probability	0.506	0.105	1.66	1.35–2.04	4.81	<.001***	1.09
	Working memory (WM)	−0.011	0.009	0.99	0.91–1.01	−1.20	.232	−0.27
	Segment prob × WM	0.014	0.015	1.01	0.99–1.04	0.97	.334	0.22
Regressions out	Segmentation probability	−0.253	0.106	0.78	0.63–0.96	−2.39	.017*	−0.54
	Working memory (WM)	−0.014	0.011	0.99	0.97–1.01	−1.35	.177	−0.31
	Segment prob × WM	−0.003	0.015	1.00	0.97–1.03	−0.17	.863	−0.04

Note. *p < .05; **p < .01; ***p < .001.

down at event boundaries, whereas high working memory readers did not. This provides support for the working memory load hypothesis. Given that we found this interaction only in a cumulative measure of total reading time, and not in first pass reading time (or any other individual measure), our results support the possibility raised earlier that the interaction of working memory and sensitivity to event boundaries might be observable only in cumulative measures of naturalistic reading.

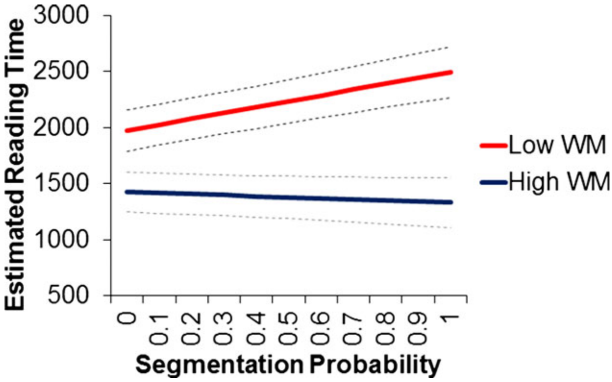

Fig. 2. Interaction between working memory capacity (as measured by reading span) and segmentation probability (as measured by the proportion of participants who coded a given clause as an event boundary) on total reading time in Experiment 2. Dotted lines indicate 95% confidence intervals.

4. General discussion

In this study, we assessed the role of event structure in reading behavior and eye movements in discourse comprehension. In both experiments we found that reading time was slower at event boundaries at several time intervals, as measured by total fixation time, first pass reading time, and first fixation time. We also found that readers were more likely to make regressive eye movements into event boundary clauses, but were less likely to regress out of an event boundary (although this latter effect was significant in Experiment 2 only). In addition, in Experiment 2, we found that working memory capacity interacted with event boundary status for total reading time, such that low working memory readers slowed down at event boundaries but high working memory readers did not.

That reading slowed down at event boundaries is consistent with previous work on event comprehension in narrative text (McNamara & Magliano, 2009; Rinck & Weber, 2003; Therriault et al., 2006; Zacks et al., 2009; Zwaan & Radvansky, 1998). The slowdown has been in part interpreted as the effects of increased processing load as situation models are updated (Radvansky & Zacks, in press; Zwaan & Radvansky, 1998). Also, readers tend to show a first-mention bias whereby information about a new event is processed more robustly than the following within-event information (Gernsbacher, 1985; Gernsbacher et al., 1989; Kurby & Zacks, 2012), and readers are typically attentionally focused on new situational information (Magliano, Zwaan, & Graesser, 1999; Trabasso & Magliano, 1996; Zwaan & Madden, 2004). We also found that these reading time effects occur as quickly as the first fixation into an event boundary clause. This is consistent with EST, which states that event structure is perceived by a fast predictive mechanism (Kurby & Zacks, 2008; Radvansky & Zacks, in press; Zacks et al., 2007).

Readers also made regressive eye movements that reflected the event structure of the narratives. Information at event boundaries is used to build new event models and guides mapping of future information (Gernsbacher, 1997). Regressions into event boundaries may then reveal coherence checking processes that occur as event comprehension unfolds (Wiley & Rayner, 2000). Regressive eye movements during reading have been proposed to reflect such processes, called "wrap up" effects (Rayner, Kambe, & Duffy, 2000). The observed difference in regressions out of event boundaries compared to non-boundaries is consistent with the possibility that previous event information becomes less accessible as new events begin. This is also expected based on a proposal that readers adopt a "here and now" perspective that draws reader attention to the new information in service of building new models, turning away attention from old event information (Zwaan & Madden, 2004).

Regarding working memory, we tested two alternative hypotheses. The skilled hypothesis states that managing event structure is an advanced comprehension process (Gernsbacher et al., 1990), and as such those with high capacity should show stronger event structure effects. A load hypothesis states that updating at event boundaries incurs a working memory load: Situation model updating is associated with the engagement of working memory processes, such as a reset of the old model, increase in encoding processes, and mapping (Gernsbacher, 1997; Zacks et al., 2007; Zwaan & Radvansky, 1998). Our data support the load hypothesis; low working memory readers showed larger event structure effects on reading time. Managing this load at event boundaries was more difficult with lower levels of working memory capacity.

Using sensitive eye tracking measures, we found that event structure has fast and reliable effects in naturalistic reading. In this study, during the main reading phase, readers did not engage in any overt judgment tasks. We used two independent sets of event segmentation data, one normative set (Experiment 1) and one set from the readers themselves (Experiment 2), to predict eye movements and both showed identical effects on reading behavior. Here we demonstrated that event segmentation is a normal concomitant of reading comprehension, consistent with some previous neuroimaging work (Ezzyat & Davachi, 2011; Speer et al., 2007). Moreover, we showed that such segmentation has immediate effects on eye movements during reading and causes working memory loads as readers close old models and open new ones.

Bringing this research back to the domain of every day reading, these findings support the notion that as we read narrative texts, we create mental representations of individual events in working memory, following a regular event-based cycle. When we perceive a new event to have begun, we read more slowly and mentally segment the current event from the previous one. That segmentation is reflected in a lack of eye movements to previous events once the boundary is encountered. Reading speed is then faster within events, although we make occasional return visits to the event beginning. All the while, we predict what might happen next and begin anew when predictions are violated.

Notes

1. The event boundary predictor had moderate positive skew (skew = 2.3). We re-ran all of the reported analyses with a log transform of the segmentation predictor and

found that all of the effects of segmentation remained significant, in the same directions as reported (see Tables S1 and S2 in Supplementary Materials).

2. As in Experiment 1, we re-ran all of the analyses with a log transform of the segmentation predictor to correct for positive skew (skew = 2.7), and found that all of the significant effects of segmentation on eye movements remained significant, in the same directions as reported (see Tables S3 and S4 in Supplementary Materials).

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Experiment 1: Mixed effects model results for the reading time (fixation) measures using a log transform of event segmentation predictor.

Table S2. Experiment 1: Logistic mixed effects model results for the regressions measures using a log transform of event segmentation predictor.

Table S3. Experiment 2: Mixed effects model results for the reading time (fixation) measures using a log transform of event segmentation predictor.

Table S4. Experiment 2: Logistic mixed effects model results for the regressions measures using a log transform of event segmentation predictor.