CAUSALITY AND EXPECTEDNESS IN ESTABLISHING EVENT BOUNDARIES

A Thesis

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by

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TABLES ........................................................................................................................................ iii

ACKNOWLEDGEMENTS ........................................................................................................ iv

INTRODUCTION ................................................................................................................ 1
  Theories of Situation Model Processing ...................................................................... 2
  Situation Dimensions .................................................................................................. 5
    Space ......................................................................................................................... 7
    Time ........................................................................................................................... 8
    Goal ........................................................................................................................... 9
    Entity .......................................................................................................................... 9
    Cause ......................................................................................................................... 10

PILOT STUDY 1 .................................................................................................................. 13
  Method ........................................................................................................................ 13
    Participants ............................................................................................................. 13
    Materials and Procedure ....................................................................................... 13
    Results and Discussion .......................................................................................... 15

PILOT STUDY 2 .................................................................................................................. 18

EXPERIMENT 1 ................................................................................................................... 21
  Method ........................................................................................................................ 21
    Participants ............................................................................................................. 21
    Materials ................................................................................................................ 21
    Procedure ............................................................................................................... 22
    Results and Discussion .......................................................................................... 23

EXPERIMENT 2 ................................................................................................................... 27
  Method ........................................................................................................................ 27
    Participants ............................................................................................................. 27
    Materials and Procedure ....................................................................................... 28
    Results and Discussion .......................................................................................... 28

EXPERIMENT 3 ................................................................................................................... 31
  Method ........................................................................................................................ 31
    Participants ............................................................................................................. 31
    Materials and Procedure ....................................................................................... 32
    Results and Discussion .......................................................................................... 32

GENERAL DISCUSSION ................................................................................................. 36
APPENDIX ..........................................................................................................................40
REFERENCES .....................................................................................................................42
TABLES

Table 1 Effect of Event Dimension on Reading Time....................................................... 6
Table 2 Mean Expectedness Ratings for Shift and Control Sentences by Shift Type..... 16
Table 3 Standardized Beta Weights for Regression Model Variables.............................. 20
Table 4 Mean Expectedness Ratings By Shift Type........................................................ 24
Table 5 Proportion of Participants Who Identified a Shift By Shift Type....................... 29
Table 6 Fixed Effects Results for Experiment 3.............................................................. 34
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INTRODUCTION

Events that people read about are often changing, and our comprehension and understanding of them need to be properly represented and updated. When people comprehend language, there are several levels of processing and representation involved. These include the surface level, or words and syntax used to convey meaning, the textbase, which is the set of propositions that link various ideas to one another, and the situation model. The situation model is a mental representation of an event that incorporates various aspects of that event, such as the people involved, the location in which it took place, and the time during which it happened (van Dijk & Kintsch, 1983; Kurby & Zacks, 2008). Frequently, a situation model needs to be updated to incorporate new information or a new model needs to be created for a new event. The objective of this thesis is to investigate the role of causal connections as contributors to the identification and processing of event shifts along other dimensions. That is, are the processing changes observed during event boundaries due to the updating of situation models along a certain dimension, or do these processing changes simply reflect the processing of a causal break?

The introduction to this thesis first outlines existing theories of situation model processing, followed by a consideration of the various dimensions along which situations
can vary. After this, the aim of the experiments is given along with some pilot data that supports the ideas they test.

Theories of Situation Model Processing

In this section, various theories of situation model processing are discussed with respect to how they bear on the issue of event boundaries. These theories include the Event Horizon Model, Event Segmentation Theory, and the Event Indexing Model.

The Event Horizon Model (Radvansky, 2012; Radvansky & Zacks, 2014) provides a framework for understanding how event segmentation and model updating occur and what the effects of these processes are. There are five basic principles of the Event Horizon Model. These are that events are segmented into units, information about the current event is more available than information about previous events, a causal network is created that can influence retrieval, recall of information stored across multiple events is better during noncompetitive retrieval, and recall of information stored across multiple events is worse during competitive retrieval. The segmentation of events is of particular importance to the current discussion and is reviewed next.

Event Segmentation Theory (EST; Zacks, Speer, Swallow, Braver, & Reynolds, 2007) describes when event segmentation will occur. According to EST, one of the driving forces behind event segmentation is that observers are continuously trying to predict the future (Kurby & Zacks, 2008). Sensory input is incorporated with prior knowledge, such as scripts and schemata, and this knowledge is used to anticipate the future state of the current event. An error monitoring system reacts when the discrepancy between the predicted and actual states becomes too great, and this discrepancy causes an
attentional gating system to open. This results in either an update to the current model or
the creation of a new model.

Generally, observers agree where the boundary between one event and another
should be placed (Zacks et al., 2007). Observers tend to mark event boundaries at places
in which a meaningful change has occurred. The change can be physical, such as an
actor’s actions or location, or less tangible, such as a change in goal or intention (Zacks et
al., 2007; Zwaan et al., 1998). Segmentation happens unconsciously and automatically
and involves several brain areas, including the posterior inferior temporal sulcus and
areas near the MT complex (when materials are viewed) and the posterior cingulate
cortex and precuneus (when materials are read) (Zacks, Braver, Sheridan, Donaldson,
Snyder, Ollinger, Buckner, & Raichle, 2001; Speer, Zacks, & Reynolds, 2007).
Segmentation has been found when people watch films (Zacks et al., 2001; Magliano,
Miller, & Zwaan, 2001), listen to descriptions of activities, and read written narratives
(Speer, Zacks, & Reynolds, 2007), showing that this is a pervasive phenomenon. A
consequence of segmentation is that, when reading a text, reading times are slower for
sentences that convey a shift or break along one of several variables (Zwaan, Langston, &
Graesser, 1995). The variables readers track during comprehension are discussed next.

The Event Indexing Model (Zwaan et al., 1995; Zwaan et al., 1995; Zwaan &
Radvansky, 1998) proposes that people track several different situational indices as they
read a text. Typically, five indices are theoretically identified: space, time, protagonist (or
entity), intentionality (goals), and causality (Speer et al., 2007; McNerney, Goodwin, &
Radvansky, 2011, Kurby & Zacks, 2012). By tracking these dimensions of experience,
people can identify event boundaries, where one event ends and another begins. For
example, when reading a story in which a character goes from her home to the museum, the change in spatial location is a signal that a new event has occurred, and the reader needs to update his or her situation model to take into account this new event.

Event Segmentation Theory and the Event Indexing Model suggest two different processes by which situation models are segmented and updated; however, the underlying reason a model is updated may be the same. It could be that encountering a new event of any kind is often unexpected, so it is not clear how the new information would be causally connected to what was happening previous in the situation model. For example a change in the temporal dimension signals that the previously established entities, their goals, or locations may no longer be relevant, so this is a break in the causal structure. Because the causal relations between the new and previous events are not readily apparent, prediction accuracy breaks down. According to EST, this triggers updating. However, for the Event Indexing Model, the change in the temporal index is sufficient, although there is some accommodation for how extensive the change is. For example, the strong iconicity assumption (Zwaan, 1996) states that readers assume that each sentence in a narrative relates to the same event as the previous. This assumption is overridden when a time shift is introduced, and the amount the previous event is deactivated depends on the extent of the shift (e.g. an hour later vs. a month later). The experiments will examine the relationship between situation model updating and the influence of expectedness and causal connectivity.
Situation Dimensions

One way to assess the process of situation model updating is to measure reading times. A common assumption is that the additional cognitive processing needed to update a situation model is reflected in increased reading times (Zwaan et al., 1995). This updating involves either the integration of new information (Zwaan et al., 1995) or the creation of an entirely new model (Radvansky & Copeland, 2010). There is evidence that updating takes place incrementally or globally, depending on the extent of the change (Kurby & Zacks, 2012). Research findings for each of the dimensions is presented in Table 1 and discussed next. To briefly preview, while there is consistent evidence that causal changes result in increased reading times, suggesting situation model updating, the evidence for the other dimensions of experience is less consistent.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Experiment</th>
<th>Spatial</th>
<th>Temporal</th>
<th>Goal</th>
<th>Entity</th>
<th>Causal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zwaan, Magliano, &amp; Graesser</td>
<td>1995</td>
<td>Exp 1</td>
<td>ns</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exp 2</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zwaan, Radvansky, Hilliard, &amp; Curiel</td>
<td>1998</td>
<td>Exp 1</td>
<td>ns</td>
<td>+</td>
<td>+%</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exp 2</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radvansky, Zwaan, Curiel, &amp; Copeland</td>
<td>2001</td>
<td>Exp 1</td>
<td>+,*</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exp 2</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Rinck &amp; Weber</td>
<td>2003</td>
<td>Exp 1 and 2</td>
<td>+%</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Radvansky &amp; Copeland</td>
<td>2010</td>
<td>Exp 1</td>
<td>ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exp 2</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>McNerney, Goodwin, &amp; Radvansky</td>
<td>2011</td>
<td></td>
<td>-</td>
<td>-</td>
<td>ns</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

Note: + Indicates increased time, - indicates decreased time, ns indicates not significant, blank space indicates the variable was not tested. % - Marginal; * Significant in older subjects only; ** Significant in younger subjects only
Space

A spatial shift occurs when the action in a narrative moves from one location to another. For example, if a character is watching television at home then meets some friends at the pub, a spatial shift has occurred. Studies of how these shifts affect reading times have yielded mixed results. In some cases they have been found to increase reading times (Zwaan et al., 1995; Zwaan, Radvansky, Hilliard, & Curiel, 1998; Radvansky, Zwaan, Curiel, & Copeland, 2001); however, several of these results were found when subjects reread passages (Zwaan et al., 1995) or memorized a map of the building in which the narrative took place (Zwaan et al., 1998). Other experiments have failed to find a difference (Zwaan et al., 1995; Zwaan et al., 1998; Radvansky & Copeland, 2010) or found only a marginal increase in reading times (Rinck & Weber, 2011). One study even found a significant decrease in reading times for sentences that conveyed a spatial shift (McNerney et al., 2011).

When a spatial shift occurs in a narrative, there may not immediately be a clear reason for why it is happening. As such, spatial shift effects may reflect causal breaks. For example, the study that found faster reading times for sentences conveying a spatial shift used a novel as the test material. It is possible that this made the shifts easier to process because there is already a rich model, whereas other experiments used shorter texts in which the models may be more difficult to update. Additionally, people read sentences faster when there was a functional spatial relationship between a space and an entity in a story, such as standing under a bridge versus under a lamppost during a rainstorm (Radvansky & Copeland, 2000; Radvansky, Copeland, & Zwaan, 2003). So it
seems that the ability to explain the causal reason for a spatial shift (or spatial relation) influences reading times and associated processing.

Time

Temporal shifts occur when there is a sizeable gap in narrative time. This may be identified by phrases such as, “A few days later…” although the length of time needed to convey a shift may vary depending on the context. For example, “five hours later” signals a new event when reading about a person watching a movie, but “twenty minutes later” generally does not (Anderson, Garrod, & Sanford, 1983).

When a new time frame has been identified, because readers must establish a new temporal framework, a new situation model may need to be created which would lead to increased reading times. This assumption has found support in several studies (Zwaan et al., 1995; Zwaan et al., 1998; Radvansky et al., 2001; Rinck & Weber, 2003; Radvansky & Copeland, 2010). However, temporal shifts have also been found to lead to decreases in reading times for materials presented as historical texts (Radvansky et al., 2001) and in a novel (McNerney et al., 2011). Presumably, readers skipped over dated materials in these texts, and it should be noted that the effects of temporal shifts in the latter study varied in a chapter-by-chapter analysis.

So, again, there is this possibility that temporal shifts may be more difficult to comprehend when they are unexpected, and so serve as causal breaks. One of the texts that led to faster reading times for temporal shifts was a novel, and the effect was strongest for a chapter that contained many dated letters. The other text described historical events. In both of these cases, one could reasonably expect that time will shift
due to the nature of the materials. As such, the reader may ignore these shifts during comprehension.

**Goal**

Goal information is also tracked during comprehension. When a protagonist’s goal changes, it generally increases processing time (Zwaan et al., 1998; Radvansky et al. 2001), although occasionally the effect is marginal (Zwaan et al., 1998) or not significant (McNerney et al., 2011). Because they provide an impetus for a character’s actions, goals are causal in nature. Readers track protagonists’ goals, and these goals remain more available to memory when they are uncompleted (Radvansky & Curiel, 1998). When there is more than one incomplete goal, readers tend to focus on the most current goal because it is more causally related to the current model (Magliano & Radvansky, 2001).

**Entity**

Entity shifts occur when either the protagonist of the story changes or a new character is introduced. For example, if a story has been centered on John and the narrator begins describing events from Julia’s point of view, an entity shift has occurred. For a reader to understand what is happening, he or she must be able to keep track of the characters involved and update his or her situation model accordingly. Generally, shifts along this dimension do result in an increase in reading time (Zwaan et al., 1998; Rinck & Weber, 2003; McNerney et al., 2011), although not exclusively. In at least one case, it led to significantly faster reading times (Radvansky et al., 2001, Exp. 1). The test materials in this particular case consisted of historical narratives, and readers may have
simply glossed over the unusual sounding names they encountered. As with the other dimensions, entity shifts can also be viewed as causal in nature. When a new character is introduced, the reason for that character’s appearance needs to be explained, along with the character’s goals and relationships with the others present.

**Cause**

Causal shifts happen when an event’s cause in a narrative cannot be explained by the prior events in the story. For example, if a character is practicing drumming and suddenly becomes angry, it would serve as a causal break. At such points, the reader needs to establish an event boundary and may begin trying to infer links between the current event and previous ones, if there is some plausible relation to the previous events (Graesser, Singer, & Trabasso, 1994). Moreover, readers may also try to link subsequent events back to the causal break to either explain why it happened or to provide a motivation for or explanation of the events that follow. Perhaps it is revealed that the drummer had broken a drumhead. Regardless of the cause and effect relations that are established, previous work suggests that causal breaks are disruptive to comprehension and reliably lead to increases in reading times (Zwaan et al., 1995; Zwaan et al., 1998; Radvansky et al., 2001; McNerney et al., 2011).

An important point to note, again, about these various event dimensions, and the likelihood of their affecting reading times, is that causality is the only one that consistently influences reading time, and in the same way (i.e., reading times always increase). This supports the notion that when reading time increases occur, there is some unexpected change, and so, in some sense, a causal break.
Consistent with the idea that causality plays an overarching role in influencing comprehension and understanding, Graesser, et al. (1994) have proposed that readers make inferences when comprehending a text to ensure that it remains coherent. When an author makes a statement about an action, goal, or event, the reader searches working and long-term memory in an attempt to explain the newly encountered information. When this search fails, it may be akin to a prediction failure in EST, which leads to an increase in unexpectedness and model updating. Such extra processing should be reflected in increased reading times.

The previously discussed finding that people read sentences faster when there was a functional spatial relationship between a space and an entity (Radvansky & Copeland, 2000; Radvansky et al, 2003) supports the idea that causality is a key component of this extra processing. It suggests that when a readily apparent causal connection exists, there is reduced need to infer a relationship and less processing is required. It is possible that situation model shifts function in much the same way: when a shift occurs, the reader must infer a relationship between the new information and that in the current model. This disparity may function more as a causal break, and the less expected the new information is, the more one has to search for meaning or generate inferences.

One of the assumptions of EST is that segmentation depends on prior knowledge (Zacks et al., 2007). If this is the case, then providing that knowledge before an event shift should reduce the amount of surprise associated with that shift and, ultimately, affect model updating. The motivation for the current project is to examine whether the prior knowledge makes the update less effortful, thus reducing reading time for the shift sentence. It may also shed light on whether there is some minimum amount of processing
that must take place to accurately update the model, even when the comprehender knows
the shift will take place and does not need to infer causal connections.
PILOT STUDY 1

The aim of the first pilot study was to determine if the event shifts present in previously existing materials (which had shown increases in reading times) were more surprising compared to controls in which there was no such event shift. To make this assessment, expectedness ratings of a particular sentence were gathered for both the original sentence and an altered control version of that sentence.

Method

Participants

Eight hundred seventy-nine participants were recruited using Amazon’s Mechanical Turk™ service. Participants were all over the age of 18 and were residents of the United States. Each was paid five cents for completing the experiment.

Materials and Procedure

Eight stories from Radvansky et al. (2001) were used. These stories were 32 to 46 sentences long. Four of the stories were about historical events, such as the gunpowder plot of 1605; the other four were the same stories modified to read more like a narrative and set in present-day. To evaluate the expectedness of each sentence, each person saw a five-sentence segment from a given text. This segment included a target sentence and the
four sentences that preceded it. The first sentence of each story was never presented because it was assumed to have maximal unexpectedness as nothing came before it. For the second, third, and fourth sentences of the stories, segments contained only the first two, three, or four lines of each story, respectively. Note that the target sentences were all of the sentences from each text (excluding the first sentence), including those that did and did not convey event shifts.

To assess the unexpectedness of a given event shift sentence, an alternate version was created that conveyed no shift. For example a sentence that introduced a new entity such as, “So he brought in other conspirators, including another cousin, Frank Tresham.” was rewritten, “So he brought in other conspirators.” This process resulted in a total of 548 unique segments that were used for testing.

Each text segment was presented using the Qualtrics Survey Software™ website. After reading a brief description of the experiment and providing consent, participants read two segments, one at a time, and rated the last sentence of each segment for unexpectedness. This was done using a scale from 1 (Least Expected) to 7 (Most Expected). Segments were paired randomly for a given person with the restriction that each pair contained one segment that ended with a sentence that conveyed a shift (or shifts) and one segment that ended with a no-shift sentence. After reading and rating, a debriefing screen was presented explaining purpose of the study, and participants were given a code to enter in Mechanical Turk for compensation. Three ratings were obtained for each sentence.
Results and Discussion

The data were analyzed to address two questions: is there a difference in expectedness ratings of shift and non-shift sentences, and what, if any, are the differences in ratings between different types of shifts?

The expectancy data are summarized in Table 2. These data were first analyzed to determine if there was a reliable difference in expectedness ratings between original sentences that did or did not convey event shifts. The result was that shift sentences were rated as less expected than non-shift sentences ($M = 4.21, SE = 0.08; M = 4.82, SE = 0.16$, respectively); $F(1,301) = 8.85, MSE = 13.42, p = .003, \eta^2 = .03$. Next original shift sentences and their altered versions were compared. Again, shift sentences had lower expectedness ratings than their non-shift counterparts ($M = 4.34, SE = 0.06; M = 4.87, SE = 0.06$, respectively); $F(1,1757) = 40.52, MSE = 123.00, p < .001, \eta^2 = .02$. Also, as can be seen in Table 2, this basic difference was significant for each type of event shift.

Next, to assess the relative impact of an event shift along each of the dimensions, the sizes of the differences between the event shift and non-shift versions were compared with respect to one another. To do this, a difference score was obtained by subtracting the rating for the modified sentence from the rating for the original sentence for each item (note that this is an items-based analysis). From these data, difference scores for each event dimension were obtained. These difference scores were compared to determine if any shift type yielded significantly larger differences than the others. The only comparisons that were even marginally significant were between causal and goal breaks ($M = .75, SE = .11; M = .38, SE = .16$, respectively); $F(1,617) = 3.60, MSE = 19.14, p = .06, \eta^2 = .006$ and between relative time and goal breaks ($M = .82, SE = .18; M = .38, SE$
=.16, respectively); \(F(1,377) = 3.28, \text{MSE} = 17.72, p = .07, \eta^2 = .009\). All other \(ps > .10\). Thus, expectation ratings did not vary based on the different types of shifts present in the sentences (i.e., no particular shift type was less expected than any other).

**TABLE 2**

MEAN EXPECTEDNESS RATINGS FOR SHIFT AND CONTROL SENTENCES

<table>
<thead>
<tr>
<th>Condition</th>
<th>Shift</th>
<th>Control</th>
<th>(F)</th>
<th>(df)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial</td>
<td>4.47</td>
<td>4.96</td>
<td>8.69</td>
<td>431</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute Time</td>
<td>4.21</td>
<td>4.96</td>
<td>19.24</td>
<td>395</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Time</td>
<td>4.30</td>
<td>5.12</td>
<td>16.86</td>
<td>317</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entity</td>
<td>4.30</td>
<td>4.89</td>
<td>25.35</td>
<td>911</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal</td>
<td>4.41</td>
<td>4.79</td>
<td>4.89</td>
<td>437</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Causal</td>
<td>4.16</td>
<td>4.91</td>
<td>36.58</td>
<td>797</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.09)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* All \(ps\) significant. Standard Errors appear in parentheses below means.

The results of Pilot Study 1 suggest the presence of shifts along situation model dimensions affects judgments of expectedness and that different shift types do not differentially impact these judgments. While the assessment of these materials is consistent with the idea event boundaries all convey a disruption of the causal flow of the
events, because there was no experimental manipulation of shifts, and the number and types of shifts were conflated in each sentence, it is difficult to adequately assess whether the effects observed here are due to the presence of a shift (or a particular type of shift), or if it may be due to other confounding variables that may be present in the materials.
PILOT STUDY 2

The aim of the second pilot study was to determine if the expectedness rating of a particular sentence was significantly related to reading times for that sentence in addition to other measures that are known to influence reading time, such as word frequency and the presence of event shifts.

Reading times for each subject in Radvansky et al. (2001) data set were included in multiple regression analyses. Because averaging over subjects and regressing the averages on the predictor variables does not adequately represent the variability of regression coefficients in the error term of a significance test, data were analyzed as recommended by Lorch and Myers (1990). For each individual, reading times were regressed on number of syllables, sentence position, number of new arguments, mean word frequency, argument overlap, and the six shift types (Space, Absolute Time, Relative Time, Entity, Goal, and Causal). Next, a second version of each regression model was made that included expectedness rating as a factor. This resulted in two separate regression equations for each of the 157 subjects. The standardized beta weight for each predictor was then entered into a one-sample t-test to determine if it differed reliably from zero. The standardized beta weights for each of these variables are presented in Table 3. As can be seen, the situation model variables were all significantly different from zero ($p < .01$) with the exception of the spatial and relative time variables;
note that because the scale runs from least to most expected, the negative coefficient indicates that reading times decreased as expectedness increased.

The results of Pilot Study 2 suggest that reading times increase in response to shifts along several situation model dimensions as well as to sentences that contain information that is not expected. Pilot Study 2 is subject to the same limitations to as Pilot Study 1. In addition, the materials were not designed to elicit differences in unexpectedness. As such, they conflate the type and number of shifts present in each sentence, which may have affected expectedness ratings. The experiments were designed to address these shortcomings.
### TABLE 3

**STANDARDIZED BETA WEIGHTS FOR REGRESSION MODEL VARIABLES**

<table>
<thead>
<tr>
<th>Expectedness rating</th>
<th>Syllables</th>
<th>Position</th>
<th>New arguments</th>
<th>Argument overlap</th>
<th>Mean frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not included</td>
<td>0.676*</td>
<td>-0.015*</td>
<td>0.078*</td>
<td>0.005</td>
<td>0.004</td>
</tr>
<tr>
<td>Included</td>
<td>0.680*</td>
<td>-0.016*</td>
<td>0.078*</td>
<td>0.010</td>
<td>0.003</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expectedness rating</th>
<th>Spatial</th>
<th>Absolute time</th>
<th>Relative time</th>
<th>Entity</th>
<th>Causal</th>
<th>Goal</th>
<th>Expectedness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not included</td>
<td>-0.006</td>
<td>0.021*</td>
<td>-0.009**</td>
<td>0.064*</td>
<td>0.049*</td>
<td>0.018*</td>
<td></td>
</tr>
<tr>
<td>Included</td>
<td>-0.007§</td>
<td>0.018*</td>
<td>-0.012*</td>
<td>0.063*</td>
<td>0.042*</td>
<td>0.017*</td>
<td>-0.024*</td>
</tr>
</tbody>
</table>

* *p < .01, ** p < .05, § p = .06
EXPERIMENT 1

The aim of Experiment 1 was to determine if people find sentences containing an event shift (spatial, temporal, entity, goal, or causal) more or less expected than those that do not and to assess how foreshadowing impacts expectedness. Stories were presented that contained one of the above shift types, and the shift was either foreshadowed or not.

Method

Participants

One hundred thirty people were recruited through Amazon’s Mechanical Turk™ website. Participants ranged in age from 18 to 77 ($M = 36.34$, $SD = 12.68$), and 69 females were included in the sample. Participants who failed to answer 12 of 16 comprehension questions (75%) were excluded. This resulted in the elimination of 18 participants. Participants were paid $0.50 for participation.

Materials

Forty-eight stories between six and seven sentences in length were used; an example of one of the stories used is included in Appendix A. Each story had four versions that differed in terms of whether a particular event shift occurred, and if so, if it
was foreshadowed. Thus, the possible versions of each story were No Foreshadow No Shift, No Foreshadow Shift, Foreshadow No Shift, and Foreshadow Shift (see Appendix A). Participants saw eight experimental and eight filler stories; stories were randomized and counterbalanced. Only one event boundary occurred in each target sentence. There were eight stories for each of five shift types, plus the additional eight filler stories. Causal shifts were included as a baseline comparison of the influence of a causal shift on processing. Because, by definition, a foreshadowed causal shift is not a causal shift these stories were analyzed separately. After each story participants were asked to answer a single true/false comprehension question to ensure that they were actually reading the materials. These comprehension questions pertained to non-shift story information.

Procedure

Participants read eight experimental and eight filler stories. After reading a brief description of the experiment and providing informed consent, they read instructions explaining how to progress through the experiment. Participants were told to press the space bar to advance to the next sentence of each story. Sentences were presented one at a time, and participants were asked to rate the expectedness of each sentence based on the one that immediately preceded it. Ratings were made on a scale of one (Completely Expected) to seven (Completely Unexpected). Experimental story versions were presented in one of four subsets that were randomized with the restriction that the first story was a filler story to familiarize participants with the task.

Participants were also asked to provide demographic information and information regarding the testing environment at the end of the experiment. Demographic information
included participant’s gender, age, highest education level attained, ethnicity, handedness, and whether the person is a native English speaker. Environmental information included noise level, type of device used to respond, type of Internet connection, and alertness level. Data from two subjects who indicated they were not native English speakers or who completed the task on a smart phone or tablet were replaced. Finally, participants read a debriefing screen and received a code for compensation.

Results and Discussion

Because the main concern in Experiments 1 and 2 is the effect of foreshadowing on the dependent variables, ratings were collapsed across stories, and the analyses were done at the item level. The ratings for each condition are reported in Table 4 and the means are presented Figure 1. The data were submitted to a 2 (Foreshadow) x 2 (Shift) x 4 (Shift Type) repeated measures ANOVA.

The main effects of Foreshadow, $F(1,28) = 6.38, MSE = 0.897, p = .02, \eta^2 = 0.19$, and Shift, $F(1,28) = 16.07, MSE = 1.20, p < .001, \eta^2 = 0.36$ were significant, but the main effect of Shift Type was not, $F < 1$. Neither the Foreshadow x Shift Type nor the Shift x Shift Type interactions were significant; $F(3,28) = 1.05, p = .39, F(3,28) = 1.61, p = .21$, respectively. Importantly, the Foreshadow x Shift interaction was significant, $F(1,28) = 11.71, MSE = 0.720, p = .002, \eta^2 = 0.29$. Simple effects tests revealed that for the No Foreshadow condition, the effect of Shift was significant, $F(1,31) = 34.08, MSE = 0.782, p < .001, \eta^2 = 0.52$, but it was not for the Foreshadow condition, $F < 1$. Additionally, the three-way interaction was not significant, $F < 1$. This suggests that the most surprising
event was an unforeshadowed shift. Ratings in this condition were the highest, while foreshadowing reduced the surprise rating to the point where it was no longer significantly different from the No Shift conditions.

### TABLE 4

**MEAN EXPECTEDNESS RATINGS**

**BY SHIFT TYPE**

<table>
<thead>
<tr>
<th>Condition</th>
<th>No Foreshadow</th>
<th>Foreshadow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Shift</td>
<td>Shift</td>
</tr>
<tr>
<td>Combined</td>
<td>3.04 (0.17)</td>
<td>4.34 (0.22)</td>
</tr>
<tr>
<td>Spatial</td>
<td>2.86 (0.37)</td>
<td>4.84 (0.52)</td>
</tr>
<tr>
<td>Temporal</td>
<td>2.91 (0.32)</td>
<td>3.60 (0.23)</td>
</tr>
<tr>
<td>Goal</td>
<td>2.88 (0.38)</td>
<td>4.18 (0.45)</td>
</tr>
<tr>
<td>Entity</td>
<td>3.54 (0.33)</td>
<td>4.71 (0.48)</td>
</tr>
<tr>
<td>Causal</td>
<td>2.92 (0.32)</td>
<td>5.25 (0.36)</td>
</tr>
</tbody>
</table>

*Note. Combined does not include causal stories. Standard Errors appear in parentheses below means.*
Because the foreshadowing sentence in causal stories should effectively act as the shift, making the Foreshadowed Shift and Foreshadowed No Shift conditions equivalent, data for these stories were separately submitted to a 2 (Foreshadow) x 2 (Shift) ANOVA. The main effect of Foreshadow was not significant, $F(1,7) = 2.60, MSE = 1.493, p = .15, \eta^2 = 0.27$, but the main effect of Shift was, $F(1,7) = 10.78, MSE = 1.09, p = .013, \eta^2 = 0.61$. The Foreshadow x Shift interaction was also significant; $F(1,7) = 14.98, MSE = 0.673, p = .006, \eta^2 = 0.68$. Simple effects tests revealed that for the No Foreshadow condition, the effect of Shift was significant $F(1,7) = 28.14, MSE = 0.774, p = .001, \eta^2 = 0.80$, but it was not for the Foreshadow condition, $F < 1$. The causal shift ratings mirror

Figure 1: Mean expectedness ratings (excluding causal shifts)
those reported above, again suggesting that the most surprising event is a shift that is not foreshadowed, while the other three conditions do not differ.

Overall, the pattern of results for Experiment 1 suggests that foreshadowing an event shift reduces the surprise with which readers react to that event. People rated the sentence containing the shift as less expected when it was not preceded by a sentence that explained what was about to happen, and this effect did not depend on shift type. Additionally, for the causal stories, the effect of foreshadowing also reduced the surprise elicited by a shift, as expected. These results lend support to the idea that expectedness, and by extension, causal connectedness, plays a role in determining when a situation model is updated. The next question is whether these sentences, even when expected, are still recognized as conveying a shift. This issue was explored in Experiment 2.
EXPERIMENT 2

The aim of Experiment 2 was to assess the degree to which foreshadowing affects the detection of event shifts. The question of interest was: will readers still segment an event at a shift even if it is foreshadowed? Participants read stories and made responses indicating when a change in the event had occurred. This task is similar to those used in other studies of event segmentation in which participants identify meaningful units of action (e.g. Newtson, 1973; Kurby & Zacks, 2008). Again, the shift was either foreshadowed or not.

Method

Participants

One hundred twenty-eight people were recruited through Amazon’s Mechanical Turk™ website. Participants ranged in age from 18 to 62 ($M = 33.76$, $SD = 10.00$), and 69 females were included in the sample. Participants who failed to answer 12 of 16 comprehension questions (75%) were excluded. This resulted in the elimination of 23 participants. Participants were paid $0.50 for participation.
Materials and Procedure

The same materials in the same counterbalanced presentation order were used as in Experiment 1. The procedure was also the same with the following modification: Instead of rating how expected each sentence was, participants were instructed to indicate whether the situation had changed after each sentence by responding yes or no. They were told that the definition of a change was up to them and that any change could give them the sense that the situation had changed in a meaningful way.

Results and Discussion

As in Experiments 1, ratings were collapsed across stories, and the analyses were done at the item level. The ratings for each condition are reported in Table 5 and Figure 2. The data were submitted to a 2 (Foreshadow) x 2 (Shift) x 4 (Shift Type) repeated measures ANOVA.

The main effects of Foreshadow, $F < 1$, and Shift Type, $F < 1$ were not significant, but the main effect of Shift was, $F(1,28) = 35.25, MSE = 0.047, p < .001, \eta^2 = 0.56$, so people identified shifts in all conditions. The Foreshadow x Shift Type, $F < 1$, Shift x Shift Type, $F < 1$, and Foreshadow x Shift interactions were not significant, $F(1,28) = 1.91, MSE = 0.037, p = .18$. Finally, the three-way interaction was not significant, $F (3,28) = 1.24, MSE = 0.037, p = .31, \eta^2 = .12$. Even when people had knowledge that a shift was likely to occur, they still recognized the shift on reading the sentence that conveyed it. The lack of interaction between Foreshadow and Shift suggests that the foreshadowing does not “erase” the shift, in comparison to Experiment 1 in which the foreshadowing did reduce the surprise associated with it.
TABLE 5

PROPORTION OF PARTICIPANTS WHO IDENTIFIED A SHIFT BY SHIFT TYPE

<table>
<thead>
<tr>
<th>Condition</th>
<th>No Foreshadow</th>
<th></th>
<th>Foreshadow</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Shift</td>
<td>Shift</td>
<td>No Shift</td>
<td>Shift</td>
</tr>
<tr>
<td>Combined</td>
<td>0.288 (0.04)</td>
<td>0.562 (0.04)</td>
<td>0.306 (0.05)</td>
<td>0.486 (0.04)</td>
</tr>
<tr>
<td>Spatial</td>
<td>0.309 (0.09)</td>
<td>0.675 (0.06)</td>
<td>0.328 (0.09)</td>
<td>0.469 (0.11)</td>
</tr>
<tr>
<td>Temporal</td>
<td>0.327 (0.06)</td>
<td>0.494 (0.12)</td>
<td>0.286 (0.10)</td>
<td>0.544 (0.07)</td>
</tr>
<tr>
<td>Goal</td>
<td>0.228 (0.09)</td>
<td>0.571 (0.08)</td>
<td>0.267 (0.11)</td>
<td>0.403 (0.07)</td>
</tr>
<tr>
<td>Entity</td>
<td>0.289 (0.08)</td>
<td>0.508 (0.09)</td>
<td>0.341 (0.10)</td>
<td>0.528 (0.06)</td>
</tr>
<tr>
<td>Causal</td>
<td>0.271 (0.06)</td>
<td>0.687 (0.05)</td>
<td>0.238 (0.06)</td>
<td>0.530 (0.09)</td>
</tr>
</tbody>
</table>

Note. Combined does not include causal stories. Standard Errors appear in parentheses below means.

Again, causal data were analyzed separately because the foreshadowing sentence should act as a shift in the stories. Data were submitted to a 2 (Foreshadow) x 2 (Shift) repeated measures ANOVA. The main effect of Foreshadow was significant, $F(1,7) = 7.00, MSE = 0.010, p = .03, \eta^2 = 0.50$, as was the main effect of Shift, $F(1,7) = 16.70, MSE = 0.060, p = .005, \eta^2 = 0.70$. The interaction was marginally
significant; $F(1,7) = 4.51$, $MSE = 0.007$, $p = .07$, $\eta^2 = 0.40$. Analysis of each level of Foreshadow separately revealed a trend for a stronger Shift effect in the No Foreshadow condition than the Foreshadow condition; $F(1,7) = 28.88$, $MSE = 0.024$, $p = .001$, $\eta^2 = 0.81$, and $F(1,7) = 7.96$, $MSE = 0.043$, $p = .026$, $\eta^2 = 0.53$, respectively.

The pattern of results for Experiment 2 suggests that even when an event shift is foreshadowed, the change in the event is still recognized as such. This was true even for causal stories where the foreshadowing could serve as a shift itself. In these cases people still recognize that a shift has occurred following the foreshadowing.

![Figure 2: Mean proportion shift identification (excluding causal shifts)](image-url)
EXPERIMENT 3

The aim of Experiment 3 was to measure online processing when an event shift is encountered after foreshadowing or not. If causal connectedness plays a role in the amount of processing required, it is expected that reading times should not increase as much at event shifts when the shift is foreshadowed. Participants read stories and answered comprehension questions to ensure that they were paying attention. As the primary dependent measures, reading times for the critical sentence were collected and analyzed.

Method

Participants

One hundred ninety-eight people were recruited through Amazon’s Mechanical Turk™ website. Participants ranged in age from 19 to 80 ($M = 35.90$, $SD = 12.63$), and 92 females were included in the sample. Participants who failed to answer 12 of 16 comprehension questions (75%) were excluded. This resulted in the elimination of 36 participants; two additional participants were replaced because they were not native English speakers. Participants were paid $1.00 for participation.
Materials and Procedure

The same materials in the same counterbalanced presentation order were used as in Experiment 1. The procedure was also the same with the following modification: Participants were not asked to make any response after each sentence. Instead they were instructed to simply read the stories and answer the comprehension questions at the end.

Results and Discussion

Again, because a foreshadowed causal shift should not be treated as a shift, causal stories were analyzed separately. Eight participants read each version of the experimental stories. Reading times less than 50 ms/syllable or greater than 500 ms/syllable were trimmed. This resulted in the elimination of 89 reading times or 8.69% of the data. The remaining times were averaged, and any reading times greater than the average plus three standard deviations were trimmed. This resulted in the elimination of 17 reading times or 1.81% of the data.

The reading time data were analyzed using a multiple regression mixed-effects model with participant and text as random effects. Reading time per syllable was the outcome variable and foreshadow condition, shift condition, and average word frequency per sentence, according to the Francis and Kučera (1982) written norms, were included as fixed effects. Analyses were carried out using the lme4 (Bates, Maechler, Bolker, Walker, Christensen, & Singmann, 2013) and lmerTest (Kuznetsova, Brockhoff, Christensen, 2013) packages in R (R Core Team, 2013). (Type of shift was also initially included as a fixed effect; however, inclusion of this factor did not significantly improve model fit, $\chi^2 = 6.59, p = .086$. Running the analysis with this factor did not change the
pattern or significance of the results.) Results are displayed in Table 6, and the reading
time interaction is shown in Figure 3. The main effect of Average Frequency was
significant, \( t(558.7.7) = -2.95, p = .004 \), as was the main effect of Shift, \( t(769.5) = 3.53, p < .001 \); however, the main effect of Foreshadow was not \( t < 1 \). Importantly, the
Foreshadow x Shift interaction was significant, \( t(751.9) = -2.75, p = .006 \). To test the
simple effects, the same mixed-effects model was run on the No Foreshadow and
Foreshadow condition reading times separately. For the No Foreshadow model, the effect
of Average Frequency was significant, \( t(288.5) = -3.35, p < .001 \), as was the effect of
Shift, \( t(387.4) = 4.02, p < .001 \). For the Foreshadow condition neither Average Frequency
nor Shift were significant, \( t < 1 \). So, if a shift was not foreshadowed, people significantly
slowed down on encountering it; however, if it was foreshadowed, reading times were
not significantly different in the Shift and No Shift conditions. Causal shift reading times
were trimmed according to the same criteria as the other data. This resulted in the
elimination of 12 reading times or 4.7% of the data for being too fast or too slow; three
reading times or 1.3% of the data were trimmed for being three standard deviations above
the mean. These data were also submitted to the previously described mixed-effects
model. The main effect of Average Frequency was significant, \( t(94.9) = 2.06, p = .04 \).
The main effect of Shift, the main effect of Foreshadow, and the interaction were not
significant, all \( ts < 1.32, ps > .19 \).
TABLE 6

FIXED EFFECTS RESULTS

FOR EXPERIMENT 3

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Standard Error</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Frequency</td>
<td>-0.004</td>
<td>&lt;.001</td>
<td>558.7</td>
<td>-2.95</td>
<td>0.003</td>
</tr>
<tr>
<td>Foreshadow</td>
<td>4.0</td>
<td>4.01</td>
<td>756.3</td>
<td>0.98</td>
<td>0.328</td>
</tr>
<tr>
<td>Shift</td>
<td>15.1</td>
<td>4.27</td>
<td>769.5</td>
<td>3.53</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Foreshadow x Shift</td>
<td>-16.1</td>
<td>5.86</td>
<td>751.9</td>
<td>-2.75</td>
<td>0.006</td>
</tr>
<tr>
<td>No Foreshadow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Frequency</td>
<td>0.004</td>
<td>&lt;.001</td>
<td>288.5</td>
<td>-3.35</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Shift</td>
<td>18.4</td>
<td>4.58</td>
<td>387.4</td>
<td>4.02</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Foreshadow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Frequency</td>
<td>-0.002</td>
<td>0.0006</td>
<td>247.6</td>
<td>-0.33</td>
<td>0.740</td>
</tr>
<tr>
<td>Shift</td>
<td>-1.19</td>
<td>4.65</td>
<td>427.3</td>
<td>-0.26</td>
<td>0.798</td>
</tr>
<tr>
<td>Causal Stories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Frequency</td>
<td>0.001</td>
<td>&lt;.001</td>
<td>94.9</td>
<td>2.05</td>
<td>0.043</td>
</tr>
<tr>
<td>Foreshadow</td>
<td>-8.1</td>
<td>11.5</td>
<td>191.3</td>
<td>-0.70</td>
<td>0.483</td>
</tr>
<tr>
<td>Shift</td>
<td>-15.3</td>
<td>11.6</td>
<td>213.1</td>
<td>-1.32</td>
<td>0.188</td>
</tr>
<tr>
<td>Foreshadow x Shift</td>
<td>-9.2</td>
<td>15.5</td>
<td>165.5</td>
<td>-0.60</td>
<td>0.552</td>
</tr>
</tbody>
</table>
The results of Experiment 3 suggest that reading times are influenced by foreshadowing. When an event shift was foreshadowed, reading times were significantly faster than when the shift was not foreshadowed. This suggests that foreshadowing helps readers integrate the new information, and makes it easier for them to process the shift. The reduction in mental effort required is reflected in the reduction in reading times. In the No Shift condition, foreshadowing did not have an effect, as expected. The causal reading time data did not show the expected interaction. A possible explanation for this result is reviewed in the General Discussion.
GENERAL DISCUSSION

The results of the three experiments demonstrate that during reading comprehension information encountered prior to an event shift can affect how that shift is processed. The results of Experiment 1 show that knowing a shift is likely to occur changes the reader’s perception of that shift. What might, by itself, be surprising to the reader becomes less surprising with foreshadowing. This was demonstrated by the finding that the Foreshadow and Shift conditions interacted, and the most unexpected sentences were those in the No Foreshadow-Shift condition.

One possible explanation of the results of Experiment 1 is that the foreshadowing sentence acts as a shift. If this is the case, then the shift sentence should no longer be recognized as a shift because the foreshadowing sentence is filling this role. Experiment 2 demonstrated that, even when the shift was foreshadowed, participants still identified a change in the situation after reading the shift-conveying sentence. Even for causal shifts, where the foreshadowing is expected to replace the shift, people responded that there was a change in the situation. This result may be an artifact of the stories themselves. To avoid a potential confound between incremental and global updating, all the shift sentences were written to be maximally obvious and disruptive to the reader. In the case of spatial shifts, for example, the change in location was more drastic than moving from one room to another; instead, the protagonist would move to a different building or city.
In causal shift sentences, the protagonist would react to the change in a sudden manner. The abruptness of this behavior could still lead to the reader identifying a change in the situation even after foreshadowing.

Experiment 3 examined the relationship between prior warning of an event shift and a measure of online processing – reading time. As with the expectedness data, there was an interaction between the Foreshadow condition and Shift condition. Reading times for Shift sentences were significantly faster when the shift was foreshadowed, indicating that people were not disrupted in their comprehension of the stories. This result supports the idea that information encountered prior to an event shift can impact the amount of processing required to comprehend the sentence. As was the case with the segmentation task in Experiment 2, causal shifts did not show the same interaction as the other situation model variables. In this case it would be expected that reading times for the No Foreshadow-Shift condition would be significantly longer than the other three. This is because the reader would have already updated at the foreshadow sentence or the lack of shift would eliminate the need to update altogether. One possible explanation for the lack of interaction is that the readers are slower in the Foreshadow-No Shift condition because their expectations are being subverted. That is, they are expecting there to be a shift when there is not one. As such, this might be viewed as a causal break of a different variety. Graesser et al. (1994) suggest that in their attempt to integrate new information, readers assume that there is a reason the author chooses to express each clause. The foreshadowing sentence may create the expectation that something is about to change, and the reader is confused when it does not, which results in a longer reading time for the No Shift sentence.
Overall, the data support the idea that causality plays a role in determining the ease with which new information can be integrated into the current event model during reading comprehension. The finding that people read foreshadowed shift sentences faster than non-foreshadowed shift sentences suggests that less mental effort is required to incorporate the shift and supports the idea that the ease with which information encountered at a shift can be causally connected to pre-shift information is a factor in the additional processing required to comprehend a shift sentence. That is, the reading time increase that has been observed in prior work is due in part to the need to update a situation model along a given dimension, but also, in part, due to the unexpectedness of the event shift itself.

Future research in this area could address the effect of the ease of making causal connections on later memory for information contained in different event models. For example, it may be that when the cause of a shift is easily connected to the current model, it is easier to incorporate the new information, and there would be better recall of previously encountered information than there otherwise would be. The reduced amount of processing required to incorporate the shift may make the previously encountered information more available. However, it is also possible that the current model maintains its privileged status in working memory regardless of the amount of processing needed to create it. Previous research has found that people remember more information from texts that contain a shift than those that do not (Thompson, 2014). Reducing the amount of effort needed to process a shift may impact the amount of information subsequently remembered because more mental resources can be used to retain the information.
Understanding these issues could aid the creation of training or educational materials by designing the text in such a way that the ultimate retention of information is maximized.
Example Temporal Shift Story

Jenny was listening to the radio.
She had been stressed all day and was finally unwinding.
The d.j. was spinning some really great stuff.
\textbf{She really liked this song, especially the pounding bass line. (No Foreshadow)}
\textbf{She turned up the volume and adjusted the bass level. (No Shift)}
It was loud enough to rattle her windows.

\hline

\textbf{No Foreshadow Shift}

Jenny was listening to the radio.
She had been stressed all day and was finally unwinding.
The d.j. was spinning some really great stuff.
\textbf{She really liked this song, especially the pounding bass line. (No Foreshadow)}
The next morning she got up and turned on the radio. (Shift)
The morning crew was talking about traffic, so she switched it off.

\hline

\textbf{Foreshadow No Shift}

Jenny was listening to the radio.
She had been stressed all day and was finally unwinding.
The d.j. was spinning some really great stuff.
\textbf{Unfortunately, she would have to call it a night soon. (Foreshadow)}
\textbf{She turned up the volume and adjusted the bass level. (No Shift)}
It was loud enough to rattle her windows.

\hline

\textbf{Foreshadow Shift}

Jenny was listening to the radio.
She had been stressed all day and was finally unwinding.
The d.j. was spinning some really great stuff.  
**Unfortunately, she would have to call it a night soon. (Foreshadow)**  
The next morning she got up and turned on the radio. (Shift)  
The morning crew was talking about traffic, so she switched it off.
REFERENCES


University of Notre Dame, Indiana.


