Stage salience and situational likelihood in the formation of situation models during sentence comprehension

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Abstract

Two experiments examined the relation between event structure, situational likelihood and eye fixation time while reading predicate modifiers in isolated sentences. Experiment 1 used activity predicates and preparatory process predicates (*climbed a mountain*), which make salient the process that leads to a culmination. Preparatory process predicates increased first pass time on durative modifiers (*for several years*) and decreased total time on frequency modifiers (e.g., *every year*). Situational likelihood was associated with fixation times on frame modifiers (*last year*) but not with fixation times on durative or frequency modifiers. Experiment 2 used activity predicates and result state predicates (*halted a class*), which make salient the result that follows from a culmination. Result state predicates had no effect on fixation times on durative modifiers and decreased total time on frequency modifiers. Situational likelihood was associated only with total time on durative modifiers. These results demonstrate that readers use the meanings of predicates and modifiers to form an initial model of a sentence and that the likelihood of the reported situation is related to reading time relatively late. The results are discussed in terms of type coercion theory and situation models in sentences and narratives.
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Two theories have dominated research on temporal interpretations in language processing. Situation model theory (Zwaan, 1999, p. 15) explains how readers use gaps in time and other properties of text as signals of event shifts and revisions of situation models, that is, mental representations of what a text is about (see also Johnson-Laird, 1983; Radvansky, 2012; Van Dijk et al., 1983). Type coercion theory (Jackendoff, 1997; Pustejovsky, 1993; Pylkkänen and McElree, 2006) explains how readers use incompatible meanings between phrases to revise an aspectual interpretation, that is, the when, for how long and how often of an event. The present research demonstrates that the meanings of verbs rapidly elicit a likely representation of what a sentence is about that readers revise according to temporal modifiers and evaluate according to background knowledge. These sentence-level models are the foundation of the spatial-temporal-causal gaps that signal event shifts in narratives.

Situation model theory proposes that readers maintain mental representations of what a text is about (Radvansky, 2012; Zwaan and Radvansky, 1998; Zwaan, 1999). Gaps in time, causal chains, protagonists, goals, and locations lead to

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revisions of the model. For example, modifiers such as *a few days later* or *the next morning* signal the end of an event and lead to revision of the model (Radvansky, 2012; Zwaan and Radvansky, 1998). Revising a situation model can increase cognitive effort and reading time (Radvansky and Copeland, 2010; Rinck and Weber, 2003). In some cases, reading time may increase because of the reader's surprise at receiving unexpected information rather than the cognitive effort of revising a model. For example, compared to a foreshadowing context sentence such as *She would have to call it a night soon*, a neutral context sentence such as *She really liked this song* produces longer reading time for a target sentence such as *The next morning she got up* (Pettijohn and Radvansky, 2016). The foreshadowing context sentence apparently activates a script that includes sleeping until morning, increasing the likelihood that the narrative will report that she got up in the morning and reducing reading time for a sentence that reports that event.

Maintaining and revising situation models occurs in sentence processing as well (Johnson-Laird, 1983). Evidence that revisions of situation models occur in sentence processing comes from observations that the initial word of *Before/After the psychologist submitted the manuscript, the journal changed its policy* produces distinct patterns of brain activity (Münte et al., 1998; Zwaan, 1999) and behavior (Clark, 1971; Townsend, 1983; Townsend and Ravelo, 1980). Just as readers keep track of causal–temporal relations between sentences in text, they keep track of these relations between the clauses of isolated sentences (Townsend, 1983; Zwaan, 1999). Moreover, the imperfective form *was delivering* and the perfective form *delivered* produce behavioral differences that suggest interpretations of background information vs. event boundaries respectively in narratives (Magliano and Schleich, 2000) and in isolated sentences (Yap et al., 2009). These studies demonstrate that the effects of processing situation models in text appear as well in isolated sentences.

The situation model of a sentence includes how long an event lasts, whether it has an inherent end, and how often it occurs. This model depends on the event structure of the predicate of the sentence. For example, *crossed a street* and *watched a street* differ in event structure (Smith, 1997). The telic predicate *crossed a street* has an inherent end in which the state of the protagonist changes to being on the other side of the street. We can demonstrate its telicity by noting that *was crossing a street* does not mean that the protagonist definitely crossed a street: while the protagonist was crossing the street, some event may have prevented reaching the other side. The atelic predicate *watched a street* does not have an inherent end. We can demonstrate its atelicity by noting that *was watching a street* means that the protagonist did watch a street regardless of what other events may have occurred (Vendler, 1957). As with perfective form, telic sentences such as *The next morning she got up* move narrative time forward and are likely to produce an event shift because of the temporal gap that *the next morning* denotes (Pettijohn and Radvansky, 2016) or because of the change of state that *she got up* denotes. As with imperfective form, atelic sentences such as *she adjusted the volume* do not move narrative time but instead may describe the setting for upcoming events (Dowty, 1986; Hinrichs, 1986; Madden and Ferretti, 2009). The event structure of predicates contributes to the situation models of sentences and texts.

The preferred model for a sentence can change as the reader recognizes more words and phrases (Johnson-Laird, 1983; Moens and Steedman, 1988). For example, the reader initially may prefer an atelic model of *John walked*. If the phrase that follows *John walked* is *to school*, the preferred model shifts to telic because *to school* establishes a culmination of walking and a change in the protagonist's state. If the phrase that follows *John walked to school* is the durative modifier *for several days*, the preferred model now shifts to an atelic (iterative) interpretation of a series of walk-to-school events. These observations suggest that studying the effects of phrases on reading time in sentences can reveal the mechanisms of forming situation models. A phrase that is consistent with the working situation model confirms the model. One that is inconsistent leads to a revision.

Studies of aspectual interpretation in sentences often explain re-interpretations in terms of "type coercion" (Jackendoff, 1997; Pustejovsky, 1991; Pylkkänen and McElree, 2006). According to type coercion theory, a temporal modifier is a function that takes a predicate as its input (Moens and Steedman, 1988). When the aspectual type of the predicate does not match the type that the modifier requires, the modifier coerces the predicate into the type that the modifier requires. For example, the durative modifier *for several days* requires an atelic predicate as in *watched a street*. As noted earlier, when the predicate is telic as in *walked to school*, the modifier *for several days* coerces *walked to school* into the atelic interpretation of a series of walk-to-school events. Neurological and behavioral studies demonstrate that aspectual incompatibility between predicates and modifiers can increase cognitive effort (Bott, 2010; Brennan and Pylkkänen, 2008; Kuperberg et al., 2010; Paczynski et al., 2014; Pickering et al., 2006; Proctor et al., 2004; Stockall and Husband, 2014; Todorova et al., 2000; Townsend, 2013).

Telic predicates can differ in how salient or accessible they make different stages of an event. The prototypical event has a preparatory process that leads to a culmination that usually corresponds to a change of state (Caudal, 2005; Moens and Steedman, 1988). The preparatory process is salient in *crossed a street*, consisting of walking from one side of the street until just before the last step onto the other side. That last step is the culmination of the preparatory process and it changes the protagonist's state to being on the other side, setting up the possibility of an event shift in the narrative-level situation model.

On the other hand, the result of the culmination is salient in *opened a window* (Caudal, 1999; Pinón, 1999). As with imperfective forms and atelic predicates, predicates in which the result of a culmination is salient makes a durative