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Time in Language, Situation Models, and Mental Simulations

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The purpose of this article is to propose a view of language processing, and particularly the role of aspect therein, from a mental-simulation perspective. I argue that situation model theories can account for the flow between and interconnectedness of event representations but that mental simulation theories are needed to account for the internal structure of event representations. The article concludes with some speculative thoughts on how simulation theories might accomplish this intellectual feat.

Introduction

As with so many things, the study of the role of time in language dates back to Aristotle, who, in his *Poetics*, decreed how events should be reported in fictional versus historical narrations. Cognitive psychological research on the topic is much more recent, originating in the 1980s. Research on the role of temporal markers in language comprehension became "timely" with the advent of the notions of mental model (Johnson-Laird, 1983) and situation model (Van Dijk & Kintsch, 1983). The main thrust of these theories was that the essence of language comprehension is not to create a mental representation of the linguistic input per se, as had previously been thought, but to create a mental representation of the situation described by the linguistic input, a situation model. The building blocks of situation models are representations of individual events and actions. A central question in situation-model research became how these event representations are integrated in memory to represent the overall comprehension of a piece of discourse.

Situation Models

According to the Event-Indexing Model (e.g., Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998; see

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also Speer & Zacks, 2005; Speer, Zacks, & Reynolds, 2007), event representations formed during language comprehension are integrated into the unfolding mental representation on five dimensions: time, space, entity, causation, and intentionality. To the extent that an event shares an index with the active part of the current mental representation (e.g., the same time frame, the same spatial location, or the same goal/plan structure), it is easier to integrate and more strongly connected in the resulting long-term memory representation. Later research has shown the effects of dimensional overlap to be additive (Zwaan, Radvansky, Hilliard, & Curie, 1998; Rinck & Weber, 2004).

Zwaan (1996) provided evidence for the role of situational overlap on the temporal dimension. This study examined how readers' tracking of the passage of time, one of the five dimensions of the Event-Indexing Model, can affect online comprehension and long-term memory of text. Time shifts are common events in narratives (e.g., *Later that day* or *A few weeks later*). When they occur, the speaker or writer can use the shift to omit events that are deemed irrelevant to the plot (of course, Aristotle did not accord such poetic license to historians). For example, we usually do not need know that the main character in a novel has brushed his teeth or tied his shoes. We could not care less. In fact, when such mundane events are actually reported in a story, it is usually a clue that they will become relevant later (like Chekhov's proverbial gun). The omission of these types of events in a story can be signaled by a time shift such as *an hour later*.

Zwaan (1996) created stories that came in three versions. In the *moment* version, the temporal adverbial *a moment later* was used. The assumption was that "a moment" does not constitute a time shift of any temporal magnitude on a human scale and thus maintains the current time frame. In the *hour* and *day* versions, the critical phrases were *an hour later* and *a day later*, respectively. These adverbial phrases should engender a shift to a new time frame. Following one of these shifts, participants were asked to identify whether a probe word had appeared in the story. Probe words were selected from descriptions preceding the temporal adverbial. The findings were consistent with the previously described assumptions of the Event-Indexing Model. Responses to probe words were significantly longer in the *hour* and *day* versions than in the *moment* versions, suggesting that the time shift made the previous event less accessible. A primed-recognition task performed after all of the stories had been read showed that when events occurred within the same time frame, they showed more priming than when these same events were separated by a time shift (both in the *hour* and *day* cases). This suggests that events from the same time frame are more strongly connected in long-term memory than events from different time frames. Subsequent studies have provided more support for the Event-Indexing Model (see Zwaan & Rapp, 2006, for a recent overview).

Situation-model theories such as the Event-Indexing Model are useful in that they make predictions about the relations between and among event representations. As such, they are aimed at the macrolevel of event representation. However, they are silent about the microlevel of event representations: the internal temporal contour, or aspect, of the events in question. There have been several studies on the role of aspect in language comprehension (e.g., Carreiras, Carriedo, Alonso, & Fernandez, 1997; Ferretti, Kutas, & McRae, 2007; Madden & Zwaan, 2003; Magliano & Schleich, 2000; Zwaan, Madden, & Whitten, 2000). In the most detailed study of this kind, Ferretti and colleagues proposed that verb aspect highlights different elements of a basic event structure. Following Moens and Steedman (1988), they assumed that basic event structures consist of initiating conditions (which have agents and instruments associated with them), the actual event (which has agents, instruments, patients, and locations associated with it), and the resultant state (which has patients associated with it). Imperfective aspect (e.g., *was skating*) was thought to preferentially activate the actual event (and thus agents, instruments, patients, and locations), whereas perfective aspect (e.g., *had skated*) was hypothesized to highlight the resultant state (and thus patients). One directly testable prediction from this view is that event components associated with the actual event should be more strongly activated by the imperfective aspect than by the perfective aspect. Ferretti et al. found evidence for this and other predictions. In an eye-movement study, Altmann and Kamide (2007) obtained converging evidence. Upon hearing a perfective sentence while looking at a computer monitor displaying four objects, subjects looked at an empty glass upon hearing *He had drunk the beer* rather than at a full beer glass.

Mental Simulation

The notion of mental simulation provides a suitable theoretical framework for studying phenomena such as these. Whereas situation-model theories tend to treat events as empty nodes, simulation theories go “inside the node.” An ecumenical approach would view the model-building perspective and the simulation perspective as complementary. The former provides insights into the flow between event representations and their interconnectedness in memory, whereas the latter provides insight into the internal structure of the event representations. A brief overview of mental simulation theories may help clarify this point.

Potentially important clues about the comprehension process come from a prima facie unlikely source: single-cell recordings in the brain of the macaque monkey. Rizzolatti and colleagues were measuring activity in area F5, for which hitherto no important function had been identified (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga,Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Fogassi, & Gallese, 1996). They discovered that neurons in this area fired not only when the monkey performed an action but also when it observed the experimenter perform the same action (grasping food). This discovery gave rise to the idea that the firing pattern that occurred during action observation actually reflected the monkey's understanding of the experimenter's action (Rizzolatti, Fogassi, & Gallese, 2001). It was using its own motor program for performing the same action to understand what was going on. Mirror neurons can be narrowly or broadly tuned (Gallese et al., 1996). Broadly tuned mirror neurons not only respond when the observed action directly corresponds to the action for which they are coded but also when there is a looser correspondence—for example, when the observed action is performed by a conspecific (e.g., a human) or with or without a tool (Ferrari, Rozzi, & Fogassi, 2005). Thus, because of the presence of broadly tuned neurons, the mirror system can abstract away from specific features of the observed action. Because area F5 in the monkey brain is considered the homologue of Broca's area in the human left-frontal cortex, the link between the mirror system and language was readily made (Rizzolatti & Arbib, 1998). This has led to a flurry of behavioral and neuroimaging studies examining the role of the motor system in the comprehension of language-mediated actions, either of single words or entire sentences. It is important to realize, however, that the role of the motor system in language comprehension is studied from a variety of theoretical perspectives, rather than exclusively from the perspective of mirror system theory (see Fischer & Zwaan, in press; Kemmerer, 2006; and Wilson & Knoblich, 2005, for recent reviews).

Paralleling this development was a more perceptually oriented development ignited by Barsalou's (1999) theoretical proposal of concepts as multimodal mental simulations, based in part on earlier work by Damasio (1989) (see also Rubin, 2006; Zwaan, 2004). Briefly, the idea is that thinking about a concept, or exposure to a corresponding word, will reactivate prior experiences with the concepts. Traces of these experiences are stored multimodally in the brain (e.g., visual experiences in the visual areas, tactile experiences in the tactile areas, and motor experiences in the motor cortex). Higher association areas, which Damasio dubs "convergence zones," code for which brain areas were simultaneously active, such that activation of neurons in these areas will activate the primary areas, thereby reactivating the multimodal experience. At the level of behavior, this should lead to interactions between sensorimotor performance and more "cognitive" tasks, such as language processing. As with mirror system theory, Barsalou's perceptual-symbol theory has given rise to a rapidly increasing number of empirical studies yielding support for the general tenets of the theory (e.g., Dijkstra, Kaschak, & Zwaan, 2007; Estes, Verges, & Barsalou, 2008; Goldberg, Perfetti, & Schneider, 2006; Kemmerer, Gonzalez Castillo, Talavage, Patterson, & Wiley, in press; Meteyard, Baharami, & Vigliocco, 2007; Pecher, Zeelenberg, & Barsalou, 2003; Richardson, Spivey, Barsalou, & McRae, 2003; Shintel, Nusbaum, & Okrent, 2006; Stanfield & Zwaan, 2001; Zwaan, Madden, Yaxley, & Aveyard, 2004; Zwaan, Stanfield, & Yaxley, 2002). Just to mention one example, Meteyard et al. (2007) found that incidental exposure to words implying vertical motion affected low-level vision of motion. Thus, there is considerable evidence for the role of sensorimotor representations in thought and language comprehension.

Linguistic Constraints on Mental Simulation

How can a simulation view on the unfolding of event representations inform us about language comprehension and, particularly, the role of aspect therein? Fischer and Zwaan (2008) noted that although it is tempting in light of the enthusiasm generated by the mirror system theory to view the comprehension of action sentences as a kind of action observation, it is important not to overlook the differences between the direct observation of an action and the comprehension of a linguistic description of that action. They listed three differences. First, directly observing an action provides analogue online temporal information about the action's unfolding, whereas language by virtue of its discrete nature (at the semantic level) does not. For example, in reading, the speed with which a described event is processed is codetermined by a number of factors unrelated to the manner of the action (lexical access, syntactic processes, etc.).

Second, even if it would take as long to hear or read, say, *He opened the door* as it would to physically carry out and/or observe the corresponding action, this would still not imply a close temporal correspondence between action observation and language comprehension. The action does not unfold in the comprehender's mind as each word is being processed. For example, we do not know what the protagonist is opening until we encounter the noun phrase. For all we know, he or she could be opening an envelope, his eyes, or a bank account, all of which involve different motor processes than opening a door (in fact, it is not even clear what kind of motor program would be relevant to understanding a sentence about opening a bank account, but more about this later). This means, in effect, that the relevant motor program cannot be accessed until a certain "uniqueness point" in the sentence has been reached at which sufficient motor-relevant information has accrued. Empirical evidence suggests that motor resonance occurs at such loci in the sentence rather than merely at verbs (Taylor, Lev-Ari, & Zwaan, in press; Taylor & Zwaan, 2008; Zwaan & Taylor, 2006). Does this mean, then, that no motor activation occurs when the verb is processed? Not necessarily. There is empirical evidence that action verbs produce motor activation in a somatotopic fashion; that is, verbs denoting hand actions activate the hand area, verbs denoting mouth words activate the mouth area, and verbs denoting leg words activate the leg area (Hauk, Johnsrude, & Pulvermüller, 2004). It would be in keeping with connectionist models of sentence processing to assume that this presumably diffuse activation of a set of motor programs is produced by the verb and is then narrowed down to a specific program when the uniqueness point of the sentence is reached. Although plausible, this hypothetical scenario still needs to be tested empirically.

The third difference between action observation and language comprehension identified by Fischer and Zwaan (2008) is that a great deal of information can be omitted from a linguistic description that is explicit during action observation. A sentence does not have to include a description of the actor or the patient, nor of the manner in which the action is being performed. For instance, the example sentence *He opened the door* does not specify who is opening the door other than that it is a male individual. Additionally, the sentence does not specify what kind of door we are dealing with: a house door, a room door, a car door. Importantly, this may be less of a problem than might be thought at first sight, given that sentences usually do not occur in isolation but in a context. For example, prior discourse context may sufficiently constrain the mental representation such that the nature of the action is clear once the verb is encountered, in which case it actually would be the uniqueness point. The following excerpt illustrates this point.

> Crouching down beneath the Cloak, he placed the Decoy Detonator on the ground. It scuttled away at once through the legs of the witches and wizards in front of him. A few moments later, during which Harry waited with his hand upon the doorknob, there came a loud bang, and a great deal of acrid, black smoke billowed from a corner. The young witch in the front row shrieked: ink pages flew everywhere as she and her fellows jumped up, looking around for the source of the commotion. Harry turned the

doorknob, stepped into Umbridge's office and closed the door behind him. (Rowling, 2007, p. 206)

Upon reading the phrase *Harry turned*, it is immediately clear what he is turning, because they reader has previously learned that Harry had his hand on the doorknob. Thus, if we extend the notion of mental simulation beyond the sentence level—a necessary move if we want the concept of mental simulation to have any relevance to language comprehension at all—then the uniqueness point should shift backward in the target sentence to the verb compared to when the sentence is seen in isolation. Predictions like these can and should be tested empirically.

A final problem with regard to equating language comprehension with action observation is that sentences are often mute on the manner in which an action is performed. For example, the sentence *He opened the door* does not specify how the action is performed (hesitantly, resolutely, furtively?). Again, as the example from *Harry Potter* shows, manner information may be readily available in a discourse context. Given that Harry tries to enter the office unnoticed, he is likely to turn the doorknob in a furtive manner.

How Aspect Might Constrain Mental Simulation

Speakers and writers have at their disposal a set of cues, which include verb tense and aspect, to *construe* (Langacker, 1990) the event in a certain way, thus offering a specific perspective on it. The interesting puzzle for researchers is how this might influence the activation of motor resonance during comprehension. Here are some speculations on this matter.

There are various analyses of the internal temporal contours of events and the ways to construe them linguistically. One of the most recent and comprehensive ones is Steedman (in press). Steedman summarized the extant literature on aspect by distinguishing two orthogonal dimensions of events—telicity and decomposability—which produces four categories. Achievements (e.g., *He started the car*) are telic (they achieve a specific goal) but cannot be further decomposed. Accomplishments (e.g., *He walked to the post office*) are telic but can be decomposed (e.g., there is a phase that has him walking and there is a phase that has him reaching the post office). Points (e.g., *He stumbled*) are neither telic nor decomposable. Finally, activities are not telic (e.g., *He walked*) but can be decomposed. As mentioned earlier, Moens and Steedman (1988) argued that the nucleus of an event always consists of a preparatory phase (akin to an activity), an event (akin to an achievement), and a consequent (e.g., as construed by the perfective). The overall nucleus is closely related to accomplishments.

What can be said about the role of motor resonance in the understanding of each of these categories? At first sight, it would seem that motor resonance is better suited to aid in the understanding of telic events than atelic ones. After all, motor programs are executed to achieve specific goals. A second issue to consider is the timescale of the events under consideration. As mentioned earlier, it is implausible to assume a close temporal correspondence between language and observed events. Nevertheless, it would seem that motor resonance is more useful for understanding instantaneous events than for understanding events of a longer duration (e.g., from slightly longer than the time it takes to understand a sentence to much grander timescales). Thus, motor resonance would seem to be the most useful with regard to achievements. The activation of the neural substrate for a right-hand clockwise manual rotation with a precision grip would be an important component of the mental simulation performed to understand *He started the car*. One might speculate that this motor program would be followed with the auditory simulation of a starting car.

Points are also short in duration, but they are not necessarily associated with motor programs. We do not have motor programs for stumbling. Rather, stumbling occurs when our motor program for walking or running is not executed well or is interfered with by some obstacle in the environment. Of course, clowns and mimes can develop motor programs for mimicking stumbling. Likewise (far too) many soccer players have developed motor programs that mimic being tripped or tackled. However, these are by definition not examples of stumbling or tripping. Thus, it would seem that a sentence such as *He stumbled* would activate memory traces of a situation in which a motor program failed to execute properly and the proprioceptive, perceptual, somatosensory, and emotional consequences thereof. In any case, activation of a motor program proper would not be central to the comprehension of this event.

How about accomplishments? Here the account is less straightforward. Take *He painted the wall*. It would be unrealistic to assume that the comprehender would pause on the sentence for half an hour while performing a real-time mental simulation of painting a wall. What happens instead? The literature on aspect suggests that what is central here is not the action but the resultant state. Thus, the simulation may be mostly visual. There might still be a fleeting activation of right-hand movement, but the simulation would quickly be dominated by a visual simulation of the result of the action.

Activities present problems of their own. Would activation of a motor program for walking be sufficient for understanding *He was walking*? Maybe. The difficulty of analyzing decontextualized sentences is particularly evident here. Perhaps the best idea would be to consider grammatical aspect and compare *He was painting the wall* with *He painted the wall*. The former describes an activity, whereas the latter describes an achievement. Possibly the difference between the mental simulations engendered by these sentences is that motor resonance is the dominant aspect of the mental simulation in the first sentence, whereas it is the nondominant aspect of the mental simulation in the second sentence. An empirically testable prediction would be that motor resonance persists until the end of the first sentence, but it is tied to the verb in the second one.

A category of nonevents that is typically considered outside of the realm of events are states (e.g., Steedman, in press). An example would be *He is a fast typist.* How is any state mentally simulated? Zwaan and Madden (2005) proposed that in connected discourse, a state is interpreted as a brief observation. Thus, *The car was red* is taken to mean *[The protagonist noticed that] the car was red.* As such, it activates the prior experience of seeing a red car. Analogously, *He types fast* activates motor traces of typing very fast as well as perceptual traces of seeing someone else type quickly or maybe of letters quickly materializing on a computer screen. It could be argued although that this is not the whole story. The sentence does not merely convey that there was an instance at which the protagonist could be observed typing really fast. Rather, it conveys that typing fast is a trait of the protagonist—he always displays this level of dexterity when typing. This generalization is exactly how the meaning of *He types fast* differs from *He is typing fast.*

How can this difference in meaning be captured in a mental simulation? As a first step, it is important to note (again) that sentences never occur in isolation, except in linguistics articles and in psycholinguistic experiments. So let us imagine a scenario in which Tom and Dick observe a third individual, Harry, who is typing fast. If Tom expresses his amazement about Harry's typing speed by uttering *Wow, he is typing fast*, then, on some level, he would be stating the obvious. The simulation derived from the sentence would have a great deal of overlap with the observation and understanding of the perceived situation. Given this redundancy, Dick, a follower of Gricean maxims, would infer that Tom's utterance was an expression of amazement or admiration. In response, he could say, *Yeah, he types fast*. Importantly, this comment is neither redundant with the observed situation nor a meaningless echo of Tom's comment. It means that Harry does not merely type fast in the current situation but also in other situations. As such, it is not a statement about the situation per se but rather a statement about Harry. Thus, typing fast should become unbound to the here-and-now and bound to Harry. In a mental simulation, this could be achieved by way of attentional focus on Harry and his manual dexterity at the keyboard. Because of this binding (e.g., via a Hebbian learning mechanism), typing speed now becomes associated with Harry in Tom's long-term memory, such that it has a high likelihood of being retrieved whenever he thinks about Harry. Because in the case of *He is typing fast*, focus is more distributed across a situation, typing speed does not become as closely associated with Harry, although there will still be an association. With regard to what I will simplistically call the "components" of the mental simulation, it could be hypothesized that motor resonance occurs during the comprehension of both sentences, but that the perceptual simulation is more extensive when an activity is described compared to when a state is described.

A similar mechanism of unbinding might occur when iterative actions are described, such as *He is slicing an onion* versus *He is slicing onions.* Both sentences could be uttered in a situation in which someone asks "What's Harry doing?" Both sentences would give rise to motor resonance (covert activation of the motor programs for small-tool use). The differences between the simulations would again presumably be perceptual in nature. In the first case, focus would be on the action of slicing an onion. In the second case, focus would be more distributed across the situation and would include the perception of other onions, whole and sliced, lying on the counter or the cutting board. Thus, the iterative nature of the action is not represented in terms of iterative motor resonance but in terms of the attentional scope of the perceptual simulation.

States and iterations are more abstract than accomplishments and especially than achievements; they necessitate some degree of abstraction from the currently observed or described situation. It is therefore interesting to note that these analyses dovetail nicely with Barsalou and Wiemer-Hastings's simulation account of abstract concepts (Barsalou & Wiemer-Hastings, 2005). They argued that both concrete (e.g., BOTTLE) and abstract concepts (e.g., JUSTICE) are essentially representations of situations, the difference being that concrete concepts have a focal object, whereas abstract concepts do not. As a result, there is a great deal of consistency within and across individuals in how they define concrete concepts, but a great deal of variability in how they define abstract concepts. Accounts such as these still await rigorous empirical tests, but there does not appear to be any a priori reason to think that mental simulation theories are not equal to the task of accounting for the comprehension of narrated events and actions.

Conclusions

The goal of this article was to review the research on the role of time in language through the prism of contemporary theorizing about comprehension. Situation models can account for the flow of events during comprehension and their interconnectedness in memory. However, they do no account very well for the internal structure of the described events. Mental simulation theories may be able to fill this conceptual void, but they face considerable theoretical and empirical challenges. Meeting these challenges will bring us that much closer to understanding how the flow of events, captured in static language by a speaker, can be returned to its fluid state by the comprehender.

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