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People Use their Knowledge of Common Events to Understand Language, and Do So as Quickly as Possible

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Abstract

People possess a great deal of knowledge about how the world works, and it is undoubtedly true that adults use this knowledge when understanding and producing language. However, psycholinguistic theories differ regarding whether this extra-linguistic pragmatic knowledge can be activated and used immediately, or only after a delay. The authors present research that investigates whether people immediately use their generalized knowledge of common events when understanding language. This research demonstrates that (i) individual isolated words immediately activate event-based knowledge; (ii) combinations of words in sentences immediately constrain people's event-based expectations for concepts that are upcoming in language; (iii) syntax modulates people's expectations for ensuing concepts; and (iv) event-based knowledge can produce expectations for ensuing syntactic structures. It is concluded that theories of sentence comprehension must allow for the rapid dynamic interplay among these sources of information.

People possess a great deal of knowledge about common types of events, such as eating breakfast or going to a pub. It is intuitively obvious that people's knowledge of how the world works influences their language behavior. People talk to each other about what they are doing, what they have done in the past, and what they are planning to do in the future. To talk sensibly about these things, and to communicate with one another in a way that is sufficiently conventionalized, it is necessary to bring to bear knowledge of common types of events both for comprehending and producing language.

In line with these ideas, all theories of sentence processing include the notion that people's knowledge of how the world works influences their ability to comprehend knowledge. The key differences among theories center on representational architecture and temporal priority of types of processing, which are most commonly investigated in terms of timing issues. That is, theories differ on whether what might be called semantic or pragmatic knowledge can influence comprehension immediately, or only after a delay.

Partly owing to the influence of formal linguistics in the field of sentence comprehension, and partly because of the fact that syntax is much easier to formalize than other levels of sentence meaning, including semantic information about how the world works, much of the theoretical and empirical work has focused on how people build a syntactic representation of a sentence. One outcome of this has been that a number of theories are based on the idea that syntax is privileged, so that during the moment-to-moment processing of sentences, syntactic information is accessed and used prior to any other type of knowledge (Frazier 1995; Binder et al. 2001; Van Gompel et al. 2005; Clifton and Staub 2008).

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Furthermore, in some theories of how people process sentences, although they do tend to be older theories, there is a clear distinction between the linguistic information that resides in the lexicon versus pragmatic world or event knowledge (Katz 1972; Chomsky 1975; Sperber and Wilson 1986; Schlesinger 1995; Bornkessel and Schlesewsky 2006; Warren and McConnell 2007; see Figure 1). Another way to state this is that certain specific types of knowledge are used initially when understanding sentences (linguistically relevant knowledge, or linguistic semantics), whereas other types of knowledge are delayed, particularly those that are not linguistic *per se*, but instead are part of people's general cognitive knowledge about the world. Jackendoff (2002) provides a nice discussion of this distinction (with which he disagrees; see also Pustejovsky 1995). In a view in which linguistically relevant knowledge is distinct from world knowledge, when people encounter a word, its core meaning, plus possibly some other information such as selectional restrictions of verbs (e.g., that the patient of *kill* must be animate) becomes immediately activated. This core meaning is an abstracted notion of what the word means, as in kill = (cause(become(not alive))). Thus, only after a time delay might information about real world events become activated. This information would include people's knowledge of typical participants, objects, and settings for killing events, for example. In contrast, we and many others believe that knowledge of various aspects of events is computed immediately from words, and used as quickly as possible for understanding language. In other words, there is no built-in architecturally determined delay of this type of knowledge in the human mind.

Event Knowledge

People possess a substantial amount of knowledge about real-world events such as *recess*. In many cultures, school children go outside to play during recess a few times a day. Because many people have participated in numerous recesses during their childhood years, they have accrued knowledge about the types of things that tend to happen (playing various types of sports, playing on teeter-totters), the primary typical participants (kids, sets of friends, teachers), common instruments (footballs, baseballs, monkey bars), common locations (the school playground), and knowledge about the usual time course of events (bell rings, put your coat on, go out and play for 15 min, bell rings, go back to your class). For many such types of events, people have accumulated a great deal of knowledge about them over their lifetime. Their experience with these events comes through first-hand participation, watching them on television and in movies, listening to others talk about them, and reading about them. The upshot of all this experience is that people develop generalized knowledge of many types of events. By generalized, we mean prototypical events, as in a general, typical recess, rather than a detailed memory of a specific recess. Of course, people accumulate specific autobiographical memories as well, but here we focus on the generalized type of event knowledge.

How people actually represent and compute event knowledge of this type is a difficult and currently unresolved issue. One thing that is apparent is it requires complex, flexible, and dynamic computations. That is, there is a great deal of information associated with events, and so, for example, when someone hears or reads the word *recess*, it is not the case that every one of their memories of recesses comes flooding into their mind. Instead, we assume that some part of their prototypical knowledge is activated, shaded by the current context and goals. One way to think about the types of information that might become activated when, for example, an event noun like *recess* is read or heard in isolation, is in terms of perceptual simulations (or dynamic type of schemas, Rumelhart et al. 1986; Barsalou 1999; Zwaan et al. 2002). In summary, people know that recesses involve the types of activities and participants described above, and this information becomes activated when the word is read or heard (as modulated by context, of course).

Language Cues Event Knowledge

Although it is definitely not the case that all language concerns common events, a great deal of language does – people often talk about stuff that they do. As such, language provides multiple types of cues that can be used to focus on various aspects of events. For example, the specific choice of verb can be used to bring to mind somewhat different scenarios, *such as eating* versus *dining*. In terms of the possible entities that participate in such events, knowing that a *waitress* is involved, for example, invokes a certain type of eating event. The phrase *hamburgers and hot dogs* produces a different type of scenario than does *turkey and stuffing*, including perhaps information about location and time of year. Instrument nouns can cue certain types of eating, as in *eating with a fork* versus *eating with a stick*. Finally, event nouns like *breakfast* or location nouns like *cafeteria* cue specific types of eating scenarios.

Language also provides salient cues to the temporal structure of events. Verb tense can be used to cue when an event occurred, as in *She is eating* versus *She ate*. In addition, researchers have investigated the role of aspect by comparing, for example, *She was eating* with *She had eaten* (Madden and Zwaan 2003). In both cases, the event is described as having happened in the past, but the former denotes an ongoing past event whereas the latter refers to an event that has been completed. The research presented in the remainder of the article investigates how people's event knowledge combines with linguistic cues to influence online language comprehension. As part of this, we also provide evidence that event knowledge is a rich source for generating expectancies during language comprehension; that is, event knowledge is a prominent cue to upcoming concepts and syntactic structure in the language stream.

In each of the following four sections, we make a specific point regarding the activation and use of event knowledge during language comprehension. The first is that single words in isolation immediately activate generalized event knowledge. Second, words (i.e., concepts) can rapidly combine in sentences to cue specific concepts that are relevant to types of events. Third, syntactic cues modulate expectations for certain aspects of event knowledge. Fourth, the reverse is true as well in that event knowledge can immediately modulate expectations for syntactic structure. Finally, it is concluded that theories of sentence comprehension must allow for the rapid dynamic interplay between people's knowledge of generalized events and the syntactic structure of sentences.

Single Words

If event knowledge influences people's comprehension of sentences, then one would expect that individual words, even in isolation, should activate knowledge about aspects of generalized events. Semantic priming studies were used to investigate this prediction. In semantic priming experiments, participants read aloud or make a decision about a target word such as *nurse* after reading or hearing a word such as *doctor*. The typical finding is that people are faster to respond to a target like *nurse* when it follows a related word like *doctor* than when it follows an unrelated word such as *table*. This task, particularly when the first word is presented for a very short period of time (such as 250 ms), is thought to provide a window into how people's semantic memory is organized. Although priming studies typically compare related with unrelated words without a great deal of regard to precisely the sort of relationship that they share (Neely 1991), we have focused systematically on event-based relations in a number of studies.

An obvious place to begin is with verbs. One might expect that verbs should lead to the activation of event-based knowledge because, in many cases, verbs label types of events. In addition, linguistically, verbs play a prominent role in assigning thematic roles. These

thematic roles are tied to the actual roles that various entities and objects play in events. For example, in an arresting event, a cop typically plays the role of agent (the one performing the action). *Criminal* is a label often used to denote the person playing the role of patient in an arresting event (the one having the action performed on them). Instruments are often salient aspects of events as well, as in the fact that stirring typically is accomplished with a spoon. Finally, although locations are considered to be adjuncts linguistically (rather than arguments, Clifton et al. 1991; Schütze and Gibson 1999), they are often salient aspects of events, as in an arena for skating.

Ferretti et al. (2001) investigated priming from verbs to typical agents, patients, instruments, and locations. Participants silently read verbs that were presented for a short period of time (200 ms), and then made decisions regarding the target word. Animacy decisions (does this word refer to a living thing?) were used for agents and patients, which all referred to animate entities. Lexical decisions (is this letter string an English word?) were used for the instruments and locations. Priming was obtained from verbs to typical agents (*arresting-cop*), patients (*serving-customer*), and instruments (*stirred-spoon*). However, verbs did not prime locations (*skated-arena*). Thus, verbs that label certain types of events do indeed immediately activate information about different types of entities and objects that participate in those events, although not locations.

A similar idea was explored by Altmann and Kamide (1999) in auditory sentence comprehension using the visual-world paradigm. In their study, participants listened to sentences such as ‘The boy will eat the cake’ while simultaneously looking at a set of pictures that included a boy, a cake, a train, a car, and a ball. Analyses of eye movements revealed that people spent more time fixating on the cake at the offset of *eat*, that is, even before participants heard the word *cake* (the cake was the only edible object in the scene). In contrast, when the sentence was ‘The boy will move the cake’, preferential looks toward the cake emerged relatively later (because there were multiple moveable objects in the scene). Such results suggest that thematic- or event-based knowledge activated by the verb immediately restricts the possible identity of objects to which the verb refers.

Elizabeth Bates coined an interesting term called ‘verb imperialism’. This term conveys the idea that although verbs are definitely important and play a central role in many theories and studies, they are not all there is to sentences. For example, a number of languages, such as Japanese, include syntactic constructions in which the verb comes last. In these cases, people presumably do not sit in a passive state waiting for the verb to arrive to begin processing (see Kamide et al. 2003; Experiment 3). Furthermore, even in languages such as English, initial nouns can cue situations or scenarios, as in ‘The astronaut …’ or ‘At the inauguration, …’ (Vu et al. 2003). Thus, nouns may cue verbs or other nouns via people’s knowledge of events. Under this view, nouns should prime both verbs and other nouns that are relevant to events.

McRae et al. (2005) investigated whether verbs that denote events could be primed by nouns that refer to typical agents (*waiter-serving*), patients (*guitar-strummed*), instruments (*chainsaw-cutting*), and locations (*cafeteria-eating*). For all four relations, participants named the verb aloud in the related condition more quickly than in the unrelated condition (as in *beach-eating* for locations). Note that priming was obtained from locations to event verbs, although it was not found in the other direction.

Hare et al. (2009) tested for noun–noun event-based priming using event, location, and instrument nouns as primes. They found that event nouns primed the types of people (*sale-shopper*) and objects (*breakfast-eggs*) that tend to take part in those events. In addition, location nouns primed the types of people/animals (*hospital-doctor*) and objects (*barn-hay*)

that typically are found at those locations. Instrument nouns primed the types of objects on which those instruments are used (*key-door*). Finally, instrument nouns did not prime the types of people who tend to use them (*knife-chef*), although the opposite was true (*chef* primes *knife*). In all cases, an animacy decision was used when the targets were animate, whereas a concreteness decision (does this word refers to concrete/touchable object?) was used when the targets were objects.

In summary, event knowledge can be cued from action verbs as well as nouns referring to agents, patients, instruments, locations, and events (see Figure 2 for a summary). Priming can be obtained as long as sufficiently strong conditional probabilities apply. For all of these studies, the experimenters used norming procedures to tap into people's event knowledge and create items that engendered strong directional relations. One case in which priming was not obtained was from instruments to the types of people who use them. Hare et al. (2009) reasoned that although it is the case that, for example, knives definitely are used by chefs, numerous other types of people use knives also, and many of the instruments were of this type (i.e., most people use them regularly). Thus, when the items were reversed, priming was obtained because these types of people were strong cues for the instruments that they typically use, but the instruments did not strongly cue the types of people who use them.

Note that in most of these studies, it was demonstrated that priming was obtained even though there was no normative word association between primes and targets (i.e., as established by a word association task; see also Chwilla and Kolk 2005 and Moss et al. 1995, for related demonstrations of what they termed 'script-based' priming). On the one hand, omitting prime-target pairs that are normatively associated convinces some researchers that event-based priming exists over and above strictly word–word associative relations (to the extent that word association norms directly tap these relations). On the other hand, it would seem to be theoretically odd to claim that there is no association between items such as *arresting* and *cop* or *spoon* and *stirring*. In the general sense of association, that is, temporal or spatial contiguity in the world or in language, rather than the more narrow sense based on the results of a word association task, one would assume that these concepts must be associated. The important point here is that the verbs, event nouns, agents, patients, instruments, and locations used in the experiments presented in this section are indeed associated in the general sense, but these associations are driven by people's knowledge of common events.

It seems reasonable to begin the exploration of how event-based knowledge is activated during language comprehension by studying the influence of single words in isolation. However, although these single-word experiments show immediate activation of event-based knowledge, stronger evidence would be obtained by investigating whether and how this type of information is used immediately during online sentence comprehension. The next three sections provide such evidence.

Event-Based Expectations from Combined Concepts

The previous section outlined how individual words immediately activate generalized event knowledge. However, many words have multiple senses, and verbs in particular can refer to multiple (often related) types of events. This begs the question of what sentential cues can be used to signal one type of event versus another, and therefore signal potential classes of upcoming event participants. Another way to state this is in terms of whether people can rapidly combine conceptual cues to narrow down the type of event that is being referred to. To test this idea, Matsuki et al. (2009) examined how the combination of instruments and actions lead people to access subtly different types of events. Participants were asked to read sentences such as following:

(1a) Donna used the hose to wash her filthy car after she came back from the beach.

(1b) Donna used the shampoo to wash her filthy hair after she …

(2a) Donna used the shampoo to wash her filthy car after she …

(2b) Donna used the hose to wash her filthy hair after she …

The critical manipulation concerned whether people are able to combine the instruments (*hose* versus *shampoo*) and verbs (*wash*) to produce an expectation for classes of patients. In (1a) and (2a), the target objects (*car* and *hair*) are typical patients of events described by the instrument–verb combinations (i.e., people usually use a hose to wash their car, and shampoo to wash their hair), whereas in (1b) and (2b), they are atypical but still reasonable (it is certainly possible to use shampoo to wash one's car or a hose to wash one's hair).

Both Rayner et al. (2004) and Warren and McConnell (2007) used sentences like these in eyetracking experiments, but did not find immediate differences at the critical patient (*car* or *hair*). That is, in Rayner et al., for example, there were no differences in first fixation or gaze durations at the patient (*car* or *hair*), although there was a marginally significant difference in go-past reading times (also called regression path duration, which includes all fixations starting from the first one in a region and ending when the reader moves past the region; i.e., regressions from that region back to earlier parts of the sentence are included). Thus, they concluded that people do not immediately make use of plausibility information when understanding language. Warren and McConnell compared a similar plausibility manipulation with one in which selectional restrictions of the verb were violated (as in *used a promise to motivate the pretty blanket* where blankets are not animate). That is, the violation depended only on the verb and patient, rather than the combination of the instrument and verb. They found immediate differences (in first fixation durations and single fixation durations) only when the patient violated selectional restrictions of the verbs. Warren and McConnell concluded that selectional restriction information, which is assumed to be privileged because it is stored directly in the lexicon, is used immediately (see also Bornkessel and Schlesewsky 2006, for similar arguments).

Rayner et al. (2004) used sentence plausibility ratings to show that their typical (control) items were significantly more plausible than their atypical (implausible) items. However, this type of norming does not establish that their typical (control) items were, in fact, highly typical. In contrast, Matsuki et al. (2009) used production norms in which participants were asked to list, for example, the types of things that people wash with a hose. Rayner et al.'s instrument–verb pairs were also included in Matsuki et al.'s norming task. This norming task showed that Matsuki et al.'s items were indeed typical, whereas Rayner et al.'s were less so. Using this stronger set of items in a self-paced moving-window reading experiment, Matsuki et al. found that people were faster to read the critical patients in (1a) and (2a) than in (1b) and (2b). Furthermore, in an eyetracking experiment using the same items, immediate differences between typical and atypical patients were found at the patient in both first fixation and gaze durations. These results confirm the hypothesis that the instruments and verbs are rapidly combined to influence people's processing of upcoming words, in this case, the patients.

One way to think about these results is in terms of verb senses and their influences on producing expectations. Senses of a word are typically considered as related meanings (polysemy), as in the *grip* and *come to understand* senses of *grasp* (versus the monetary institution and river meanings of *bank*, which are not related in any obvious way, i.e., homonymy). Extending this notion a bit, one could think about verb senses as being delineated along the lines of the classes or clusters of events that a particular verb can denote. That is, a verb is said to have multiple senses if it can be used to denote multiples

classes or clusters of events. Thus, when an instrument is combined with a verb, it can alter the sense of the verb by modulating the set of events to which the verb and thus the sentence refer. For instance, *washing with a hose* brings to mind a different set of events or scenarios than does *washing with shampoo*. This leads to different expectations regarding the patient nouns that are likely to follow the verb, which then influences comprehension.

Similar ideas have been explored and confirmed in studies in which expectations regarding the probable patient were altered by a specific agent, as in 'The lifeguard saved' versus 'The shopper saved' (Kamide et al. 2003; Bicknell et al. 2008) or reversed by a more extensive discourse context (Race et al. 2008).

Furthermore, a number of event-related potential (ERP) studies have shown that people use their knowledge of the world to compute expectations for upcoming concepts in the linguistic stream (Federmeier and Kutas 1999; Hagoort, Hald, Bastiaansen, & Petersson, 2004; Van Berkum et al. 2005; Camblin et al. 2007; Otten and Van Berkum 2007). Although these studies did not focus on specific thematic roles or combinations thereof, they share the notion that comprehension is at least in part driven by expectations that are produced (implicitly) based on comprehenders' real-world knowledge and/or a situation model constructed over the course of understanding a sentence. In summary, people can combine concepts using their knowledge of real-world events and this immediately influences processing of upcoming information.

Syntax Modulates Event-Based Expectations

An important aspect of sentence comprehension research involves interactions between meaning and syntax. If event knowledge and syntactic cues interact, then activation of event participants should be contingent on syntax. That is, one would not expect facilitation for a component of a type of event if it did not fit into a specific position in a sentence. In fact, Traxler et al. (2000) have shown that there is no facilitation if a noun appears in a syntactic slot where it should not, even if it is expected given an event scenario, as in 'The lumberjack chopped the axe'. In this case, *axe* is expected as an instrument (based on event knowledge), but it appears syntactically as a patient, where it is not expected.

Ferretti et al. (2001) provided related evidence for event knowledge/syntactic interactions by comparing cross-modal naming latencies for typical agents and patients of events. They compared priming for 'She arrested the' *cop/crook* versus 'She was arrested by the' *cop/crook*. Thus, actives were compared with passives, and the only difference in the sentence primes was the presence or absence of *was* and *by*. These conditions were compared with ones in which the verb was unrelated ('She loved the' *cop*). Priming was obtained when the agent or patient was expected given the syntactic cues (*arrested the crook* and *was arrested by the cop*), but absolutely no priming was obtained in the opposite condition. Note that issues regarding selectional restrictions were obviated here because all verbs required animate patients and all patients were animate in this study. Thus, syntactic cues immediately modulate the activation and anticipation of specific components of events.

We have also investigated how aspect cues components of events. Recall that no priming was found from verbs to locations (*skated-arena*) in Ferretti et al. (2001). Locations may not have been activated from isolated verbs because locations are less salient than agents, patients, and instruments. This might occur because they are literally background event information, or because they are adjuncts rather than verbal arguments (Clifton et al. 1991; Schütze and Gibson 1999). In addition, Ferretti et al. used past tense verbs such as *skated* as primes, making locations even less salient because the past tense signals that the event is completed. To test this hypothesis, Ferretti et al. (2007) investigated the priming of locations when events were portrayed as ongoing, as in imperfective aspect (*was skating*), versus as

completed, as in perfect aspect (*had skated*). Note that tense was equated because the past tense was used in both cases, but aspect signaled the event as ongoing (albeit in the past) versus completed. The logic was that if the event is ongoing, then the location should be more salient. In contrast, if a person had already finished skating, then they could be anywhere and the location of the (completed) event is not a salient component of the scenario. Priming was found for locations using verbs with imperfective, but not perfect aspect. In addition, in an ERP sentence reading study, the N400 to location prepositional phrases was larger in sentences in which perfect aspect was used than in those with imperfective aspect.

In a study that made a similar point, Altmann and Kamide (2007) used the visual world paradigm to compare eye movements with pictures of a full versus an empty glass when participants heard sentences beginning with ‘The man will drink all of’ versus ‘The man has drank all of’. Participants looked more to an empty glass upon hearing the former, whereas they looked more to a full glass upon hearing the latter, showing their immediate sensitivity to the temporal structure of events.

In summary, these studies illustrate one side of meaning–structure interactions. Syntactic structure (or word order) and grammatical cues such as tense and aspect immediately interact with event-based knowledge in that they modify or guide expectations for specific components of events.

Event Knowledge Modulates Syntactic Expectations

Throughout the previous sections, it has been demonstrated that verbs play an important role as a cue for activating generalized event knowledge. For syntactic processing, verbs also play a critical role, as they are closely linked to sentence structure. In addition, some verbs can occur in more than one syntactic structure, although in many of these cases, the verbs are statistically biased toward one or the other structure, and people appear to both possess and use such probability information during sentence comprehension (Trueswell et al. 1993; MacDonald 1994; Garnsey et al. 1997). For example, the verb *admit* can occur in the two structures shown next, although it is biased toward being followed by a sentential complement structure, as in (3b):

(3a) The professor admitted the student into his class.

(3b) John admitted his mistake caused problems for everyone.

In this case, *admit* can take either a direct object (*the student*) or a sentential complement (*his mistake caused problems for everyone*). Several studies have shown that such structural biases of verbs rapidly influence people’s interpretation of the sentence (Trueswell et al. 1993; Garnsey et al. 1997).

Recently, researchers have shown that this verb–structure relation is mediated by verb sense, such that different senses of verbs often are tied to different structural preferences (Roland and Jurafsky 2002; Hare et al. 2003, 2004). One clear example is *grasp*. It has the concrete physical sense of *grip* as in ‘She grasped the handrail’, which is direct object biased (you have to grasp hold of something). It also has the more abstract psychological sense of *come to understand* as in ‘He grasped that she wanted him to be quiet’, which is biased toward being followed by a sentential complement because ideas are often expressed using such a structure. This leads to the hypothesis that if context provides event-based cues that constrain verb sense, readers might be more likely to interpret the sentence in terms of the structure associated with that sense. In fact, Hare et al. (2003) found that using sentence contexts to bias people toward a direct object-biased or a sentential complement-bias sense

of the verb influenced their ability to understand the less frequent, more difficult sentential complement structure.

Probably, the most frequent structural alternation in English concerns transitive (in 4a and 4b) and intransitive (5a and 5b) structures, as in:

(4a) The brick shattered the fragile goblet when they bumped together.

(4b) The glass shattered the fragile goblet when they bumped together.

(5a) The glass shattered into tiny pieces when it hit the floor.

(5b) The brick shattered into tiny pieces when it hit the floor.

This alternation is tied to the semantic alternation between causative and inchoative meanings (or different types of events). Sentences (4a) and (4b) illustrate the causative meaning in that the initial noun (*brick* or *glass*) is the agent that causes a change of state in the patient (causes the *fragile goblet* to be shattered). In (5a) and (5b) on the other hand, no agent is stated, and it is the *glass* or the *brick* that shatter.

Hare et al. (2009) tested whether manipulating the initial noun could bias comprehenders toward a causative or inchoative meaning when it was combined with the verb. Norming studies showed that *the brick* biases people toward the causative sense of *shattered*, which in turn leads to a high proportion of transitive sentence completions (as in 4a). In contrast, *the glass* biases people toward the inchoative sense of *shattered*, which in turn leads to a high proportion of intransitive sentence completions (as in 5a). Hare et al. found that participants were faster to read the direct object in (4a) than in (4b), and were faster to read the prepositional phrase in (5a) than in (5b). These results show immediate modulation of structural expectations based on people's pragmatic knowledge of how the world works.

Expectancy Generation

Throughout the article, we have used the term expectancy generation or expectation to describe the results of a number of studies. However, we acknowledge that the evidence provided by our studies in particular does not unambiguously imply expectancy generation, in that the results could equally be accounted for by any model that allows for extremely rapid integration of information. However, there is a growing consensus that sentence comprehension involves some form of anticipation for forthcoming inputs at various levels of representation, and empirical evidence in favor of this view is growing (Kutas and Federmeier 2000; Spivey 2006; Pickering and Garrod 2007; Kamide 2008).

A number of studies have reported anticipatory processing based on general world knowledge. Kamide (2008) reviews several visual world eyetracking and ERP studies that do so, some of which we have described herein. In terms of the visual world studies, an important point is that patterns of eye movements differentiate prior to participants hearing the word that must be integrated into the sentence's meaning, so that effects are truly a result of generating expectancies. Several ERP studies (Wicha et al. 2004; DeLong et al. 2005; Van Berkum et al. 2005) also have provided convincing demonstrations of expectancy generation. In these studies, under sufficiently constraining contexts (e.g., *The day was breezy so the boy went outside to fly*), comprehenders anticipate upcoming words at the level of phonological representations (*a kite*, in this case). Differences in the amplitude of ERP components (generally the N400) emerge not just at the target word (e.g., *kite* versus *airplane*) but also at the *preceding* words whose phonological manifestation depends on the expected target word (English articles *a* versus *an*, or gender marking on prenominal articles or adjectives in Spanish and Dutch). These studies, combined with the evidence reviewed in

the article, suggest that the computation of event knowledge is an integral component in generating expectancies during online sentence processing.

Conclusion

In some theories of sentence comprehension, syntactic and/or linguistically relevant semantic information is accessed and used immediately, whereas the use of knowledge about common types of events is assumed to be delayed (Sperber and Wilson 1986; Schlesinger 1995; Binder et al. 2001; Bornkessel and Schlesewsky 2006). However, the bulk of recent evidence strongly suggests there exists no type of architecturally determined delay. We argued that people possess a great deal of knowledge about numerous types of generalized events, and demonstrated various ways in which language cues event knowledge. From priming and visual world eyetracking experiments, it was concluded that people's generalized event memory is organized to allow immediate access of this knowledge from multiple types of single-word cues. Furthermore, these cues can combine rapidly to constrain people's expectations for the types of concepts that are upcoming in the linguistic stream. It was also shown that event knowledge and syntax are intertwined, and that they constrain each other extremely quickly. The take-home message of this research is that theories of sentence comprehension must allow for the rapid dynamic interplay among these sources of information.

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Biographies

Ken McRae has been studying sentence processing and semantic memory since the early 1990s. His graduate research was conducted with Mark Seidenberg at McGill University, and his postdoc was with Mike Tanenhaus at Rochester. For a number of years now, he has been collaborating on sentence processing research with Mary Hare and Jeff Elman. Ken's research combines experiments with adult human participants, computational modeling of various types (mainly connectionist), and some ERP and fMRI (functional Magnetic Resonance Imaging) experiments. He is currently a professor at the University of Western Ontario, where he has spent his entire career.

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Works Cited

Altmann, Gerry; Kamide, Yuki. Incremental interpretation at verbs: restricting the domain of subsequent reference. Cognition. 1999; 73:247–264. [PubMed: 10585516]

Altmann, Gerry TM.; Kamide, Yuki. The real-time mediation of visual attention by language and world knowledge: linking anticipatory (and other) eye movements to linguistic processing. Journal of Memory and Language. 2007; 57:502–518.

Barsalou, Lawrence W. Perceptual symbol systems. Behavioral and Brain Sciences. 1999; 22:577–660. [PubMed: 11301525]

Bicknell, Klinton; Elman, Jeffrey L.; Hare, Mary; McRae, Ken; Kutas, Marta. Online expectations for verbal arguments conditional on event knowledge. In: Love, Bradley C.; McRae, Ken; Sloutsky,

Vladimir M., editors. Proceedings of the Thirtieth Annual Meeting of the Cognitive Science Society; Austin, TX: Cognitive Science Society; 2008. p. 2220-2225.

Binder, Katherine S.; Duffy, Susan A.; Rayner, Keith. The effects of thematic fit and discourse context on syntactic ambiguity resolution. Journal of Memory and Language. 2001; 44:297–324.

Bornkessel, Ina; Schlesewsky, Matthias. The extended argument dependency model: a neurocognitive approach to sentence comprehension across languages. Psychological Review. 2006; 113:787–821. [PubMed: 17014303]

Camblin, C Christine; Gordon, Peter C.; Swaab, Tamara Y. The interplay of discourse congruence and lexical association during sentence processing: evidence from ERPs and eye tracking. Journal of Memory & Language. 2007; 56:103–128. [PubMed: 17218992]

Chomsky, Noam. Reflections on language. New York, NY: Pantheon; 1975.

Chwilla, Dorothee J.; Kolk, Herman HJ. Accessing world knowledge: evidence from N400 and reaction time priming. Cognitive Brain Research. 2005; 25:589–606. [PubMed: 16202570]

Clifton, Charles, Jr; Speer, Shari R.; Abney, Stephen. Phrase structure and argument structure as determinants of initial parsing decisions. Journal of Memory and Language. 1991; 30:251–271.

Clifton, Charles, Jr; Staub, Adrian. Parallelism and competition in syntactic ambiguity resolution. Language and Linguistics Compass. 2008; 2:234–250.

DeLong, Katherine A.; Urbach, Thomas P.; Kutas, Marta. Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. Nature Neuroscience. 2005; 8:1117–1121.

Federmeier, Kara D.; Kutas, Marta. A rose by any other name: long-term memory structure and sentence processing. Journal of Memory and Language. 1999; 41:469–495.

Ferretti, Todd R.; Kutas, Marta; McRae, Ken. Verb aspect and the activation of event knowledge. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2007; 33:182–196.

Ferretti, Todd R.; McRae, Ken; Hatherell, Andrea. Integrating verbs, situation schemas, and thematic role concepts. Journal of Memory and Language. 2001; 44:516–547.

Frazier, Lynne. Constraint satisfaction as a theory of sentence processing. Journal of Psycholinguistic Research. 1995; 24:437–468. [PubMed: 8531169]

Garnsey, Susan M.; Pearlmutter, Neal J.; Meyers, Elizabeth; Lotocky, Melanie A. The contribution of verb-bias and plausibility to the comprehension of temporarily ambiguous sentences. Journal of Memory and Language. 1997; 37:58–93.

Hagoort, Peter; Hald, Lea; Bastiaansen, Marcel; Petersson, Karl Magnus. Integration of word meaning and world knowledge in language comprehension. Science. 2004; 304:438–441. [PubMed: 15031438]

Hare, Mary; Elman, Jeffrey L.; Tabaczynski, Tracy; McRae, Ken. The wind chilled the spectators, but the wine just chilled: sense, structure, and sentence comprehension. Cognitive Science. 2009; 33:610–628. [PubMed: 19750146]

Hare, Mary; McRae, Ken; Elman, Jeffrey L. Sense and structure: meaning as a determinant of verb subcategorization preferences. Journal of Memory and Language. 2003; 48:281–303.

Hare, Mary; McRae, Ken; Elman, Jeffrey L. Admitting that admitting verb sense into corpus analyses makes sense. Language and Cognitive Processes. 2004; 19:181–224.

Jackendoff, Ray. Foundations of language: brain, meaning, grammar, evolution. New York, NY: Oxford University Press; 2002.

Kamide, Yuki. Anticipatory processes in sentence processing. Language and Linguistics Compass. 2008; 2:647–670.

Kamide, Yuki. The time-course of prediction in incremental sentence processing: evidence from anticipatory eye movements. Journal of Memory and Language. 2003; 49:133–156.

Katz, Jerrold J. Semantic theory. New York, NY: Harper and Row; 1972.

Kutas, Marta; Federmeier, Kara D. Electrophysiology reveals semantic memory use in language comprehension. Trends in Cognitive Sciences. 2000; 4:463–470. [PubMed: 11115760]

MacDonald, Maryellen C. Probabilistic constraints and syntactic ambiguity resolution. Language and Cognitive Processes. 1994; 9:157–201.

Madden, Carol; Zwaan, Rolf. How does verb aspect constrain event representations? Memory and Cognition. 2003; 31:663–672.

Matsuki, Kazunaga; Chow, Tracy; Hare, Mary; Elman, Jeffery L.; Scheepers, Christoph; McRae, Ken. Event-based plausibility immediately influences on-line language comprehension. 2009 Manuscript submitted for publication.

McRae, Ken; Hare, Mary; Elman, Jeffrey L.; Ferretti, Todd R. A basis for generating expectancies for verbs from nouns. Memory and Cognition. 2005; 33:1174–1184.

Moss, Helen E.; Ostrin, Ruth K.; Tyler, Lorraine K.; Marslen-Wilson, William D. Accessing different types of lexical semantic information: evidence from priming. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1995; 21:863–883.

Neely, James H. Semantic priming effects in visual word recognition: a selective view of current findings and theories. In: Besner, Derek; Humphreys, Glyn W., editors. Basic processes in reading: visual word recognition. Hillsdale, NJ: Lawrence Erlbaum; 1991. p. 264-336.

Otten, Marte; Van Berkum, Jos JA. What makes a discourse constraining? Comparing the effects of discourse message and scenario fit on the discourse-dependent N400 effect. Brain Research. 2007; 1153:166–177. [PubMed: 17466281]

Pickering, Martin J.; Garrod, Simon. Do people use language production to make predictions during comprehension? Trends in Cognitive Sciences. 2007; 11:105–110. [PubMed: 17254833]

Pustejovsky, James. The generative lexicon. Computational Linguistics. 1995; 17:109–441.

Race, David; Klein, Natalie; Hare, Mary; Tanenhaus, Michael K. What do shoppers expect to save? Agents influence patients via events, not associative priming. Poster session presented at the 21st Annual CUNY Conference on Human Sentence Processing; Chapel Hill, NC, USA. 2008.

Rayner, Keith; Warren, Tessa; Juhasz, Barbara J.; Liversedge, Simon P. The effect of plausibility on eye movements in reading. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2004; 30:1290–1301.

Roland, Douglas; Jurafsky, Dan. Verb sense and verb subcategorization probabilities. In: Merlo, Paola; Stevenson, Suzanne, editors. The lexical basis of sentence processing: formal, computational, and experimental issues. Philadelphia, PA: Benjamins; 2002. p. 303-324.

Rumelhart, David E.; Smolensky, Paul; McClelland, James; Hinton, Geoff E. Schemata and sequential thought processes in PDP models. In: Rumelhart, David E.; McClelland, James L., editors. Parallel distributed processing: explorations in the microstructure of cognition. Vol. Vol. 2. Cambridge, MA: MIT Press; 1986. p. 7-57.

Schlesinger, Izchak M. Cognitive space and linguistic case. Cambridge, MA: Cambridge University Press; 1995.

Schütze, Carlson T.; Gibson, Edward. Argumenthood and English prepositional phrase attachment. Journal of Memory and Language. 1999; 40:409–431.

Sperber, Daniel; Wilson, Deirdre. Relevance. Cambridge, MA: Harvard University Press; 1986.

Spivey, Michael. The continuity of mind. New York, NY: Oxford University Press; 2006.

Traxler, Matthew J.; Foss, Donald J.; Seely, Rachel E.; Kaup, Barbara; Morris, Robin K. Priming in sentence processing: intralexical spreading activation, schemas, and situation models. Journal of Psycholinguistic Research. 2000; 29:581–595. [PubMed: 11196064]

Trueswell, John C.; Tanenhaus, Michael K.; Kello, Christopher. Verb-specific constraints in sentence processing: separating effects of lexical preference from garden-paths. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1993; 19:528–553.

Van Berkum, Jos JA.; Brown, Colin M.; Zwitserlood, Pienie; Kooijman, Valesca; Hagoort, Peter. Anticipating upcoming words in discourse: evidence from ERPs and reading times. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2005; 31:443–467.

Van Gompel, Roger PG.; Pickering, Martin J.; Pearson, Jamie; Liversedge, Simon P. Evidence against competition during syntactic ambiguity resolution. Journal of Memory and Language. 2005; 522:284–307.

Vu, Huang; Kellas, George; Petersen, Eric; Metcalf, Kim. Situation-evoking stimuli, domain of reference, and the incremental interpretation of lexical ambiguity. Memory and Cognition. 2003; 31:1302–1315.

Warren, Tessa; McConnell, Kerry. Investigating effects of selectional restriction violations and plausibility violation severity on eye-movements in reading. Psychonomic Bulletin and Review. 2007; 14:770–775. [PubMed: 17972747]

Wicha, Nicole YY.; Moreno, Eva M.; Kutas, Marta. Anticipating words and their gender: an event-related brain potential study of semantic integration, gender expectancy, and gender agreement in Spanish sentence reading. Journal of Cognitive Neuroscience. 2004; 16:1272–1288. [PubMed: 15453979]

Zwaan, Rolf A.; Stanfield, Robert A.; Yaxley, Richard H. Language comprehenders mentally represent the shape of objects. Psychological Science. 2002; 13:168–171. [PubMed: 11934002]

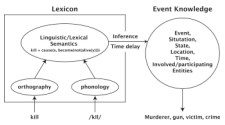

Fig. 1.
A schematic illustration of theories in which event or world knowledge is represented separately from linguistic semantics of words (i.e., linguistically relevant parts of word meaning).

Fig. 2.
A summary of a number of experiments that have investigated event-based priming.