Activating Verbs from Typical Agents, Patients, Instruments, and Locations via Event Schemas

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Abstract

Verbs are a major component of theories of language processing, partly because they exhibit systematic restrictions on their arguments. However, verbs follow their arguments in many constructions (particularly in verb-final languages), making it inefficient to defer processing until the verb. Computational modeling suggests that during sentence processing, nouns may activate information about subsequent lexical items, including verbs. We investigated this prediction using short stimulus onset asynchrony (SOA, the time between the onsets of the prime and target) priming. Robust priming obtained when verbs were named aloud following typical agents (*nun - praying*), patients (*dice - rolled*), instruments (*shovel - digging*), and locations (*arena - skating*). This research is the first to investigate systematically the priming of verbs from nouns. It suggests that event memory is organized so that entities and objects activate the class of events in which they typically play a role (Lancaster & Barsalou, 1997). These computations may be an important component of expectancy generation in sentence processing.

Introduction

Expectancy generation is a central construct in many theories of language comprehension, although the term has been used in a variety of ways. In the current work, we use it to refer not to explicit generation of expectancies (as in Becker's, 1980, verification model) but rather to the implicit expectancy generation that is a natural by-product of language comprehension processes (as exemplified, for example, by simple recurrent networks and other types of networks that implement processing through time, or by incremental parsing models with a predictive component). Consistent with the notion that comprehenders implicitly generate expectations, a number of computational models and human experiments have shown that both local and global context can narrow expectations for upcoming words in a sentence (e.g. Elman, 1990; Schwanenflugel & Shoben, 1985).

Expectancy generation in theories of sentence processing has focused primarily on verbs. This is reasonable because verbs, as predicating functions, tend to exhibit regular and systematic restrictions on the arguments with which they co-occur. In line with this notion, researchers have concentrated on the ways in which people's knowledge of verb argument structure and of the thematic roles associated with verbs constrains what may follow. It has been shown, for example, that a verb can restrict the range of syntactic structures or broad classes of words that are likely to follow it. One clear example of this is the influence of verb subcategorization preferences on resolving the direct-object/sentence complement ambiguity (Garnsey et al., 1997).

Thematic Roles

Verbs and their associated thematic roles are a major component of most linguistic and psycholinguistic theories of language processing, and many psycholinguistic experiments have focused on thematic role assignment. One reason for this is that thematic roles are hypothesized to be an important locus of semantic/syntactic interaction (Tanenhaus & Carlson, 1989). Recently, McRae, Ferretti, and Amyote (1997) incorporated and extended the important work of Carlson and Tanenhaus (1988), Dowty (1991), and others to construct a theory of thematic roles that incorporates event-specific information. On this account, thematic roles are viewed as including verb-specific concepts, and this conceptual/world knowledge is computed and used immediately in on-line language processing (see Altmann & Kamide, 1999, for supportive evidence from head-mounted eyetracking). As part of this research, Ferretti, McRae, and Hatherell (2001; Experiments 1 and 2) showed that verbs in isolation prime typical agents, patients, and instruments. Their Experiment 4 showed further that priming was limited to the appropriate role when active versus passive sentence fragments were used to cue roles. Given these conjoint effects of semantic and syntactic cues, they concluded that verbs activate event schemas and that this knowledge should be considered as part of thematic roles.

Expectancies from Nouns to Verbs

Because of the emphasis on verbs in the sentence processing literature, one often finds characterizations in which processing is dependent to a high degree on the verb, implying that processing may be held in abeyance until the verb is heard or read. However, in verb-final languages such as German, deferring any hypothesis about structure and meaning until the end of the sentence or clause would be an inefficient processing strategy (Frazier, 1987). Furthermore, a number of recent articles have addressed incremental syntactic processing in verb-final constructions in German and Japanese (e.g., Kamide & Mitchell, 1999).

There are reasons to believe that under many circumstances, words from major syntactic categories other than verbs may exert powerful constraining forces on expectancy generation. For example, nouns can possess valence restrictions, although they do so to a lesser degree than do verbs. In addition, our work with modeling suggests that network dynamics will encode the degree to which elements other than the verb restrict the range of what may follow. Therefore, non-verbs may generate powerful expectations about what might follow, including expectations about possible verbs.

Strong candidates for driving expectations for semantic classes of verbs are typical fillers of their thematic roles: that is, the agents, patients, and instruments that often are involved in specific types of events, as well as locations at which specific events typically occur. The present research was designed to test this possibility. The logic underlying the experiment is that certain nouns may produce expectations for certain semantic classes of verbs during normal on-line sentence comprehension by activating event schema knowledge. If nouns do activate event knowledge associated with verbs, then those nouns should prime corresponding verbs in a short SOA single-word priming task. Note that we are not claiming that expectancy generation necessarily drives performance in a short SOA priming task. Instead, the claim is that nouns activate event schemas, and this drives the priming. The implication is that this knowledge, once activated, can then serve as a source for expectancy generation during on-line comprehension of full sentences in natural language. Before describing the experiment itself, we briefly outline another aspect of the theoretical motivation, based on recent work on event memory.

Autobiographical Event Memory

In much the same way that language researchers have focused on knowledge computed from verbs, theories of autobiographical memory often have focused on activity as a primary organizing principle of event representations. Some researchers have characterized this as the *strong activity view*, whereby events are organized and accessed by activity only. Thus in parallel with the emphasis on verbs in the psycholinguistic literature, much of the literature on the organization of autobiographical memory emphasizes the centrality of events, which often are realized linguistically as verbs. The Ferretti et al. (2001) results showing that some verbs provide strong expectations for classes of noun concepts to fill specific thematic roles could be viewed as on-line support for this position.

At the same time, the literature on the organization of event memory also suggests that nouns may produce expectations for specific classes of verbs. Lancaster and Barsalou (1997) found that people are adept at organizing short narratives in terms of multiple components of events, including activity (i.e., by verb), time, participants (i.e., agents and patients), and location. They argued that contrary to the strong activity view, memory is organized to allow access from multiple components of events.

Our argument assumes that people's knowledge of a generalized event such as *skating* is constructed over time from individual event instances, and can be computed in multiple ways. If this is correct, nouns should quickly activate well-learned event knowledge, so that typical agents, patients, instruments and locations should prime verbs denoting the event.

Experiment

The present research tested this prediction using short SOA priming from nouns to verbs. The noun primes referred to entities, objects, and locations that are typically involved in the events denoted by the target verbs. We predicted shorter naming latencies for verbs primed by their common thematic role fillers than for verbs primed by unrelated nouns because a related noun will activate the schema corresponding to the type of event in which it typically participates, thus activating a verb denoting that type of event.

Method

Participants. Forty University of Western Ontario undergraduates participated for course credit. All participants were native speakers of English and had normal or corrected-to-normal visual acuity.

Materials. To tap into people's knowledge of the types of events in which certain entities and objects play a specific role, we used what we will refer to as *thematic-based event generation norms*. These norms are designed to estimate the conditional probability of a generalized event given an entity or object playing a specific role. Participants were asked to generate verbs in response to typical agents, patients, instruments, and locations. In the agent norms, participants were given nouns such as *nun* and were asked to "List the things that these people commonly do." In the patient norms, participants were given nouns such as *dice* and asked to "List the things that these objects/people commonly have done to them." In the instrument norms, participants were given nouns such as *shovel* and asked to "List the things that people commonly use each of the following to do." Finally, in the location norms, participants were given nouns such as *arena* and asked to "List the things that people commonly do at/in each of these locations." both For each item, ten blank lines were provided for responses. No time limit was imposed. Participants were undergraduate students from Bowling Green State University. Each participant completed only one list; there were approximately 25 items per list. In total, 20 participants responded to each item.

Responses were scored based on their rank order within a participant, and on their response frequency. That is, each response was scored in terms of the number of participants listing it first, second, third, through to tenth. A weighted score was calculated for each response by multiplying the frequency with which it was produced first times 10, second times 9, and so on, and then summing those products. Wherever possible, noun-verb pairs were chosen for the priming experiment by taking the verb with the highest weighted score. In a few cases, the response with the highest weighted score could not be used because it was a multi-word phrase, such as *work out* for *gymnasium*, and the constraints of the naming task demanded a single-word verb target. In a few other cases, the same verb was the best response for more than one item (e.g., *cut* for both *chainsaw* and *knife*). In both of these cases, the verb chosen for the priming experiment was either the next-best response, or a synonym or near synonym of the best response. For example, because *cutting* was used as the target for chainsaw, *slicing* was used instead of *cutting* as the target for *knife*.

From these norms, we chose 30 agents paired with the present participle of a verb such as *nun - praying, waiter - serving,* and *lawyer - defending,* 30 patients paired with the past participle form of a verb, such as *teeth - brushed, dice - rolled,* and *tax - paid*, 32 instrument-present participle pairs such as *shovel - digging, pen - writing,* and *chainsaw - cutting*, and 24 location-present participle pairs such as *cafeteria - eating*, *bedroom - sleeping,* and *bathroom - showering.* The weighted scores for the verbs for each thematic role were (maximum of 200): agents, M = 91, SE = 10; patients, M = 111, SE = 10; instruments, M = 134, SE = 8; and locations, M = 114, SE = 11.

Target verbs were presented in present participle form with the agent, instrument, and location primes. Verb targets paired with typical patients, however, were presented in their past participle forms to avoid including prime-target pairs that formed coherent familiar phrases, such as *cigar smoking*.

Lists. Two lists were created for each type of noun (i.e., agents, patients, instruments, and locations). Each list contained half of the related and the opposing half of the unrelated items. Unrelated items were created by re-pairing the nouns and verbs from the related trials in the opposite list. Filler trials consisted of unrelated noun-verb pairs such as *stapler vacuuming*. Each list contained four times as many unrelated filler trials as related target items (relatedness proportion was .17). Thirty-five unrelated practice trials were used for the practice session for every participant. No participant saw any word twice.

Procedure. For each trial, the participant was instructed to read silently the first word presented on the computer screen and to pronounce aloud the second word as quickly and accurately as possible into the microphone. Stimuli were presented on a 14-inch Sony Trinitron monitor connected to a Macintosh LC630 using PsyScope (Cohen et al., 1993). A microphone connected to a CMU button box measured naming latency (in ms) as the time between the onset of the target and the participant’s pronunciation of it. Each trial consisted of: a focal point (*) for 250 ms; the prime for 200 ms; a mask (&&&&&&&&&) for 50 ms; and the target until the participant named it. The intertrial interval was 1500 ms, and a break was given every 40 trials. Testing sessions began with the practice trials and lasted approximately 20 minutes. The experimenter recorded trials in which the participant mispronounced a word (a pronunciation error), extraneous noise caused the voice key to trigger (a machine error), or the voice key failed to trigger (a machine error). Participants were assigned randomly to be tested on either the agents and locations, or on the patients and instruments. The order of the two lists was counter balanced across participants (i.e., ten participants were tested on agents then locations, and another ten on locations then agents, and the same for the patients and instruments).

Design. Naming latencies and the square root of the number of pronunciation errors (Myers, 1979) were analyzed by separate two-way analyses of variance for each thematic role (agents, patients, instruments, and locations). The factor of interest was relatedness (related vs. unrelated), which was within both participants (F_1) and items (F_2). List was included as a

Table 1: Mean Verb Naming Latencies (ms) and Percentage Pronunciation Errors

	Agents		Patients		Instruments		Locations	
Dependent Measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Response Latency								
Unrelated	592	21	583	20	565	20	578	16
Related	574	19	561	18	549	17	560	19
Facilitation	18*		22*		16*		18*	
Percentage Errors								
Unrelated	1.9	0.8	3.2	1.4	1.4	0.7	2.5	1.2
Related	1.9	0.9	1.9	0.8	1.1	0.6	1.5	0.8
Facilitation	0		1.3		0.3		1.0	

* Significant by participants and items

between-participants dummy variable and item rotation group as a between-items dummy variable to stabilize variance that may result from rotating participants and items over the two lists (Pollatsek & Well, 1995).

Results

Naming latencies greater than three standard deviations above or below the grand mean were replaced by that value (1% of trials). Two participants were dropped because their soft speaking style resulted in an extreme number of trials in which the voice key was not activated. Machine errors, the majority of which were caused by the microphone failing to register the participant's response, occurred on 4% of the trials, were excluded from all analyses. Pronunciation errors were excluded from the latency analyses. Mean naming latency and percent pronunciation errors are presented for each condition in Table 1. Verbs were named more quickly when preceded by a related versus an unrelated noun for each of the four thematic roles: agents: $F_1(1,18) = 6.19$, $p < .05$, $F_2(1,28) = 4.12$, $p < .06$; patients: $F_1(1,18) = 7.54$, $p < .05$, $F_2(1,28) = 11.98$, $p < .001$; instruments: $F_1(1,18) = 5.66$, $p < .05$, $F_2(1,30) = 7.64$, $p < .01$; and locations: $F_1(1,18) = 5.33$, $p < .05$, $F_2(1,22) = 10.41$, $p < .01$. There were no reliable differences in pronunciation error rates, all F's < 1.

Discussion

Noun-verb pairs were chosen using thematic-based event generation norms designed to tap into people's knowledge of the conditional probability of a generalized event given an agent, patient, instrument, or location. Significant noun-verb priming was found in all four cases. To our knowledge, this is the first experiment to investigate systematically the priming of verbs from nouns.

This experiment shows that nouns make available information about events in which they typically play a role. One plausible explanation of these results is that, as in the weak activity view of event memory (Lancaster & Barsalou, 1997), event schemas are organized so that they are accessible from common agents, patients, instruments and locations. That is, mental representations of generalized events are structured so that they can be computed quickly when a noun that refers to a typical component of a specific type of event is read or heard. When this generalized event knowledge is computed, the verb corresponding to this type of event is partially activated, thus resulting in the priming effects found in the Experiment. In other words, language and event memory are organized so that event knowledge can be accessed quickly from nouns, as well as from verbs. This explanation is consistent with Moss et al. (1995) who found priming using functionally-related items such as *broom-floor*. Moss et al. concluded that priming in their experiment occurred through representations of generalized events.

The fact that nouns can activate information about corresponding verbs suggests that, at least in some circumstances, nouns may be a strong source of expectancy generation for ensuing verbs. This may be particularly important for languages such as German and Japanese, which contain numerous verb-final constructions, but it may also play a key role in sentence comprehension (and production) in English. At least one noun phrase precedes the verb in the vast majority of English utterances, and in many constructions the verb appears late in the clause, as in questions (Which customer did he serve?) and it-clefts (It was vase on the coffee table that she broke.).

One question that might be asked of the present results is why priming was found from locations to verbs, whereas Ferretti et al. (2001) failed to find priming from verbs to locations. The most likely explanation concerns the type of norming used in the two experiments. The present study used thematic-based event generation norms designed to tap people's knowledge of the conditional probability of an event given (in this case) a location. In contrast, Ferretti et al. used role/filler typicality norms in which participants were asked to provide ratings for questions such as "How common is it for someone to draw in each of the following locations?" This may not be the best way to measure the conditional probability of the location given the event. For example, although the mean role/filler typicality rating for *draw-studio* was 6.5 out of 7, there are numerous locations where drawing can occur, and a studio might not rank as the best.

To test this possibility, we conducted a further set of norms, parallel to the event generation norms used in the current study. Participants listed locations at which some event might occur, providing an estimate of the conditional probability. In these norms, the mean weighted score for Ferretti et al.'s (2001) verb-location items was only 44 (maximum of 200). In contrast, the mean weighted score of the location-verb items used in the present research was 114. This difference between the conditional probabilities in the relevant directions may account for the discrepancy between studies.

Note, however, that the Ferretti et al. (2001) study *did* find robust priming in the other three verb-noun conditions (i.e., verbs primed agents, patients, and instruments), raising the possibility that our results may be due to backward priming from the verb. If this was the case, it would seriously reduce the theoretical import of our results. In response to this potential criticism, we note that Kahan, Neely, and Forsythe (1999) and Peterson and Simpson (1989) have shown that backward priming occurs in a naming task at a short SOA, but not at an SOA of 500 ms. Therefore, we currently are replicating this experiment using a 500 ms SOA. If verbs are primed, which we expect they will be given the conditional probabilities as evidenced by our norms, then we can be positive that backward priming is not responsible for our results.

Spreading Activation Networks. A common explanation of word-word priming results focuses on spreading activation in a semantic network. Therefore, an interesting question concerns whether spreading activation networks would predict priming of verbs from agents, patients, instruments, and locations. Although the first semantic networks focused solely on noun representations (Collins & Quillian, 1969), relatively early extensions incorporated verbs (Gentner, 1975; Rumelhart & Levin, 1975). Verb representation included core meaning plus thematic links to nodes that stood as placeholders for possible noun phrases that fill those roles in sentences. Note that these links could be bi-directional, so that activation could spread from the thematic role nodes to the verb node. However, these thematic links and nodes included minimal semantic content that was restricted to general selectional restriction information. For example, a thematic link between a verb and an agent node might specify that the filler of that node must be animate. Thus, spreading activation models of this type predict no priming because the experiment reported herein controlled for general selectional restrictions in that the related and unrelated trials were equivalent in terms of this factor.

If current semantic networks were expanded, it could be assumed that noun nodes representing common agents, patients, instruments, and locations become linked to specific verb nodes over time. These links might be formed because of people's experience with events (via noticing that chainsaws are used for cutting), and/or linguistic descriptions of events (e.g., via word co-occurrence in speech and text). In this view, when participants read the noun prime in our experiment, activation might spread to the verb node and priming might result. Thus spreading activation networks could predict priming of verbs from typical thematic role fillers, but only by incorporating ad hoc assumptions well outside the scope of current versions of the theory.

Undifferentiated links encoding associative relatedness provide a possible second way in which spreading activation networks might predict priming from typical thematic role fillers to verbs. If the representations of words and/or concepts that often co-occur in events and language become linked in one or more of semantics, orthography, and phonology via an unspecified associative relation, then those links could serve as the basis for priming from nouns referring to typical components of events to verbs. Theoretically, however, it is a step backward to treat this knowledge as an undifferentiated associative relation because it is known to be thematic-driven knowledge concerning the relationship between generalized events and their common components.

Finally, a recent experiment, part of this line of research, produced results that are extremely difficult for a spreading activation network to account for, even given the additional ad hoc assumptions described above. Ferretti (2000) manipulated verb aspect to reference various components of the temporal structure of events. In one condition, he presented a verb prime in its imperfective aspect (e.g., *was skating*), which references an event as ongoing. Ferretti reasoned that if an event is in the process of occurring, then the location at which the event is taking place should be salient. In the second condition, the verb prime was presented in its past perfect form (e.g., *had skated*), which references the event as completed. That is, perfect aspect focuses on the resultant states of an event. Ferretti reasoned that if the event is referred to as completed, the location at which that type of event typically occurs should not be as salient. Thus, if priming is due to event knowledge and aspect references various components of the temporal structure of events, priming should be found with imperfective aspect (where location is salient) but not with perfect aspect (where it is not). In a spreading activation network account, there should be no influence of aspect. In a short SOA priming task, typical locations were significantly primed by verbs presented in their imperfective aspect, whereas no priming obtained when perfect aspect was used. These results follow naturally from an account in which priming occurs via event schemas. However, accounting for them in a spreading activation network requires incorporating some mechanism by which aspect can modulate the flow of activation.

Conclusions

Event memory is organized in multiple ways, making it accessible from nouns as well as from verbs. Because of this, agents, patients, instruments, and locations prime verbs denoting events in which they typically play a specific role. These results suggest that nouns can be a basis for generating expectancies for upcoming verbs during on-line sentence comprehension.

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