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Generalized event knowledge activation during online sentence comprehension

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Abstract

Recent research has demonstrated that knowledge of real-world events plays an important role in guiding online language comprehension. The present study addresses the scope of event knowledge activation during the course of comprehension, specifically investigating whether activation is limited to those knowledge elements that align with the local linguistic context. The present study addresses this issue by analyzing event-related brain potentials (ERPs) recorded as participants read brief scenarios describing typical real-world events. Experiment 1 demonstrates that a contextually anomalous word elicits a reduced N400 if it is generally related to the described event, even when controlling for the degree of association of this word with individual words in the preceding context and with the expected continuation. Experiment 2 shows that this effect disappears when the discourse context is removed. These findings demonstrate that during the course of incremental comprehension, comprehenders activate general knowledge about the described event, even at points at which this knowledge would constitute an anomalous continuation of the linguistic stream. Generalized event knowledge activation contributes to mental representations of described events, is immediately available to influence language processing, and likely drives linguistic expectancy generation.

Keywords

sentence processing; psycholinguistics; language comprehension; event knowledge; event-related potentials; expectancy generation

Introduction

Despite its great complexity, the world is a highly structured environment. Events in the world are not random, but instead exhibit regularities that people learn throughout their lives. Knowledge of these regularities, for example that police arrest criminals or that glass often breaks when dropped, supports numerous cognitive capacities, including

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language comprehension. The importance of event knowledge to language comprehension has been appreciated for some time. Work dating back several decades has unequivocally demonstrated that successful comprehension involves engaging real-world knowledge stored in long-term memory (Bransford & Johnson, 1972; Sanford & Garrod, 1981; Schank, 1980; van Dijk & Kintsch, 1983). Some theories of language comprehension invoke the mapping between linguistic input and relevant event knowledge as entirely fundamental to what it is to understand language (Altmann & Mirkovic, 2009; Elman, 2009; Sanford & Garrod, 1998; van Dijk & Kintsch, 1983). Although much early work on discourse comprehension supports this notion, these studies generally do not provide an account of how event knowledge is engaged in real time, as a sentence is comprehended incrementally.

Determining the time-course of event knowledge activation and use is a central issue in developing any theory of online language processing, and this is the central goal of this study. Some theories propose that the early stages of online comprehension are largely informationally encapsulated, with only syntactic and basic lexical information being immediately accessed as a word is processed in real-time (Bornkessel & Schlesewsky, 2006; Frazier, 1978, 1990, 1995; Frazier & Rayner, 1982; Rayner, Carlson, & Frazier, 1983). However, in recent years, accumulating evidence indicates that event knowledge exerts a rapid influence on incremental comprehension processes, suggesting that the earliest stages of comprehension engage the wealth of world knowledge a comprehender brings to the task of understanding language.

At the level of individual words, lexical priming studies suggest that the processing of isolated words immediately activates knowledge of events of which the words are components. Agent, patient, instrument, and location nouns prime verbs denoting events in which these elements participate (McRae, Hare, Elman, & Ferretti, 2005), and nouns denoting events prime people and objects typically found at those events (Hare, Jones, Thomson, Kelly, & McRae, 2009). Instrument nouns prime objects on which those instruments are typically used, and location nouns prime typical people and objects found at those locations (Hare, Jones, et al., 2009). Chwilla and Kolk (2005) found priming in a word triplet paradigm when the combination of two primes denote an event to which the target word is related (e.g., *director* and *bribe* together prime *dismissal*). Ferretti, Kutas, and McRae (2007) found that priming of event locations by event verbs is modulated by verb aspect: imperfective verbs prime event locations while perfective verbs do not (e.g., *was cooking* primes *kitchen*, but *had cooked* does not), demonstrating that isolated verb processing results in immediate accessibility of likely event locations only when the verb denotes the event as ongoing. This notion is consistent with other experimental work showing that imperfective verbs highlight the internal structure of an event, while perfective verbs promote a representation of the event as a completed whole (Madden & Zwaan, 2003). It is worth noting that these priming results are unlikely to be due to undifferentiated associations between individual lexical items. In Chwilla and Kolk (2005), the individual prime words were not normatively associated with each other or the target word, meaning that the priming effect most likely resulted from rapid integration of the meanings of the two prime words through mapping onto an event knowledge structure. Likewise, in Ferretti et al. (2007), direct lexical associations cannot account for the obtained effect, as priming of event locations by a single verb depends upon the grammatical form of that verb. If direct associations between lexical items alone were at play, verb aspect should not modulate the priming effect. It thus appears that even in the absence of a sentential or discourse context, language comprehension involves rapid mapping of linguistic input onto event knowledge, resulting in activation of other event-relevant information. Such a finding suggests that mapping linguistic input to event knowledge is a fundamental characteristic of the language comprehension system.

From this conclusion, it follows that event knowledge should exert an immediate influence during online sentence and discourse comprehension. Sentences and discourse provide not only individual content words capable of evoking event knowledge, but also cues as to the relations between these words, providing rich information to be used in mapping linguistic input onto event knowledge. Along these lines, Altmann and Kamide (1999) demonstrated that the thematic fit between a verb and possible patient objects, in combination with concurrent visual input, can drive expectations for postverbal arguments. Participants viewed a scene depicting, for example, a boy, a cake, and several toys. Participants were faster to fixate the target (cake) when they heard *The boy will eat the cake* than when they heard *The boy will move the cake*, with fixation patterns suggesting that participants were able to anticipate the target following the verb *eat* but not following the less restrictive verb *move*. This finding shows that upon encountering the verb, comprehenders were able to rapidly apply their world knowledge (i.e., that a boy will likely eat something that is edible), in conjunction with visual information (i.e., that the cake is the only edible object in the scene), to anticipate an upcoming referent. Expanding upon this finding, Kamide, Altmann, and Haywood (2003) found that comprehenders launch anticipatory saccades based on the event implied by the integration of an agent noun and following verb - for example, participants were more likely to launch anticipatory saccades to a picture of a motorbike upon hearing *The man will ride...* than upon hearing *The girl will ride...* This finding indicates that comprehenders can integrate information provided at multiple points in a sentence to engage event knowledge, which then, in conjunction with information provided by a visual display, guides anticipatory processing.

Additional evidence for the rapid influence of event knowledge has been obtained in reading time studies. Postverbal patient nouns are read faster when they are plausible given the combination of a preceding agent and verb (Bicknell, Elman, Hare, McRae, & Kutas, 2010) or preceding instrument and verb (Matsuki, Chow, Hare, Elman, Scheepers, & McRae, 2011). These results, like those of Kamide et al. (2003), demonstrate that the online assessment of thematic fit of a post-verbal argument is not determined by the verb alone, but rather by information regarding the real-world event denoted by the verb in combination with its preceding arguments. Verbs therefore appear to encode thematic roles in an event-specific fashion, a conclusion that has major consequences for theories of lexical knowledge (Elman, 2009).

Reading time studies have shown event knowledge to exert a rapid influence in the syntactic domain, as well. Expectations for a reduced relative clause are affected by the status of the grammatical subject as a typical agent (*The crook arrested by the detective was guilty*) or patient (*The cop arrested...*) of the initial verb (McRae, Spivey-Knowlton, & Tanenhaus, 1998). Similarly, postverbal regions of intransitive sentences are read faster when the subject is a plausible patient of the verb versus a plausible agent (e.g., *into tiny bits* is read faster following *The glass shattered* than following *The brick shattered*), and the converse holds true for transitive sentences (Hare, Elman, Tabaczynski, & McRae, 2009). This finding and that reported by McRae et al. (1998) show that event knowledge exerts an immediate influence on syntactic expectations during incremental comprehension.

Research using the event-related brain potential (ERP) technique has demonstrated that the compatibility of an eliciting word with the described event modulates the amplitude of the N400 component. The N400 is a negative going deflection in the ERP waveform peaking at approximately 400ms following the onset of a word. Its amplitude is inversely related to the eliciting word's degree of contextual fit, which is often captured offline by the word's cloze probability (the proportion of people who provide the word as a continuation of the sentence at that point). N400 amplitude is generally viewed as an index of online meaning processing via semantic memory activation (Kutas & Federmeier, 2000, 2011; Kutas & Hillyard, 1980,

1984). The previously discussed studies by Ferretti et al. (2007), Chwilla and Kolk (2005), and Bicknell et al. (2010) included ERP experiments that showed their obtained reaction time and reading time effects are reflected in N400 amplitude modulations. Hagoort and colleagues have shown that violations of world knowledge that are nevertheless semantically appropriate elicit N400s of similar amplitude to lexico-semantic violations (Hagoort, Hald, Bastiaansen, & Petersson, 2004). Given that Dutch trains are typically yellow, the target word *white* in *The Dutch trains are white and very crowded* elicits an N400 equal in amplitude to that elicited by *sour* in *The Dutch trains are sour and very crowded*. This amplitude similarity, in addition to similarity in topography, onset, and peak latency of the N400 for the two violation types, suggests that both world knowledge and lexical semantic knowledge influence online meaning processing in a similar fashion, a conclusion consistent with the notion that world knowledge and lexical semantic knowledge are not entirely dissociable (Elman, 2009). These and other ERP studies (e.g., Camblin, Gordon, & Swaab, 2007; Hald, Steenbeek-Planting, & Hagoort, 2007; Otten & Van Berkum, 2007) strongly suggest that general event knowledge engaged during discourse comprehension serves to guide online semantic processing, and that N400 amplitude can serve as an accurate index of this process.

The Scope of Real-time Event Knowledge Activation

The research discussed above has conclusively demonstrated through a variety of techniques that event knowledge is an important source of information used to guide language comprehension in real time. When we comprehend language about events, we activate knowledge regarding those events and use this knowledge to facilitate online linguistic processing. It is important to note, however, that previous work described above demonstrates facilitated processing exclusively for words that are semantically congruent with the linguistic context. With respect to the scope of event knowledge activation during the course of incremental comprehension, such research allows us to infer that activation includes elements that are congruent with both the event being described and (crucially) the linguistic context itself. The question we ask here is whether real-time event knowledge activation extends to elements that are anomalous within the local linguistic context (i.e., are not predicted by the context) but which are nonetheless consistent with the global event being described. That is, despite the fact that the reviewed lexical priming results demonstrate that processing isolated words engages a range of event knowledge elements, it is possible that during online sentence comprehension, the cues provided by the unfolding linguistic context constrain event knowledge activation to only those elements that would constitute semantically congruent or expected continuations of the sentence at that point. Alternatively, as we hypothesize, additional event-relevant but contextually anomalous entities might become activated in comprehenders' minds even when they violate the linguistic context.

To illustrate, consider the passage in (1):

(1) A huge blizzard ripped through town last night. My kids ended up getting the day off from school. They spent the whole day outside building a big snowman in the front yard.

Given previous results indicating that comprehenders utilize event knowledge to guide linguistic expectancy generation, it is likely that upon processing *building a big*, a comprehender will activate objects often built by children playing in the snow, such as a snowman or igloo. However, people know more about “playing in the snow” events than snowmen and igloos, such as the likelihood that the children are bundled up with hats, mittens, and jackets, but none of these items satisfy the semantic constraints imposed by the verb *building*. Therefore while these items are salient components of “playing in the snow” knowledge, the linguistic context suggests that these items should not appear in the sentence

at this point. If specific cues provided by the linguistic context interact with activation of event knowledge to yield activation of only those elements that would constitute congruent or expected continuations of the current sentence at that point, it would suggest that event knowledge activation, as it occurs as a sentence is comprehended incrementally, serves mainly to facilitate processing of the linguistic input that the comprehender is likely to receive. On the other hand, the ability of comprehenders to make causal or bridging inferences clearly indicates that language comprehension must engage general event knowledge that is not explicitly stated in the discourse. The issue we address, thus, is how activation of particular elements of event knowledge is constrained in real time by the specific cues present in an unfolding sentential context.

This specific issue speaks directly to the more fundamental question regarding the nature of the mental representations that are dynamically constructed during incremental sentence comprehension. Mental representations of described events are not static, but rather are continuously modified during the course of comprehension. If event knowledge is itself not merely used to guide incremental sentence processing, but is itself a *target* of the comprehension process, then we would expect to find facilitated processing for salient event knowledge elements even at specific times at which the elements do not align with the particular cues provided by the local linguistic context.

This is the hypothesis we pursue here. This hypothesis generally aligns with previous research on inferencing. This research has demonstrated that discourse comprehension often involves instantiation of relevant, unstated information accessed from long-term memory (see Graesser, Singer, & Trabasso (1994) and McKoon & Ratcliff (1992) for reviews of inferencing research and theories of inference generation)¹. While inferencing research has established that discourse comprehension can engage unstated but relevant background knowledge at least in some circumstances, we do not know how such knowledge activation interacts with linguistic contextual cues as a sentence is comprehended incrementally. Research in this area typically employs paradigms in which a probe word or sentence is presented following comprehension of a preceding sentence or discourse. Such paradigms allow one to assess activation of unstated event knowledge after comprehending a discourse, but they do not provide insight into how activation of this knowledge interacts with explicit linguistic cues unfolding in real time. Facilitated processing of a probe following discourse comprehension may show that this knowledge is activated at some point following offset of discourse presentation, but it is an open question whether contextual cues encountered as a sentence is processed incrementally dynamically limit activation of event-relevant information to only that which aligns with the linguistic context.

In fact, there are experimental results suggesting that unfolding contextual cues may limit the scope of event knowledge activation. Traxler, Foss, Seely, Kaup, and Morris (2000) monitored participants' eye movements during reading of sentences such as *The [lumberjack/young man] chopped the axe early in the morning*, and found no difference in first fixation or gaze duration times for the target word (*axe*) following the different agents (*lumberjack* vs. *young man*). The authors concluded that schematic knowledge does not drive general activation of words describing event participants during online comprehension. If it did, *axe* should have been read faster following *lumberjack chopped*, because an axe is a prototypical instrument associated with a "lumberjacking" schema. In an earlier study, Kintsch and Mross (1985) found similar results using a cross-modal lexical decision task. Participants listened to brief stories describing common events (e.g., catching a flight) and made a lexical decision to a visually presented word mid-discourse. The authors found only

¹The degree to which certain types of inference are automatically generated is debated. We will touch upon this issue with respect to the present study in the General Discussion.

a marginal priming effect for event-associated versus -unassociated words (e.g., *gate* vs. *stack* in the airport scenario), and in a version of the experiment employing all-visual presentation, this marginal priming effect disappeared completely. This result, like that found by Traxler et al., suggests that online event knowledge activation does not extend to elements that do not fit the local linguistic context. However, Traxler et al. used only a few sentence-initial words to establish a situation, and Mross and Kintsch tested for activation of ensuing actions. Thus, we believe that these results should not be taken to indicate conclusively that linguistic cues dynamically limit event knowledge activation. The relationship between these studies and the present study is discussed in more detail in the General Discussion.

The Present Study

In two experiments, we investigated the real-time activation of contextually anomalous event knowledge elements during incremental language comprehension. We recorded participants' EEG as they read brief scenarios such as the "playing in the snow" example in (1) above. In each scenario, two sentences established an event context, and a third and final sentence included one of three target word types. In one condition, participants read a highly expected word (e.g., *building a snowman*; the *expected* target). In another condition, participants read a contextually anomalous word that was unrelated to the event being described (e.g., *building a towel*; the *event-unrelated* target), and in a third, they read an anomalous word that crucially was related to the described event (e.g., *building a jacket*; the *event-related* target). ERPs elicited by these three target types were analyzed, with special attention paid to the amplitude of the N400 component.

Given previous N400 results, we predicted that the expected targets should elicit an N400 of very small amplitude (perhaps even a positivity in the 200-500ms N400 latency range), as they are contextually congruous and on average are highly expected in context. Furthermore, the event-unrelated targets should elicit a large N400 because they are contextually anomalous and completely unexpected. The major issue hinges on the amplitude of the N400 elicited by the event-related but contextually anomalous targets. If they elicit an N400 equal to the event-unrelated targets, it would suggest that fit with the local linguistic context is necessary to observe facilitated processing of event-related concepts, and that linguistic cues greatly constrain event knowledge activation in real time. However, if event knowledge activation extends beyond contextually congruent information to include other prominent elements of event knowledge, then the event-related targets should elicit a reduced N400 compared to the event-unrelated targets.

There are a number of previous ERP studies demonstrating N400 reduction for unexpected contextually inappropriate words based on various relationships between those words and the preceding context or most expected word. Unexpected words elicit a reduced N400 when semantically related to the most expected word (Kutas & Hillyard, 1984), with context-independent semantic category structure likely supporting this effect (Federmeier & Kutas, 1999). Along similar lines, incorrect reinstatement of a categorical anaphor elicits a reduced N400 when the reinstatement is from the same category as the correct antecedent (e.g., *seat* referring to the antecedent *stool*, but being reinstated in a subsequent sentence as *couch*; Ditman, Holcomb, & Kuperberg, 2007). Other work has shown that semantic illusion stimuli elicit N400s of similar amplitude to the most expected word (e.g., In a recent trial, a ten-year sentence was given to the *victim*; Sanford, Leuthold, Bohan, & Sanford, 2010). This effect holds even for words that violate animacy restrictions of a verb when the violating word has been stated previously and constitutes the theme of the discourse (Nieuwland & Van Berkum, 2005). In addition, words that violate real-world plausibility can elicit smaller N400s than generally plausible words when the discourse explicitly highlights the implausible situation as acceptable (Nieuwland & Van Berkum, 2006).

Discourse cues do not completely trump prior knowledge, though; words that align with world knowledge but not the specific discourse message elicit smaller N400s than words that align with neither (Hald et al., 2007; Otten & Van Berkum, 2007).

These findings highlight several important issues with respect to the present study. First, because studies have shown N400 reduction due to semantic relatedness between an unexpected target word and the most expected word, we controlled this relation in our study. Second, because Nieuwland & Van Berkum (2005) found that a contextually anomalous word can elicit a reduced N400 when explicitly mentioned as the theme of the discourse, we ensured that our event-related and event-unrelated targets were not previously mentioned in their discourse contexts. Finally, the latter studies underscore the specific theoretical contribution of the present study. Previous research has established that event knowledge can exert an influence on N400 amplitude independently of information provided by the discourse message. For example, when the discourse describes traffic issues and road layout in Venice, *canals* nonetheless elicits a similar N400 to *roundabouts* following *The city of Venice has many...* (Hald et al., 2007). However, no study has investigated how association with a described event affects the N400 elicited by a word that is anomalous at a particular point in the linguistic stream. In doing so here, this study seeks to determine whether event knowledge elements that violate the local linguistic context are active during the course of incremental comprehension. Reduction of the N400 elicited by a contextually anomalous but event-related word would indicate that incremental comprehension involves activation of event knowledge elements beyond those supported by the local linguistic context. Uncovering such an extended scope of event knowledge activation would add to our knowledge of how information in long-term memory is engaged during the course of comprehension and would inform all theories regarding how people comprehend language about real-world events.

Experiment 1

In Experiment 1, participants' EEG was recorded while they read three-sentence scenarios describing typical events. The dependent measure was the amplitude of the N400 elicited by three types of target words: a highly expected word, a contextually anomalous word that was related to the described event, and an equally anomalous word that was unrelated to the event. Based on numerous studies in which cloze probability of targets has been manipulated, we anticipated that the expected targets would elicit the lowest amplitude N400 response. Because both the event-related and event-unrelated targets were zero-cloze and generally nonsensical in context, one possibility is that their N400 responses would not differ from one another, but would be significantly greater than the expected targets. However, if activation of event knowledge extends to elements that violate the linguistic context, we would observe a three-way contrast: expected targets would elicit the lowest amplitude N400, event-unrelated targets would elicit the largest, and event-related targets would elicit an N400 intermediate to these two extremes.

Methods

Participants—Thirty undergraduates (22 women; ages 18 to 22 years) at the University of California, San Diego completed the ERP experiment for course credit. All were right-handed, native monolingual English speakers, and none reported any history of learning or reading disabilities or neurological or psychiatric disorders.

Materials—The experimental materials consisted of 72 scenarios similar to that presented in (1) above. Each scenario consisted of three sentences. The first two sentences were designed to establish the event context. The third sentence contained one of three possible target words: the most expected word (the expected target), a contextually anomalous word

that was related to the event described (the event-related target), or a contextually anomalous word that was unrelated to the event (the event-unrelated target).

We began by creating 72 three-sentence scenarios in which the first two sentences were complete, and the third sentence terminated at a point at which we believed that a specific noun would be deemed highly likely to come next. In a cloze task, participants read the scenarios and provided the word they believed would be most likely to continue each story. Thirty UCSD undergraduates (23 women; all native English speakers), none of whom participated in the ERP experiment, completed the cloze task through an online form. Cloze probability was calculated as the proportion of participants who provided a particular response for a given scenario. For each scenario, the word with the highest cloze probability was chosen as the expected target. Across the 72 scenarios, the mean cloze probability of the expected target was 0.81 (range = 0.367 to 1.00; $SD = 0.17$).

Following the cloze task, we used the scenarios with the expected targets filled in to probe comprehenders' knowledge of people or objects that were unstated but highly likely to be components of the described events. Responses were used to select the event-related targets. Participants were instructed to read each scenario and to "paint a mental picture" of the event being described. They were told that these mental pictures would probably include various people and objects that were present at the event but not explicitly mentioned in the text itself. They were asked to list up to five of these people/objects for each scenario. Forty-five UCSD undergraduates (26 women; all native English speakers), none of whom participated in the ERP experiment or previous cloze task, completed the task through an online form. Responses for each scenario were given weighted scores based on order of mention (5 points for the first response, 4 for the second, etc.). The highest scoring response that was not provided as a response in the cloze study (i.e., was zero-cloze) was chosen as the event-related target. In a few instances, the highest scoring event related target was deemed by the authors to constitute a sensible continuation of the sentence despite not being provided as a response in the cloze task. In these cases, the next highest scoring zero-cloze response was chosen. This was to ensure that each event-related target, although highly likely to be part of the described event, would be truly anomalous in context. Across the 72 scenarios, the mean score for the event-related targets was 92.4 (range = 38 to 171; $SD = 35.3$). The maximum possible score for a given item, had every participant provided the same item as their first choice for that scenario, was 225 (45 subjects x score of 5).

We then constructed event-unrelated targets by shuffling the event-related targets across scenarios. This ensured that the event-related and event-unrelated targets consisted of the same lexical items, thereby controlling lexical factors across the two conditions. The 72 experimental items were split into three rotation groups of 24 scenarios each, allowing for three lists to be constructed by rotating each group through the three conditions. Each scenario thus appeared once in each list and once in each condition across the three lists. To minimize variability across the lists, the rotation groups were matched on the following factors: mean cloze probability, log frequency, and orthographic length of the expected targets; mean event-relatedness score, log frequency, and orthographic length of the event-related targets. Event-related targets were then shuffled across the scenarios within each rotation group to obtain the event-unrelated targets. Event-unrelated targets were shuffled ensuring that each was zero-cloze. In all but two of the 72 scenarios, event-unrelated targets had event-relatedness scores of zero². In addition, the shuffling was done in such a way as to match the event-related and event-unrelated targets within each scenario for animacy and concreteness. The norming results are presented in Table 1. Following these norming

²The two exceptions had extremely low event-relatedness scores of 1 and 3. It is worth noting that the presence of non-zero event-relatedness scores in the event-unrelated targets would only serve to mask the hypothesized effect.

procedures, additional material was added to the final sentence of each scenario to make each target word sentence-medial. All experimental items are presented in the Appendix.

One final issue concerned ensuring that the two anomalous target types were not associated with the expected targets. Previous studies have shown that a contextually inappropriate word can elicit a reduced N400 when closely associated with the most expected word (Federmeier & Kutas, 1999). We quantified the degree of association between the expected target and the two anomalous target types using the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 2004). From Nelson et al.'s norms, we looked for a forward association from the expected target (the cue) to either the event-related or event-unrelated target (the response). Of the 72 experimental scenarios, 65 contained expected targets that appeared in the Nelson norms; mean association scores for the event-related and event-unrelated targets were calculated across these 65 items; mean associative strength was calculated across these items. The mean associative strength was 0.0005 for the event-related targets, and 0.0001 for the event-unrelated targets. Therefore, associative strengths for event-related and event-unrelated targets correspond to one response per two thousand participants and one response per ten thousand participants, respectively. These extremely low scores, and the small, statistically nonsignificant difference between them were deemed acceptable for the purposes of the study.

Each scenario was accompanied by a simple Yes/No comprehension question (also provided in the Appendix). These were included to ensure that participants read each scenario for comprehension. In addition to the 72 experimental items, 24 filler items were included. Like the experimental scenarios, each of these items consisted of three sentences describing a real-world event. None contained any contextually anomalous words. These fillers were included to achieve an even number of trials containing anomalous and non-anomalous words.

Procedure—Participants sat in a soundproofed, electromagnetically shielded chamber and read each scenario from a computer monitor. They were instructed to read the scenarios carefully, as they would be required to answer a comprehension question following each scenario. The first two sentences of each scenario were presented in paragraph format. Once participants understood them, they pushed a button to advance to the final sentence. A small red cross then appeared at the center of the screen to cue participants to avoid behaviors such as blinking, eye movements, and muscle tension, which could introduce artifacts into the EEG signal. The final sentence was presented directly above the cross one word at a time (rapid serial visual presentation, RSVP) with a 350ms stimulus onset asynchrony (SOA), divided into a 200ms stimulus duration and a 150ms inter-stimulus interval (ISI). After the offset of the final word, participants answered a yes/no comprehension question by pushing a button with their left or right hand (e.g., left for “No”, right for “Yes”). Yes/No hand was counterbalanced across participants.

The experiment was divided into five blocks, with the first block containing 20 trials and the remaining four blocks containing 19 trials each. Participants were able to request a short break within or between blocks. The entire experimental session, including preparation of EEG recording, lasted approximately two hours. Ten participants were randomly assigned to each of the three lists. Stimulus presentation order was fully randomized for each participant.

Immediately following the experiment, each participant completed an Author Recognition Test and the Magazine Recognition Test. These tests were local adaptations of the earlier tests described in Cunningham (1990) and Stanovich and Cunningham (1992). ART/MRT questionnaires consisted of 80 author names/magazine titles, 40 real and 40 fake.

Participants were told to mark each author/magazine they knew to be real and to avoid guessing. Scores were calculated as number of correct IDs minus the number of false positives across both tests. Stanovich and Cunningham (1992) present these tests as measures of print exposure, and show that performance on these tests correlates with measures of analytic intelligence, vocabulary, verbal fluency, reading comprehension, and history and literature knowledge. We hypothesized that performance on these tests might also reflect individual differences in participants' knowledge of real-world events, which aligns with Stanovich and Cunningham's proposal that increased print exposure contributes to a richer world knowledge base than that supported by individual experience alone. With ART/MRT performance likely capturing individual differences in linguistic proficiency and world knowledge, we hypothesized that varying performance on these tests might coincide with individual differences in N400 responses to the event-related and event-unrelated target words.

EEG recording and processing—EEG was recorded from 26 tin electrodes distributed evenly across the scalp, referenced online to the left mastoid and re-referenced offline to the average of the left and right mastoids. Electrodes were placed on the outer canthus and infraorbital ridge of each eye to monitor eye movements and blinks. All electrode impedances were kept below 5 K Ω . EEG was amplified with Nicolet amplifiers with a bandpass of 0.016 to 100 Hz and digitized at a rate of 250 Hz. A diagram of the scalp electrodes is provided in Figure 1.

To obtain ERPs for the three target word types, each participant's EEG was time-locked to target word onset and averaged within each condition across a 2044ms epoch, relative to a 500ms pre-stimulus baseline. Trials contaminated by blinks, muscle tension (EMG), channel drift, and/or amplifier blocking were discarded before averaging. Approximately 9% of target word epochs were rejected due to such artifacts, with losses distributed approximately evenly across the three conditions. Individual participant averages were then averaged together to obtain a grand average ERP for each condition. Each participant's performance on the comprehension questions was assessed before entering the participant's data into the analysis. All participants scored at least 89% correct on the 72 target comprehension questions, indicating that they read the scenarios for comprehension as instructed, and therefore no participant's data were excluded.

Results

N400 amplitude—Figure 2 displays the grand average target word ERPs for the 26 scalp electrodes from 500ms pre-stimulus to 1000ms post-stimulus, arranged according to the distribution of electrodes across the scalp presented in Figure 1. The N400 can be seen as a negative-going deflection in the ERP waveform peaking at approximately 400ms post-stimulus. To analyze N400 amplitude differences across the three conditions, mean ERP amplitudes from 200-500ms were entered into a repeated measures ANOVA with three levels of Condition and 26 levels of Electrode. A main effect of Condition was obtained, $F(2,58) = 38.33$, $\epsilon_{GG} = 0.7756$, $p < .001$, as was a Condition-by-Electrode interaction, $F(50,1450) = 7.26$, $\epsilon_{GG} = 0.1075$, $p < .001$.³

Planned comparisons revealed the critical pattern of results in which the event-related condition lay statistically between the expected and event-unrelated conditions. N400 amplitude in the event-unrelated condition was significantly greater (i.e., more negative)

³For F -tests with more than one degree of freedom in the numerator, we report p -values for Greenhouse-Geisser epsilon-adjusted degrees of freedom (Greenhouse & Geisser, 1959), the unadjusted degrees of freedom, and the value of the Greenhouse-Geisser epsilon.

than the event-related condition ($F(1,29) = 13.00, p < .01$; no interaction with Electrode), which in turn was greater than the expected condition ($F(1,29) = 35.44, p < .001$; Condition-by-Electrode interaction: $F(25,725) = 7.77, \epsilon_{GG} = 0.097, p < .001$). This graded N400 effect can be seen clearly in the waveforms, beginning at approximately 200ms post-stimulus and peaking around 400ms. (See Figure 3 for a close-up of the midline parietal electrode site.) In summary, the event-related targets elicit a reduced N400 compared to the event-unrelated targets, with both types of anomalous targets eliciting larger N400s than the expected targets. In other words, the N400 effect for the event-unrelated targets (i.e., the N400 amplitude difference between the event-unrelated and expected targets) is larger than that for the event-related targets (i.e., the difference between the event-related and expected targets), as illustrated by the difference waves presented in Figure 4.

Because we argue that the differences in N400 amplitude in the three conditions reflect the activation of event knowledge during online comprehension, and with ART/MRT performance providing an indirect measure of both linguistic proficiency and general world knowledge, we analyzed the relationship between ART/MRT performance and N400 amplitude. Participants were assigned to two groups according to a median split on ART/MRT performance. The high scoring group consisted of the top 15 scorers ($M = 24.5, SD = 5.5$); these were separated from the bottom 15 scorers ($M = 12.7, SD = 4.4$). In an omnibus ANOVA with within-subjects factors of Electrode (26 levels) and Condition (3 levels) and a between-subjects factor of ART/MRT Group (2 levels), Group did not interact with Condition, $F(2,56) = 0.13, \epsilon_{GG} = 0.7711, p > .8$, and there was no three-way interaction between Group, Condition, and Electrode, $F(50,1400) = 1.36, \epsilon_{GG} = 0.1071, p > .2$.

However, a separate analysis of each ART/MRT group suggests that individual differences may be present. The bottom 15 participants show an effect of Condition in the omnibus ANOVA, $F(2,28) = 16.51, \epsilon_{GG} = 0.7234, p < .001$, and a Condition-by-Electrode interaction, $F(50,700) = 6.52, \epsilon_{GG} = 0.0850, p < .001$, but the pairwise comparison between the event-related and event-unrelated conditions shows only a marginal effect of Condition, $F(1,14) = 3.81, p = .071$, and no Condition-by-Electrode interaction, $F(25,350) = 1.15, \epsilon_{GG} = 0.1821, p > .3$. The numerical difference between event-related and event-unrelated N400s was $0.891 \mu V$. The top 15 participants show an effect of Condition in the omnibus ANOVA, $F(2,28) = 21.37, \epsilon_{GG} = 0.8152, p < .001$, and a marginal Condition-by-Electrode interaction, $F(50,700) = 2.26, \epsilon_{GG} = 0.0928, p = .059$. Importantly, the pairwise comparison between the event-related and event-unrelated conditions shows a significant effect of Condition, $F(1,14) = 10.06, p < .01$, and no Condition-by-Electrode interaction, $F(25,350) = 1.02, \epsilon_{GG} = 0.1176, p > .3$. The numerical difference between event-related and event-unrelated target N400s was $1.297 \mu V$. These analyses therefore are suggestive of ART/MRT-based individual differences, though the current design and data do not allow us to make definitive conclusions about the nature of such possible differences at this time. We present this analysis simply to highlight the potential for individual differences in activation of event knowledge during online language comprehension. Such individual differences are worthy of future investigation, but will not be discussed further.

Scalp distribution—The graded N400 effect is generally widespread across the scalp but appears most prominently at medial posterior sites. Figure 4 contains ERP difference waves (event-related minus expected and event-unrelated minus expected) that portray the size of the N400 effect for each anomalous target type at each electrode. Figure 5 presents scalp topographies of mean amplitude in the 200-500ms window for the two N400 effects. The scalp distributions of the two N400 effects were assessed by analyzing mean amplitudes from 200 to 500ms of the difference between each anomalous target type and the expected targets. Mean amplitudes were entered into a repeated measures ANOVA with two levels of Difference (event-related minus expected vs. event-unrelated minus expected), two levels of

Hemisphere (right vs. left), two levels of Laterality (lateral vs. medial), and four levels of Anteriority (prefrontal vs. frontal vs. parietal vs. occipital).⁴

The results show a main effect of Difference, $F(1,29) = 12.71, p < .01$, again showing that the N400 effect is larger for the event-unrelated condition than the event-related condition. The analysis also shows main effects of Hemisphere, $F(1,29) = 25.78, p < .001$, Laterality, $F(1,29) = 23.52, p < .001$, and Anteriority, $F(3, 87) = 7.01, \epsilon_{GG} = 0.3824, p < .05$. The main effect of Hemisphere indicates that N400 effects were larger over the right than left hemisphere, and the main effect of Laterality indicates that N400 effects were larger over medial than lateral sites. The main effect of Anteriority results from larger N400 effects at frontal, $t(29) = 3.54, p < .01$, and parietal, $t(29) = 3.29, p < .01$, sites than at prefrontal sites.⁵ A Hemisphere-by-Laterality interaction, $F(1,29) = 14.61, p < .001$, indicates that while right medial sites show larger N400 effects than left medial sites, $t(29) = 3.83, p < .001$, the drop-off from medial to lateral sites is larger in the left, $t(29) = 5.98, p < .001$ than right, $t(29) = 3.21, p < .01$, hemisphere. A Laterality-by-Anteriority interaction, $F(3,87) = 10.32, \epsilon_{GG} = 0.7602, p < .001$, reveals that the effect of Anteriority is reliable at medial sites (prefrontal vs. frontal: $t(29) = 4.71, p < .001$; prefrontal vs. parietal: $t(29) = 4.64, p < .001$) but not lateral sites (all $t(29) < 1.89, p > .07$). However, a three-way interaction between Hemisphere, Laterality, and Anteriority, $F(3,87) = 3.15, \epsilon_{GG} = 0.7191, p < .05$, suggests that this Laterality-by-Anteriority interaction holds only in the left hemisphere. Right lateral sites show an effects of Anteriority that become statistically nonsignificant after controlling for multiple comparisons (prefrontal vs. frontal: $t(29) = 2.05, p < .05$; prefrontal vs. parietal: $t(29) = 2.45, p < .05$), while left lateral sites do not show even marginal effects of Anteriority (all $t(29) < 1.31, p > .2$).

On the whole, these results indicate that the N400 effects are largest at right centro-parietal sites and decrease in size moving laterally and toward the front of the scalp. This right-lateralized, centro-parietal distribution is typical of that found in many N400 studies. In this analysis, none of the distributional factors interacted with Difference, indicating that the distribution of the N400 effects in the event-related and event-unrelated conditions were statistically equivalent.

Late window analysis—Although we generated no predictions regarding effects outside of the N400 time window, we conducted an analysis of the 500-900ms post-stimulus window in which late positive effects typically arise. We entered mean amplitudes from 500-900ms into a repeated measures ANOVA with three levels of Condition and 26 levels of Electrode. The results show no main effect of Condition, $F(2,58) = 0.59, \epsilon_{GG} = 0.785, p > .5$, but do show a reliable Condition-by-Electrode interaction, $F(50,1450) = 7.06, \epsilon_{GG} = 0.1009, p < .001$. Looking at the ERPs in Figure 2, it generally appears that at anterior electrodes, the event-unrelated targets elicit a greater negativity than the other two target types, with this difference being slightly more prominent over the left hemisphere. At posterior electrodes, the event-unrelated targets elicit a greater positivity than the other two target types until approximately 800ms, at which point the event-related targets begin to exhibit a positive shift, as well. The presence of effects in the late window is worth noting, but because this experiment was not designed to investigate late positivity effects, we conduct no further analyses in this time window. We return to this late effect briefly in the General Discussion.

⁴See Figure 1 for electrode groupings applied in this distributional analysis.

⁵In both experiments, all post-hoc t-tests are two-tailed paired-sample tests using Bonferroni-adjusted alpha values to correct for multiple comparisons.

Discussion

The N400 elicited by a locally anomalous word is reduced if that word denotes a prominent component of the event being described. Previous research has demonstrated that event knowledge exerts a strong, rapid influence during incremental language comprehension, and the present experiment demonstrates that event knowledge activation during comprehension interacts with, but is not fully constrained by, local linguistic cues. Unstated event-relevant information is active even at points at which contextual cues indicate that it would not make a sensible continuation of the linguistic stream, leading to the facilitated processing we observe in the form of N400 reduction. The timing of the effect relative to the presentation of the word - namely, that it appears in the canonical N400 time window - highlights that this activated event knowledge influences processing within several hundred milliseconds of word onset.

The present results also show that a contextually anomalous event-related word does elicit a larger N400 than a highly expected word. This finding indicates that local contextual cues do interact with event knowledge activation to yield the greatest facilitation for words that are compatible with both the described event and local contextual cues. Words that satisfy both contextual and event knowledge constraints elicit the lowest amplitude N400s, words that satisfy neither elicit the largest, and words that satisfy event knowledge but not contextual constraints elicit N400s of intermediate amplitude. Thus, while comprehension involves activation of event knowledge elements beyond those that are contextually congruent, linguistic input dynamically modulates the activation levels of these elements such that contextually congruent elements receive greater activation than incongruent elements.

This result may be interpreted in at least two ways. It may be the case that N400 reduction for event-related targets arises through construction of a relatively detailed, unified mental representation of the described event that combines both explicitly stated information and additional knowledge of the comprehender. Under this account, the observed effect is driven by discourse comprehension processes and the mental representations they serve to construct. Yet, recall that previous studies have shown direct lexical priming between elements of event knowledge, even in the absence of normative association (Hare, Jones, et al., 2009). Presumably, processing an isolated word does not give rise to a detailed mental representation of an event along the lines of that constructed through comprehension of a full discourse, but yet it can prime event components either through direct association or through some mediating knowledge structure. An alternative explanation for the results of Experiment 1 is that this type of priming is at play. Under this account, the mental representation constructed through processing the full discourse context is not necessary to observe N400 reduction for event-related targets. Instead, only the presence of associated words in the preceding context is required. This contrasts with the former interpretation of the results, which argues that a full, coherent mental representation of the described event drives the effect. To illustrate, consider the “playing in the snow” example in (1). Under the discourse processing account, *jacket* elicits a reduced N400 because it refers to additional knowledge activated to enrich the representation of the specific event described by the full discourse. Under the priming account, *jacket* elicits a reduced N400 simply because it is preceded by one or more content words that prime it directly, with the mental representation of the event described by the discourse as a whole playing no role.

Contrary to the lexical priming account, previous research suggests that effects of lexical priming during discourse comprehension are generally weak or nonexistent. Camblin, Gordon, and Swaab (2007) report a series of experiments addressing the role of lexical associative priming and higher-level discourse information in online sentence comprehension. Using eye-tracking and ERP measures, the authors examined responses to

contextually congruent words that either did or did not align with the general discourse context and either were or were not preceded by a direct lexical associate. Across all experiments, they generally found that effects of discourse context were immediate and strong, while effects of an immediately preceding lexical associate were delayed and weak, if present at all. Reliable effects of lexical association arose only when single sentences were presented in isolation or when texts were made incoherent through scrambling of words. Camblin et al. conclude that “automatic spread of activation, as a function of associative relations between words, does not contribute to processing of words in sentences that are part of a larger discourse” (p. 126). With the scenarios in the present experiment providing relatively rich discourse contexts before target presentation, the findings presented by Camblin et al. strongly suggest that lexical priming is not at play here.

Despite this evidence suggesting that lexical associative priming does not affect the processing of words embedded in full discourses, we conducted an analysis addressing this alternative account directly. First, we sought to quantify the level of association of our event-related and event-unrelated targets with their preceding context words. If the event-related targets were more strongly associated with the individual context words than the event-unrelated targets, we would have evidence suggesting that the results of Experiment 1 could potentially be driven by direct priming of the event-related targets through activation of the semantic representations of one or more key content words (as opposed to construction of a mental representation of the described event as a whole). To quantify lexical semantic associations, we utilized Latent Semantic Analysis (Landauer, Foltz, & Laham, 1998), which captures semantic association between individual words or groups of words through co-occurrence statistics computed over large-scale corpora. In investigating lexical priming between event associates (e.g., *hospital* and *doctor*), Hare, Jones, et al. (2009) demonstrated that LSA captures lexical priming between associated elements of event knowledge that do not exhibit association in a standard free-association task. Hare, Jones, et al. argue that LSA captures priming between event associates because words associated with a common event should often co-occur together in text describing that type of event. Because it is plausible that our event-related targets were preceded by context words denoting event associates more often than the event-unrelated targets, the present analysis required a measure capable of capturing priming between event associates. We therefore chose LSA over free association norms due to its ability to capture such associations.⁶

We obtained LSA scores using the one-to-many application on the LSA website at lsa.colorado.edu. We computed the cosine between each target word and its entire preceding context, using the General Reading - Up to First Year of College topic space with 300 factors. We found a statistically significant difference between the event-related and event-unrelated targets: the mean association score for the event-related targets was 0.27, and the mean score for the event-unrelated targets was 0.22, $t(71) = 3.032$, $p < .01$. The LSA association scores therefore provide support for the lexical priming interpretation of the results of Experiment 1.

To determine whether the N400 reduction found in Experiment 1 might be due to priming of the event-related targets by particular context words, we identified a subset of the 12 experimental items that showed the largest differences between LSA association scores for

⁶Hare, Jones, et al. (2009) conclude that LSA actually may overestimate priming between event associates, with LSA incorrectly predicting priming from instrument nouns to people who typically use those instruments, which was a relation for which Hare, Jones, et al. did not find priming. This potential for LSA to overestimate priming between event associates is actually a strength for the current analysis: overestimation of such priming should, if anything, bias the analysis toward finding the event-related targets to be more closely associated with preceding context words than the event-unrelated targets. LSA may therefore bias the analysis in favor of the lexical priming interpretation of the results of Experiment 1.

the event-related and event-unrelated targets. We then reanalyzed the data from Experiment 1 excluding these 12 items. In the remaining 60 experimental items, the new mean LSA score for the event-related targets was 0.24, and for the event-unrelated targets was 0.23, $t(59) = 0.5216$, $p = .60$. An analysis of the ERPs identical to that described above again showed that the event-related targets elicit smaller N400s than do the event-unrelated targets, $F(1,29) = 13.7$, $p < .001$. This result, combined with the findings presented by Camblin et al. (2007) suggesting that lexical priming exerts at most a weak influence during discourse comprehension, strongly suggests that the N400 reduction observed in Experiment 1 is a discourse-level phenomenon, resulting from online activation of generalized event knowledge during the construction of a coherent mental representation of the described event. This interpretation is further tested in Experiment 2.

Experiment 2

Experiment 1 demonstrated that a contextually anomalous word elicits a reduced N400 if that word refers to a salient component of the comprehender's general knowledge regarding the described event, and that the effect results from engagement of generalized event knowledge during construction of a mental representation of a described event. The interpretation of the N400 reduction for event-related targets as arising through discourse comprehension processes leads to the prediction that if the discourse context was stripped from the experimental scenarios, the observed N400 reduction for event-related targets should disappear. Without the first two context sentences, the scenarios would be devoid of the discourse context necessary to drive activation of generalized event knowledge. Experiment 2 investigated this hypothesis by comparing the ERPs elicited by the three target types when only the final sentence of each scenario from Experiment 1 was presented.

Method

Participants—Fifteen undergraduates (8 female; ages 19-28 years) at the University of California, San Diego completed the experiment for course credit. All were right-handed, native monolingual English speakers, and none reported any history of learning or reading disabilities or neurological or psychiatric disorders. The data from one participant were dropped due to experimenter error.

Materials—The materials consisted of the final sentences of the experimental and filler items used in Experiment 1. The target words in the three experimental conditions were unchanged. The materials therefore differed from those in Experiment 1 only in that the first two context sentences of each item were not presented. Because these context sentences were removed, a new cloze task was administered. Twenty UCSD undergraduates, all native English speakers, read the final sentence of each scenario up to the word preceding the target and provided the word they felt would be most likely to come next. The task was again administered through an online form. The mean cloze probability of the expected targets was 0.41 (range = 0.00 to 1, $SD = 0.33$), a decrease of 0.4 from Experiment 1. This decrease was unsurprising, because the lack of full discourse contexts was expected to result in a greater variety of responses. In 41 of the 72 experimental items, the expected target did constitute the highest cloze response in this new cloze study. The results of this cloze study indicate that expectations for the expected targets were weakened in the absence of a full discourse context, and in a fair number of items, the expected target did not constitute the most expected word. Still, the event-related and event-unrelated targets were again zero-cloze and contextually anomalous, and with the expected targets being relatively predictable in context (as indicated by the mean cloze probability of 0.41), we predicted that the event-related and event-unrelated targets would elicit robust N400 effects with respect to the expected targets.

Procedure, EEG recording and processing—The experimental procedure was the same as in Experiment 1, except that the two context sentences were not presented before presentation of the final sentence of each scenario. RSVP parameters were the same as in Experiment 1. Yes-no comprehension questions were presented on 1/3 of trials. Comprehension questions were taken from Experiment 1 and were modified where necessary to refer only to information presented in the final sentence of each item. All participants scored above 80% correct on the comprehension questions, indicating they read the sentences for comprehension. EEG recording and processing was identical to Experiment 1. Artifact rejection resulted in loss of approximately 9% of target word epochs, with losses distributed evenly across the three conditions.

Results

N400 amplitude—Mean amplitude from 200-500ms post-stimulus onset were entered into a repeated measures ANOVA with three levels of Condition (expected vs. event-related vs. event-unrelated) and 26 levels of Electrode. The results show a main effect of Condition, $F(2,26) = 7.37$, $\epsilon_{GG} = 0.868$, $p < .01$, and a Condition-by-Electrode interaction, $F(50,650) = 2.56$, $\epsilon_{GG} = 0.128$, $p < .05$. Planned comparisons showed that expected targets elicited smaller N400s than the event-related targets ($F(1,13) = 9.34$, $p < .01$; Condition-by-Electrode interaction: $F(25,325) = 3.36$, $\epsilon_{GG} = 0.186$, $p < .01$) and the event-unrelated targets ($F(1,13) = 17.97$, $p < .01$; Condition-by-Electrode interaction: $F(25,325) = 2.78$, $\epsilon_{GG} = 0.166$, $p < .05$). The event-related and event-unrelated targets did not differ ($F(1,13) = 7 \times 10^{-4}$, $p = .98$; no Condition-by-Electrode interaction). This N400 pattern - expected targets eliciting smaller N400s than the two anomalous target types, which did not differ from each other - can be seen clearly in Figure 6, which presents the grand average ERPs for the three conditions at the 26 electrodes. Figure 7 presents a close-up of the midline parietal site, showing no reliable difference in N400 amplitude between the event-related and event-unrelated targets. This can also be seen in Figure 8, which presents the difference waves (event-related minus expected and event-unrelated minus expected) showing the size of the two N400 effects.

Scalp distribution—The scalp topographies of the N400 effects for the event-related and event-unrelated targets are presented in Figure 9. An analysis of the distribution of the N400 effects for event-related and event-unrelated targets was conducted according to the same procedure and electrode groupings used in Experiment 1. The results show a main effect only of Laterality, $F(1,13) = 11.48$, $p < .01$, indicating that the N400 effects in the two conditions are larger over medial than lateral sites. The lack of other main effects indicates that the N400 effects are more broadly distributed than in Experiment 1, appearing most prominently at medial sites over both hemispheres.

There was a three-way interaction among Difference, Hemisphere, and Anteriority, $F(3,39) = 5.15$, $\epsilon_{GG} = 0.718$, $p < .05$, and a four-way interaction among Difference, Hemisphere, Laterality, and Anteriority, $F(3,39) = 8.80$, $\epsilon_{GG} = 0.599$, $p < .05$. These high-order interactions of distributional factors with Difference suggest that differences between the event-related and event-unrelated conditions may exist at limited regions of the scalp. In the 200-500ms window, the difference waveforms (Figure 8) show small differences between the event-related and event-unrelated conditions at some electrodes, maximal over right lateral anterior sites. However, post-hoc comparisons between the event-related and event-unrelated conditions conducted at individual electrodes (to investigate the four-way interaction) and averaging across levels of Laterality (to investigate the three-way interaction) found no reliable differences (all $t(13) < 1.50$, $p > .15$; largest t value at RLFr). In particular, no reliable differences were found at centro-parietal sites where N400 effects were largest in Experiment 1 (all $t(13) < 0.45$, $p > .66$). The presence of marginal differences at right lateral anterior sites, in combination with no differences at other scalp regions, may

be driving the interaction effects. However, with all post-hoc comparisons not reaching significance, and with the electrodes most closely approaching significance being outside the centro-parietal N400 region, the high-order interactions obtained in this analysis do not indicate differences in N400 amplitude between the two conditions.

Late window analysis—We conducted an analysis of mean amplitude in the 500-900ms window in order to determine if the late effect obtained in Experiment 1 was present in this experiment. A repeated measures ANOVA with three levels of Condition (expected vs. event-related vs. event-unrelated) and 26 levels of Electrode showed no effect of Condition, $F(2,26) = 1.43$, $\epsilon_{GG} = 0.796$, $p > .2$, and no Condition-by-Electrode interaction, $F(50,650) = 2.11$, $\epsilon_{GG} = 0.088$, $p > .09$. It thus appears that the late positivity obtained in Experiment 1 was not present in the data from Experiment 2, indicating that the late effect is related to the presence of the context sentences in some way. This is discussed briefly in the General Discussion.

Discussion

The results of Experiment 2 indicate that the two context sentences preceding the target sentence in Experiment 1 were necessary to observe N400 reduction for the event-related targets. When the cues provided by the global discourse context are removed, N400 reduction for event-related targets does not occur. This indicates that the information in the target sentence did not drive the N400 reduction for event-related targets in Experiment 1. Instead, the effect was driven fully by information in the previous discourse. This provides further support for the interpretation of N400 reduction for event-related targets as arising from the engagement of generalized event knowledge in constructing a relatively detailed mental representation of the event described by the full discourse. Furthermore, it should be noted that these results indicate that if lexical priming were to contribute to the N400 reduction observed in Experiment 1 (which we have already established to be very unlikely), this priming would have had to come from one or more words in the two context sentences. Given that Camblin et al. (2007) found weak, unreliable effects of lexical associative priming in situations in which a lexical associate immediately preceded the target word within the same sentence, the possibility that lexical priming was at play across multiple sentences in Experiment 1 is highly implausible.

General Discussion

Experiments 1 and 2 demonstrate that event knowledge activation during the course of incremental language comprehension extends to elements that are anomalous in the linguistic context. The results of Experiment 1 show that a contextually anomalous word elicits a reduced N400 if that word is related to the described event. An analysis of a subset of experimental items indicates that this N400 reduction does not result from priming of the event-related targets by the activation of lexical semantic representations of individual content words. While priming results suggest that event knowledge can be considered a component of lexical semantics, the subset analysis showed that when lexical semantic associations are controlled, N400 reduction for the event-related targets still holds. This indicates that the effect results from discourse-level comprehension processes that engage generalized event knowledge to construct a detailed mental representation of the described event. This conclusion is further supported by the results of Experiment 2, which show that the N400 reduction observed in Experiment 1 disappears when the discourse context is removed. This indicates that it is not information in the target sentence that drives the effect, but rather information presented by the preceding discourse context. Together, these experiments show that online engagement of event knowledge extends beyond those elements that are congruent or predicted given the preceding linguistic context. Furthermore,

the emergence of an effect in the N400 time window indicates that this activated knowledge influences processing within several hundred milliseconds of word onset.

Various researchers have proposed that meaning construction during comprehension involves the formation and dynamic updating of a coherent mental representation of the described event (e.g., Altmann & Kamide, 2009; Altmann & Mirkovic, 2009; Zwaan & Radvansky, 1998). Event knowledge is generally believed to play an important role in this process, but the degree to which unmentioned elements of event knowledge become activated as part of an event representation has remained unclear. Along these lines, Zwaan and Radvansky (1998) discuss studies of the activation of implied instruments during comprehension and note that mixed results indicate that subtle contextual factors play a large role in determining whether or not an unmentioned but implied instrument becomes active as part of an event representation. Utilizing ERPs, this study suggests that a wealth of unstated information regarding described events is activated during online language processing.

This issue is directly relevant to previous work on inferencing, where research has focused on the types of inferences that are automatically generated during language comprehension (Graesser et al., 1994; McKoon & Ratcliff, 1992). Theories differ as to which types of inferences they propose to be generated automatically, but it is generally assumed that inference generation is limited in scope in some way and does not extend to elements simply by virtue of generally being part of a described event. For example, Alba and Hasher (1983) and Seifert, McKoon, Abelson, and Ratcliff (1986) have shown that inferences based on “filling in schema information” are not made, at least when inferences are tested after the presentation of a sentence or scenario. The present study did not strictly control potential types of inferences triggered by the scenarios, or the relation of the event-related targets to any such inferences. The event-related targets were chosen because participants indicated that they were likely to be present during the described event. It is therefore unclear on the surface how activation of the event-related targets in our study (which we do not consider to be full-blown inferences) might be related to inference generation as it is typically portrayed in the literature. However, in general, the event-related targets were not required to make statements in the discourse locally coherent, nor did they correspond to causal or bridging inferences. For example, there is nothing in the “playing in the snow” scenario that requires jackets to be inferred, inferring jackets is not at all useful for establishing textual coherence, and it would be highly unlikely that participants would report that they actually had read the word *jacket*.

The on-line activation of general event-relevant information at points at which inferring it is not necessary may support inference generation processes. During incremental comprehension, activation of a range of salient event knowledge elements would allow such information to be readily available when a related inference becomes necessary. In the “playing in the snow” scenario in (1), there is no clear mapping between *jacket* and some inference necessary to understand the discourse, but if the text were to trigger such an inference down the line (e.g., It began to snow some more, so Tommy put his hood up), the information necessary to support the inference would be active. Thus, activation of generalized event knowledge may facilitate rapid generation of inferences during incremental comprehension.

The present findings also relate to previous studies in which it has been demonstrated that unexpected or anomalous words that are related to the most expected word elicit faster reaction times and smaller N400 amplitudes than do equally unexpected or anomalous words unrelated to the most expected word (Federmeier & Kutas, 1999; Kleiman, 1980; Kutas & Hillyard, 1984; Kutas, Lindamood, & Hillyard, 1984; Kutas, 1993; Schwanenflugel

& LaCount, 1988). These “related oddball” findings are generally interpreted as showing that sentence processing involves word pre-activation or expectancy generation, a claim that is supported by additional findings (Altmann & Kamide, 1999; DeLong, Urbach, & Kutas, 2005; Kamide, et al., 2003). Under this account, sentence contexts pre-activate words with certain semantic characteristics, with the most expected word receiving greatest activation but semantically similar words also receiving partial activation regardless of fit with the linguistic context. Early studies of this effect did not control for the nature of the relationship between the most expected word and the critical word, leaving open multiple possibilities for what information (e.g., associative, categorical, event knowledge, etc.) actually drives linguistic prediction. Federmeier and Kutas (1999) controlled this relationship by measuring ERPs to unexpected words that specifically shared semantic features with the expected word. They found N400 reduction for these words relative to unexpected and unrelated words, indicating that context-independent category structure in long-term memory drives prediction of upcoming words. Sentential contexts drive activation of sets of semantic features possessed by concepts that are likely to come next, such that an unexpected word that matches some of these features will elicit a smaller N400 than an equally unexpected word that does not match those features.

The N400 reduction for the event-related anomalous targets observed in this study suggests that event knowledge also is an important knowledge source for driving linguistic prediction. In the present study, event-related anomalous targets did not share semantic features with the expected targets (e.g., *jacket* does not share features with *snowman*), suggesting that semantic feature overlap such as that in Federmeier and Kutas is not responsible for the present results. In addition, it is uncertain if the stimuli in Federmeier and Kutas and other “related oddball” studies involved unexpected or anomalous targets that were not only related to the most expected word in some way, but also to the event being described. It is therefore an open question as to what extent event knowledge can account for these previous findings. It is likely that multiple information sources drive linguistic prediction, with relatively context-independent semantic category knowledge interacting with more context-dependent representations of described events. The nature of interaction among different information sources in driving linguistic prediction is worthy of future study.

Conflicting Findings

As discussed in the introduction, Traxler et al. (2000) and Kintsch and Mross (1985) present results that seem to demonstrate that online event knowledge activation does not extend to contextually anomalous elements. There are, however, several important differences between the present study and those by Traxler et al. and Kintsch and Mross that may explain the discrepancy. First, the dependent measures differ: Traxler et al. measured fixation times during reading, and Kintsch and Mross measured lexical decision times to probe words presented mid-discourse. It is possible that the N400, a neural measure of semantic processing, is sensitive to the activation of event knowledge in a way that lexical decision times and fixation times during reading are not. Second, we collected norming data in order to choose event-related targets that were strongly related to the described event. Although Traxler et al. collected plausibility norms indicating that their implausible target words were contextually anomalous, it is unclear whether they controlled for the relationship of their target words with the events denoted by the preceding context. It is possible that their target words were not as centrally related to the described events as were our event-related targets. Kintsch and Mross chose their scenario-related target words by consulting script norms collected by Galambos (1982), choosing a word that related in some way to what a reader might expect to be mentioned as the next activity in an ongoing description of a common event. It is possible that while the script norms capture how a reader might expect a story to

progress, the particular words chosen by Kintsch and Mross as probe words nevertheless did not correspond to central components of the event knowledge activated by the preceding discourse.

One final difference relates to the degree of contextual buildup. Traxler et al.'s stimuli established event contexts through only a few words preceding the target, whereas the present study used multiple context sentences. Traxler et al.'s stimuli thus may not have provided sufficient contextual buildup for generalized event knowledge activation to occur by the time participants encountered the critical words. The same cannot be said of Kintsch and Mross, however, with their stimuli involving several context sentences before target word presentation. Still, given the myriad differences between the present study and those by Traxler et al. and Kintsch and Mross, along with the fact that those studies ultimately were designed to address different questions than that addressed here, the present findings still firmly support the conclusion that online language comprehension involves activation of event knowledge elements that violate the linguistic context.

Late window effect

The results of Experiment 1 showed an effect of the experimental manipulation on mean ERP amplitude in the 500-900ms time window. In Experiment 2, this effect was not found. Analyses in the late time window were limited to omnibus ANOVAs due to the fact that this study was not designed to address late effects, and detailed analyses in the late window based on visual identification of potential differences may capitalize on chance. Still, the presence of an effect merits brief discussion.

Past research has demonstrated a link between late positivities and syntactic processing (e.g., Friederici, Hahne, & Mecklinger, 1996; Osterhout & Holcomb, 1992), but as detailed by Kuperberg (2007), numerous studies have demonstrated more recently that late positivities are elicited by certain types of semantic violations as well. Some studies (e.g., Kuperberg, Caplan, Sitnikova, Eddy, & Holcomb, 2006; Nieuwland & Van Berkum, 2005) may be interpreted as indicating generally that late positivities might be linked in some way to the eliciting word's status as related or unrelated to the described event, but the exact relationship between late positivities and eliciting words' association with described events remains unclear. Given that our manipulation was one of event-relatedness, and that we see no effects in the late time window in Experiment 2 in which the discourse context was removed, our results may suggest that late effects elicited by semantic violations are in some way modulated by the eliciting word's degree of relation to the described event. Ultimately, our study was not designed to investigate late effects elicited by semantic violations and offers no ready explanation for that obtained, so we simply note the presence of an effect in the late time window and acknowledge that such effects merit future study.

Why?

At the outset, we alluded to a deep and troublesome question that is often avoided in sentence processing research: What is the target of language understanding? Of course, there is probably not a single target. Language can be used for many purposes. Task and strategic demands undoubtedly play a large role in determining what information a comprehender will extract and focus on at any given time. Some tasks may focus attention on the sound structure; others on identifying specific words; others might focus attention on well-formedness of grammatical structure. The present study suggests that under at least the task circumstances involved here, comprehenders have as one important target the construction of mental representations of events and situations. Furthermore, these mental representations are sufficiently potent and influential that they participate in comprehenders' processing of and perhaps expectancies about upcoming words, even to the point where they expect (or

conversely, are able to quickly integrate) words that do not make sense in the local linguistic context but are appropriate in the context of the event being described.

Why would comprehenders do this? We suggest two (mutually compatible) possibilities. The first is that the activation of generalized event knowledge is so central to language understanding that it cannot be turned off. Event knowledge may be so fundamental in language understanding that its influence on other levels of processing cannot be suppressed.

The second possibility is that processing discourse at a high level of analysis (in our task, the general description of an event), sometimes at the expense of full and accurate processing based on explicit linguistic cues, is adaptive when compared to full and accurate processing at all levels of analysis. That is, it may be advantageous for information that aligns with a higher-level representation of the described event to be active even when in conflict with direct bottom-up cues present in the linguistic stream. Kukona, Fang, Aicher, Chen, and Magnuson (2011) present evidence suggesting, as the present findings do, that activation of event or thematic knowledge proceeds in partial independence of explicit prediction of contextually appropriate words. Utilizing visual world eye-tracking, Kukona et al. found that upon hearing *Toby arrests the...* participants were more likely to fixate a police officer than other distractors not related to an arresting event, even though *police* constitutes a poor patient of *arrest* and a proper patient (a crook) was depicted. Thus, thematic knowledge regarding an *arresting* event drives eye movements to a depicted policeman even though this conflicts with bottom-up interpretation of linguistic input (i.e., *policeman* should not be predicted to come next). Kukona et al. suggest that activation of thematically appropriate but contextually incongruent information can serve discourse comprehension functions such as establishing complex relations among discourse referents and facilitate connection of information presented in a discourse with knowledge stored in long-term memory. Limiting activation of information to only that which is likely to appear in the upcoming linguistic input could be detrimental to these functions. Processing language beyond the level of the particular words received or likely to appear next may be critical to complex discourse comprehension functions achieved through the real-time engagement of generalized event knowledge.

Conclusion

Event knowledge exerts a strong and rapid influence on language comprehension processes. With respect to the scope of real-time event knowledge activation, this study has demonstrated that as a discourse is processed incrementally, activation of event knowledge extends beyond those elements that are congruent with local linguistic cues to include other salient event knowledge elements that might constitute anomalous continuations of the linguistic stream at that point. This activated information influences online processing within several hundred milliseconds of word onset, and supports both linguistic prediction and higher-level discourse comprehension functions.

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Appendix

Experimental items and comprehension questions.

(Target words are in caps in the following order: Expected, Event-Related, Event-Unrelated)

1. ACCIDENT

Elizabeth was standing at the intersection waiting for the light to change.

All of a sudden she saw a car barrel through the red light.

A moment later, she heard a terrible CRASH / POLICEMAN / CONDUCTOR come from down the street.

Was somebody driving recklessly? Y

2. ARREST

For several months, there had been burglaries in the neighborhood.

Many people thought they knew who the crook was.

Finally, he was caught when he set off somebody's ALARM / POLICE / DOCTOR one night.

Was the crook eventually caught? Y

3. BREAKFAST

I think it's important to start the day right.

Every morning, I make sure to eat a hearty breakfast.

Sometimes there's almost no room left on my PLATE / EGGS / HOTDOGS once I finish dishing up.

Do I usually eat a modest breakfast? N

4. CONCERT

The band was very popular, and Joe was sure the concert would be sold out.

Amazingly, he was able to get a seat down in front.

He couldn't believe how close he was when he saw the group walk out onto the STAGE / GUITAR / BARN and start playing.

Did Joe get stuck with a bad seat? N

5. FUNERAL

My Aunt Bettie was very popular in our family.

When she died, lots of people gathered to pay their respects.

Her three brothers and three sisters all gave very moving SPEECHES / COFFINS / DRINKS during the service.

Was Aunt Bettie liked by the rest of the family? Y

6. TRAVEL

Traveling these days is much less fun than it used to be.

Now you have to deal with worries about terrorism.

It can take several hours to make it through SECURITY / LUGGAGE / VEGETABLES and find your gate.

Has the threat of terrorism made travel more difficult? Y

7. MORNING

I'm very sluggish when I wake up.

Sometimes it takes me an hour to get ready in the bathroom.

I often end up staring blankly at myself in the MIRROR / TOOTHBRUSH / EGGS for a while.

Am I usually energetic in the morning? N

8. GAMBLING

Debbie is more of a risk taker than she should be.

She loves to gamble but really isn't very good at card games.

Last night, she had a rough time playing POKER / DEALER / SALESMAN at the casino.

Is Debbie a good card player? N

9. COUNTRY LIFE

Many people think living in the country is easy.

But I grew up on a farm and I know there are some downsides.

What I hated most was being woken up early each morning by the ROOSTER / BARN / BOOTS outside my window.

Did I grow up on a farm? Y

10. EXERCISE

My friend Julie spends all her time exercising.

The machine she likes the most is the treadmill.

By the time she's done, she's drenched in SWEAT / TOWEL / COUCH and breathing very heavily.

Does Julie exercise frequently? Y

11. MOVIES

Going to the movies is great fun.

Before the show starts, I like to get a snack.

There's nothing like watching the show while eating a big box of POPCORN / SODA / CAR covered with butter.

Is chocolate my favorite movie snack? N

12. ANNIVERSARY

Bob and Linda celebrated their 25th anniversary recently.

Their kids wanted to do something nice for them.

So they all got together and threw a big PARTY / FAMILY / CORAL at the beach.

Did Bob and Linda get married last year? N

13. DENTIST

Michelle had a toothache for several months.

She knew she should do something about it, but held off.

She finally got checked out when she was told she could get some anesthetic to reduce the PAIN / DENTIST / DRIVER and ease her discomfort.

Did Michelle eventually see somebody about her toothache? Y

14. BAPTISM

The parents were very excited about their new baby girl.

One of the first things they did was to get her baptized in their church.

The baby liked baths, so she smiled when she was sprinkled with WATER / PRIEST / DEALER on her forehead.

Did the baby enjoy getting baptized? Y

15. BARBECUE

During the summer, many people like to cook outdoors.

Everybody has different preferences for what to make.

My father likes both hot dogs and HAMBURGERS / GRILLS / BOOTHS but his favorite is bratwurst.

Do people like to cook indoors during the summer? N

16. DIVORCE

Getting divorced is always difficult.

Even when people get along, there are many details to work out.

If there are children, the hardest part is the question of who gets CUSTODY / LAWYER / PRIEST of them.

Is getting divorced a simple matter? N

17. BEACH

The summer is a great time to go the beach.

It's true you have to bring a lot of things with you, but that's OK.

The only thing I don't really like is that your food gets full of SAND / TOWEL / ROD and attracts lots of ants.

Do you need to bring a lot of things with you when you spend the day at the beach? Y

18. ZOO

If you live in a city, the best way to see unusual animals is to go to the zoo.

There are all kinds of exotic animals that children don't normally see.

Sometimes, however, the kids are scared by the roar of the LION / CAGES / DRESS and scream in terror.

Do kids sometimes get scared at the zoo? Y

19. BALLGAME

A favorite American pastime during the summer is going to a ballgame.

Of course, people occasionally get rowdy.

My sister gets really upset when people drink too many BEERS / HOTDOGS / CAGES and start acting crazy.

Does my sister like it when people drink a lot at the ballgame? N

20. WASHING THE CAR

After a day of off-roading, my truck was covered in mud.

I parked it out on the driveway to give it a wash.

When I started, I realized that I had forgotten to turn on the HOSE / SOAP / GUN on the side of the house.

Did I take my truck to the car wash? N

21. TRIAL

The case of Bill the Butcher was the largest that this court had ever tried.

The entire town came out to hear the opening statements.

Once they were finished, the prosecution called its first WITNESS / LAWYER / RECEPTIONIST to the stand.

Did the opening statements draw a large crowd? Y

22. GARDENING

This spring, I decided to start growing my own vegetables.

I bought a variety of seeds and planted them in my backyard.

I made sure to choose a spot that got plenty of SUN / DIRT / MONEY during the day.

Did I start a vegetable garden? Y

23. WEDDING

My parents were very happy when my sister finally got married.

At the ceremony, my father looked so proud.

My mother started crying when the couple recited their VOWS / RING / DIRT and proclaimed their love.

Were my parents worried about my sister getting married? N

24. BUS RIDE

I usually take the bus to work in the morning.

It was over twenty minutes late on Friday.

To top it off, when it finally came I realized that I didn't have any MONEY / DRIVER / TEACHER to pay the fare.

Did the bus arrive on time on Friday? N

25. RESTAURANT

The restaurant down the street is known for its lousy service.

One time, I actually caught a waiter taking a bite of someone's dinner.

I immediately asked to speak with the MANAGER / FOOD / POLES about the waiter's conduct.

Is it common to have bad service at the restaurant? Y

26. PLAYING IN THE SNOW

A huge blizzard swept through town last night.

My kids ended up getting the day off from school.

They spent the whole day outside building a big SNOWMAN / JACKET / TOWEL in the front yard.

Did my kids play outside on their day off from school? Y

27. SKIING

My dad had a lot of trouble when I took him skiing for the first time.

It took him forever just to figure out how to stand up.

Then he fell when he tried to get onto the LIFT / POLES / FOOD with his skis crossed.

Is my dad a good skier? N

28. POKER

Jackie is a very methodical poker player.

During the high-stakes tournament, she was even more careful than usual.

Every few hands, she made sure to count her CHIPS / TABLE / WATER silently to herself.

Was Jackie playing carelessly during the poker tournament? N

29. BIKE ACCIDENT

My friend Mike went mountain biking recently.

He lost control for a moment and ran right into a tree.

It's a good thing he was wearing his HELMET / DIRT / TABLE or he could have been seriously hurt.

Did Mike crash on his bike? Y

30. TRAFFIC STOP

It's generally a good idea to drive slowly and obey traffic laws.

If you don't, you're likely to get pulled over.

It's always a terrible feeling when the officer issues you a TICKET / LICENSE / HELMET and sends you on your way.

Is it a good idea to obey traffic laws? Y

31. FIELD TRIP

I used to love taking field trips with my elementary school.

We got out of class for the day, and we usually went someplace fun.

I would always get excited when we were about to board the BUS / TEACHER / SALESMAN and head off.

Were my field trips usually boring? N

32. MUSEUM

We're lucky to live in a town with such a great art museum.

Last week I went to see a special exhibit.

I finally got in after waiting in a long LINE / PAINTING / TOOTHBRUSH and paying an entrance fee.

Did I see a special exhibit at the aquarium? N

33. CAMPING

I took my friends to the desert for a few days of camping.

After a couple hours of hiking, we found a good spot to spend the night.

The weather was so nice that we didn't even pitch a TENT / FIRE / HAMMER or use our sleeping bags.

Did we have nice weather on our camping trip? Y

34. MATH TEST

Jenny had a really difficult math exam earlier this week.

She was so worried about being late that she arrived twenty minutes early.

As soon as she arrived, she made sure to sharpen her PENCIL / CALCULATOR / BED and find a seat.

Did Jenny arrive early to the test? Y

35. HOCKEY GAME

My friends and I played a game of pond hockey over the weekend.

It was clear from the beginning that one of my friends had never played before.

The poor guy couldn't even lace up his SKATES / PUCK / GLASS or hold his stick properly.

Are all my friends experienced hockey players? N

36. MOVIE SET

Filming for the new movie was getting underway, and the crew was ready to shoot the first scene.

One of the cameramen mentioned that she was getting some really bad glare in the shot.

Somebody quickly dimmed the LIGHTS / ACTORS / TURKEYS and the director called action.

Did the cameraman complain about the lights being too dim? N

37. BANK ROBBERY

A high profile bank was robbed yesterday afternoon.

The robbers entered through the back and made their way to the lobby.

All the customers froze when they saw several masked men pointing GUNS / MONEY / DIRT and threatening to shoot.

Were there customers present during the bank robbery? Y

38. LIBRARY

It's a good idea to get some reading material before going on a long trip.

I tend to go to the library the day before I leave.

Last time I went, I was shocked to find out that I owed a huge FINE / BOOK / TIRE for something I had already returned.

Do I usually go to the library before going on a trip? Y

39. BUYING A CAR

Shopping at the used car lot can be a stressful ordeal.

Even if you find a car you like, you never know if it has any problems.

Just make sure to have a good look under the HOOD / SALESMAN / POLICEMAN before buying anything.

Can you be certain whether or not a used car has problems? N

40. GOING TO THE POOL

My little brother doesn't know how to swim, but we still bring him along when we go to the pool.

One time, he fell into the deep end while no one was looking.

He was quickly brought to safety by the LIFEGUARD / WATER / PARACHUTE and given to our mother.

Is my brother a good swimmer? N

41. WATCHING TV

Last Saturday I laid around watching television into the middle of the night.

I eventually found myself watching an infomercial for some new cleaning product.

I wanted to change the channel, but I couldn't find the REMOTE / COUCH / BRUSH anywhere.

Was I watching TV late at night? Y

42. CLEANING THE HOUSE

Even the laziest people clean up around the house every once in a while.

The worst part is always the bathroom.

When you tackle the toilet, it's good to wear some GLOVES / BLEACH / BLOOD to guard against bacteria.

Is the bathroom the worst part of cleaning the house? Y

43. ON AN AIRPLANE

The airlines are getting so stingy that they don't even provide free food anymore.

A lot of people complain that they no longer get a complimentary meal on long flights.

I'd be happy just to get a bag of PEANUTS / DRINKS / FIRE or some crackers.

Do all the airlines still provide complimentary meals? N

44. SETTING THE TABLE

We had our entire family over to our house for Thanksgiving this year.

My mother set the table as if the President were coming for dinner.

She laid out a nice tablecloth and even lit a couple CANDLES / TURKEYS / RUNNERS for effect.

Did we set the table for an ordinary dinner? N

45. VOTING

The last presidential election drew an incredible number of voters.

My polling place had a line out the door when I arrived on election day.

I waited three hours before I was finally able to cast my VOTE / BOOTHS / COFFINS and head to work.

Did a lot of people vote in the election? Y

46. GIVING A SPEECH

My sister was only twenty when she won a Grammy for her first album.

She seemed so nervous as she gave her acceptance speech.

Her voice was shaky as she spoke into the MICROPHONE / DRESS / PAINTING and thanked everyone.

Was my sister young when she won her Grammy? Y

47. PLAYING FOOTBALL

Jeremy is a great athlete despite being prone to injury.

During his last high school football game, he was knocked unconscious twice.

That still didn't stop him from scoring the winning TOUCHDOWN / HELMET / LICENSE with only seconds remaining.

Did Jeremy sprain his ankle during the football game? N

48. SURFING

Living in San Diego is great if you love to surf.

The downside is that the water can be freezing during the winter.

You'll be sorry if you go out without wearing your WETSUIT / SURFBOARD / GRILLS or at least a shirt.

Is the winter water warm enough to surf in just your bathing suit? N

49. GROCERY SHOPPING

Raja likes to go to the supermarket early in the morning to avoid the crowds.

He usually brings his daughter along.

She always insists on riding in the CART / VEGETABLES / LUGGAGE while Raja pushes.

Does Raja try to do his shopping when the store isn't crowded? Y

50. DRINKING WINE

My husband and I had some nice red wine with dinner last night.

He's so clumsy that he ended up spilling some all over me.

At least my shirt was dark enough to partially hide the STAIN / GLASS / CAR for the rest of the evening.

Was I wearing a dark shirt? Y

51. DRIVER'S TEST

Andy was excited to get his driver's license, but he was afraid he wouldn't pass the parallel parking section of the test.

He tried to remain calm as he checked his mirrors and began.

Unfortunately, he ended up failing for knocking over too many CONES / INSTRUCTORS / CLOWNS and had to retake the test.

Did Andy pass his driver's test? N

52. SURGERY

Having major surgery is never a pleasant experience.

You lie in a sterile room next to an operating table full of scary tools and devices.

As if the anxiety isn't enough, you usually have to deal with a cold draft up your GOWN / DOCTOR / POLICE while you wait to begin.

Can major surgery be a pleasant experience? N

53. HAIRCUT

I used to love getting my hair cut when I was a kid.

I got so excited every time I walked into barbershop.

I would giggle with joy as I hopped into the CHAIR / SCISSORS / GUITAR and greeted the barber.

Did I enjoy haircuts as a child? Y

54. SKYDIVING

Tanya was totally pumped to be skydiving for the first time.

When it was her turn to jump, she got a huge smile on her face.

She didn't hesitate at all before leaping out of the PLANE / PARACHUTE / SODA head first.

Was Tanya excited to be skydiving? Y

55. CHOOSING A COMPUTER

When Maya's laptop was stolen, she went to the Apple store to buy a replacement.

She wanted to make sure to get one with a fast processor.

She also had tons of files to store, so she wanted a lot of MEMORY / SALESMAN / DENTIST as well.

Did Maya do her computer shopping online? N

56. ROAD TRIP

My friends and I took a cross-country road trip after graduating from college.

We ended up getting lost somewhere in the middle of Nevada.

We eventually decided to stop and ask for some DIRECTIONS / CAR / BOX at a gas station.

Did we stop because we were out of gas? N

57. BUILDING A SHED

I helped my neighbor build a shed recently, and we managed to run into a few problems.

First, we realized that we didn't make the doorway the right size.

Then we didn't have enough shingles to finish the ROOF / HAMMER / SURFBOARD so we returned to the store.

Did we run out of shingles? Y

58. DOCTOR'S OFFICE

The doctor was running very late, which was not uncommon.

Mary couldn't wait any longer and decided to reschedule her check-up.

So she asked if she could make another APPOINTMENT / RECEPTIONIST / LAWYER for the following week.

Did Mary try to reschedule her appointment? Y

59. RUNNING A MARATHON

Marathons take a lot out of you, and it's important not to get dehydrated.

Ralph had been doing OK up until mile twenty-six.

As he rounded the final bend, someone gave him some WATER / RUNNERS / ACTORS and cheered him on.

Did Ralph compete in a triathlon? N

60. FIXING THE CAR

Having serious car trouble is the worst.

Aside from being unable to drive, it's hard to find a mechanic you can trust.

You never know if you're being charged a fair PRICE / TIRE / MEDAL or not.

Is it easy to find a trustworthy mechanic? N

61. THE CIRCUS

Little kids love to go to the circus.

There are always exotic animals, and children find the acts very exciting.

The scariest act is of course when the lion tamer puts his head inside the lion's MOUTH / CLOWNS / INSTRUCTORS while the crowd gasps in horror.

Are there any scary acts at the circus? Y

62. THE OLYMPICS

The Olympic ice skating competition is always well attended.

Last year, the winner was the favorite, who was extremely popular.

The crowd roared with delight as she took her place on the PODIUM / MEDAL / BOOK and waved to her fans.

Was the winner of the competition popular? Y

63. BOXING MATCH

The boxing match had gone on for seven rounds, and both contestants were exhausted.

One of them had sustained serious injuries and finally fell to the mat.

Worried about his condition, the referee declared the other fighter the WINNER / BLOOD / BLEACH and ended the match.

Did the referee end the match because one of the fighters cheated? N

64. PAINTING

I started taking an introductory painting course a few weeks ago.

During the first class, the instructor had a very hard time giving even a simple demonstration.

It was clear that he didn't have much teaching EXPERIENCE / BRUSH / JACKET and wouldn't be a good instructor.

Did my painting class start out well? N

65. SNORKELING

Nadia went snorkeling in the Great Barrier Reef while on vacation in Australia.

She found it to be more beautiful than she had ever imagined.

After several hours of swimming around, she still couldn't bring herself to climb back in the BOAT / CORAL / FAMILY and head to shore.

Did Nadia enjoy her time at the Great Barrier Reef? Y

66. GOING TO THE SYMPHONY

Music fans have a lot of different tastes when it comes to live performances.

A lot of people like to go to rock concerts, but I prefer a symphony.

My favorite part is the string QUARTET / CONDUCTOR / LAWYER because I love the violin.

Do I prefer a symphony over a rock concert? Y

67. MOVING

Moving to a new house is always a huge hassle.

If you do it yourself, the whole ordeal can last several days.

Things go much faster if you hire a moving COMPANY / BOX / RING to help you.

Is moving to a new house an easy job to do alone? N

68. CLIMBING A MOUNTAIN

The climb up Mount Whitney is beautiful but very challenging.

Manny and Julia were tired but looking forward to what they knew awaited them at the top.

Finally, they rounded the last bend and were awed by the magnificent VIEW / BOOTS / SCISSORS of Owens Valley below.

Did Manny and Julia go hiking down by the river? N

69. HUNTING

The last time Tommy went hunting, he was nearly shot by another hunter.

He was creeping quietly through the woods when the other hunter almost mistook him for a deer.

It's a good thing he was wearing his orange VEST / GUN / SOAP over his camouflage.

Was Tommy almost shot by another hunter? Y

70. FISHING

I used to spend a lot of Saturday mornings fishing with my dad.

We would wake up early and load the car with all of the equipment.

We always brought a bucket of worms to use as the BAIT / ROD / PUCK even though worms grossed me out.

Did I used to go fishing with my dad? Y

71. GOING TO BED

I usually fall asleep pretty quickly.

Sometimes, though, if I've had a busy day I find it hard to wind down.

Then I find the best thing is to read a good BOOK / BED / TOWEL or magazine.

Do I like to watch TV when I can't fall asleep? N

72. FINDING A PARKING SPOT

It can be difficult to find a decent parking spot downtown.

A lot of the time you have to park on the street.

That's why it's always good to have some change to feed the METER / CAR / CALCULATOR or you might get a ticket.

Is it easy to find good parking downtown? N

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Two ERP experiments examine event knowledge activation during online language comprehension.

A contextually anomalous word elicits a reduced N400 if related to the described event.

The effect disappears when the discourse context is removed.

Online language comprehension involves activation of event knowledge that violates the linguistic context.

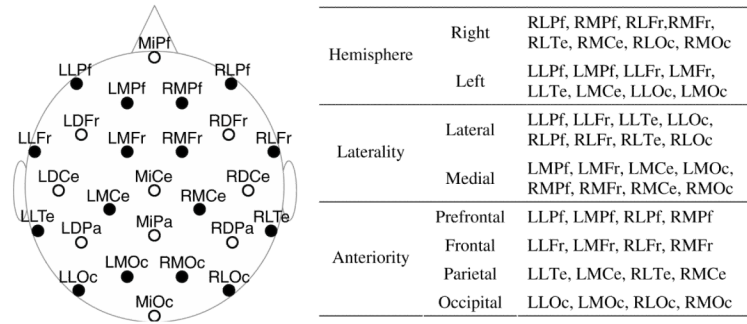


Figure 1. Layout of the 26 electrodes across the scalp. The embedded table summarizes the electrode groupings for the distributional analyses in Experiments 1 and 2. Filled-in electrodes were included in the distributional analyses.

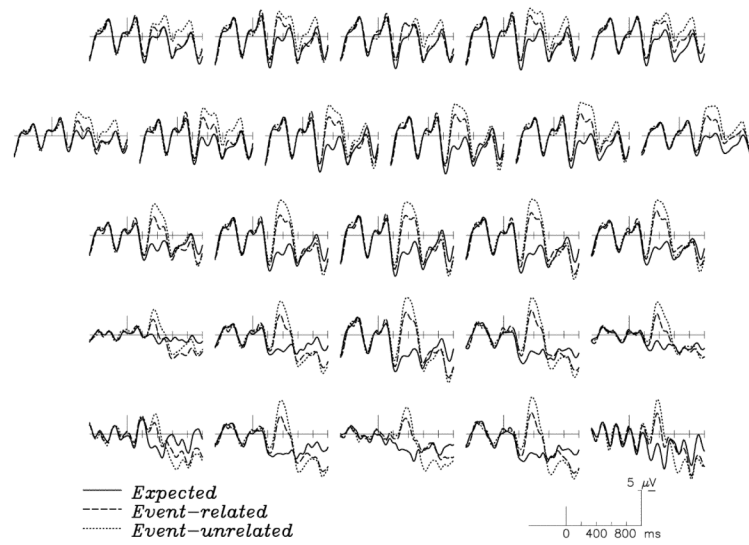


Figure 2. Grand average ERPs elicited by the target words in the three conditions from Experiment 1. Ticks on the abscissa mark 200ms intervals from target word onset. Negative voltage is plotted up.

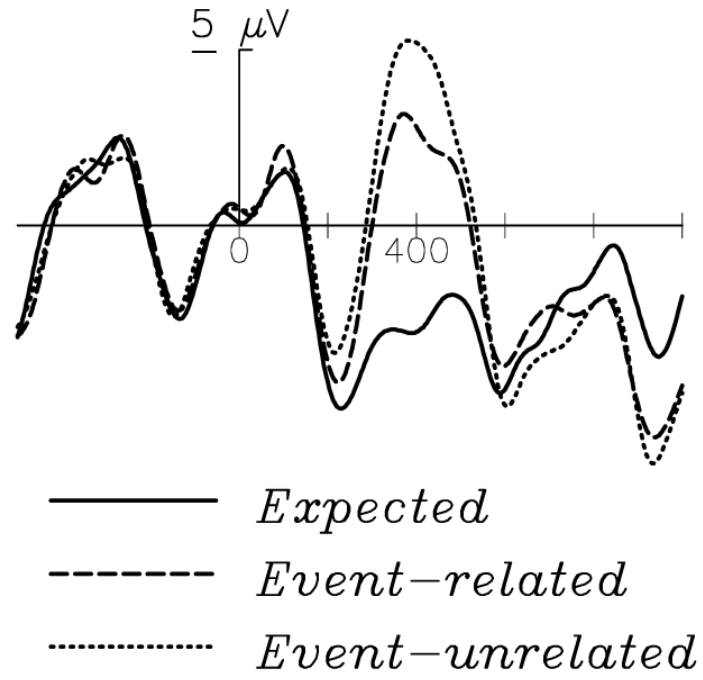


Figure 3. Grand average ERPs at the midline parietal electrode (MiPa) in Experiment 1.

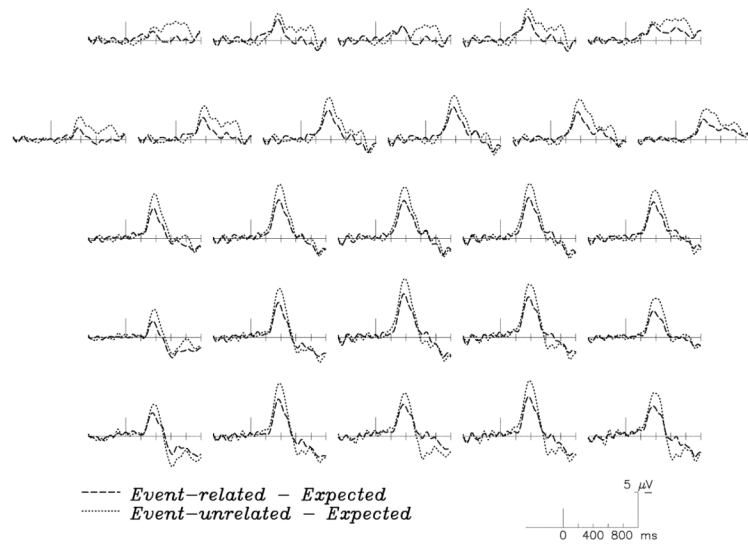


Figure 4. Difference waves reflecting the size of N400 effects in the event-related and event-unrelated conditions in Experiment 1.

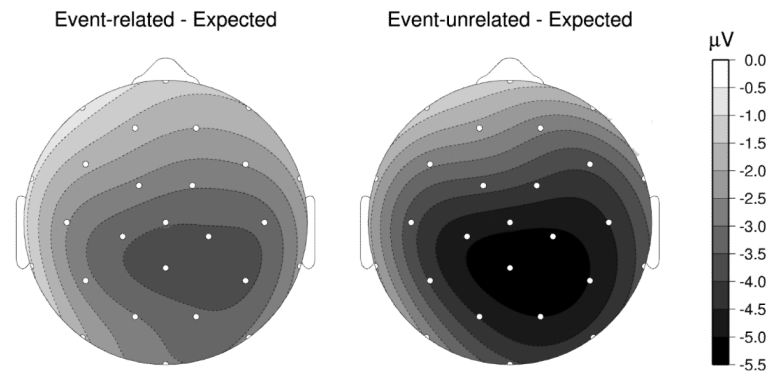


Figure 5. Scalp topographies of the N400 effects in the event-related and event-unrelated conditions from Experiment 1. The left plot reflects the N400 effect for the event-related targets, and the right the event-unrelated targets. Values correspond to mean amplitude 200-500ms post-stimulus onset.

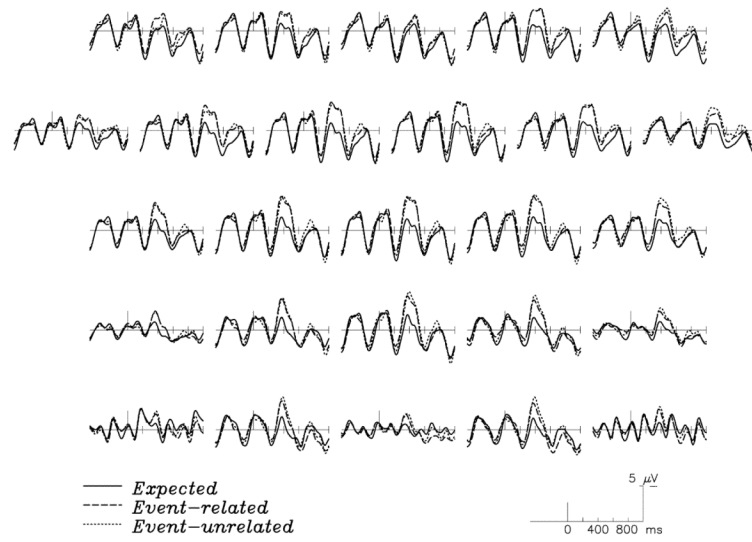


Figure 6. Grand average ERPs for the target words in the three conditions from Experiment 2.

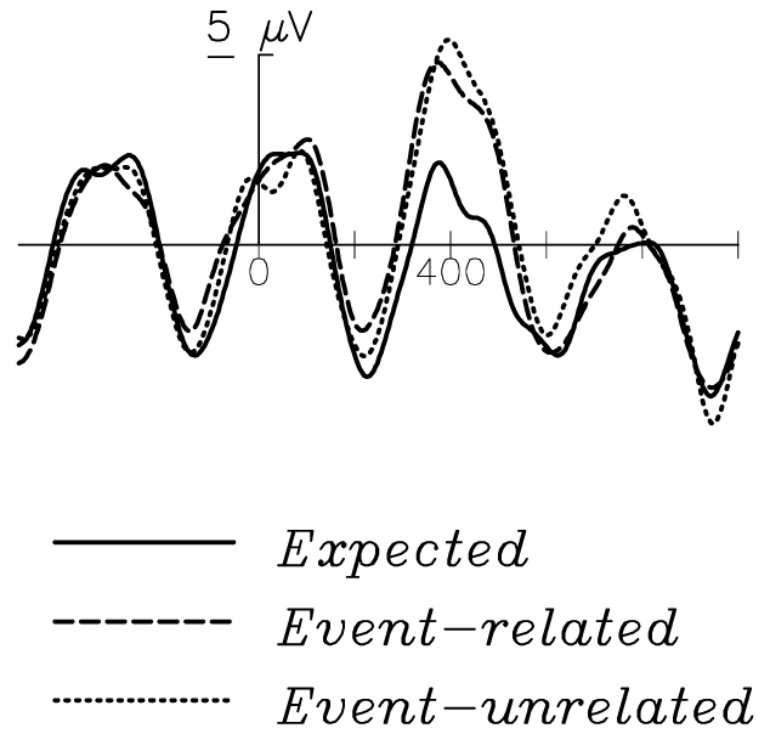


Figure 7.
Grand average ERPs at the midline parietal electrode (MiPa) in Experiment 2.

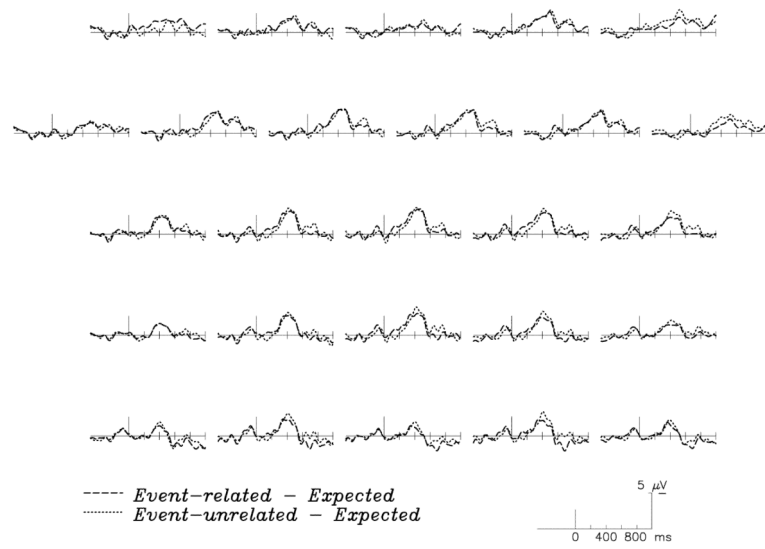


Figure 8. Difference waves reflecting size of N400 effects for the event-related and event-unrelated conditions in Experiment 2.

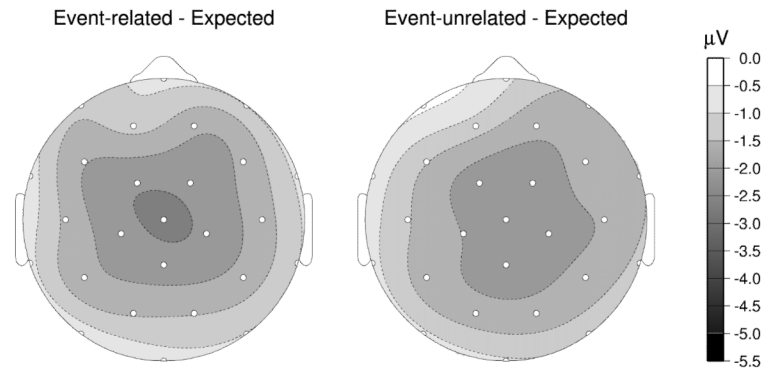


Figure 9. Topographies of the N400 effects in the event-related and event-unrelated conditions from Experiment 2. The left plot reflects the N400 effect for event-related targets, and the right the event-unrelated targets. Values correspond to mean amplitude 200-500ms post-stimulus onset.

Table 1

Norming results for the three rotation groups and the stimuli set overall.⁷

	Group 1	Group 2	Group 3	Overall	
Expected targets	Cloze probability	0.81	0.80	0.80	0.81
	Log frequency	6.95	7.01	6.88	6.95
	Orthographic length	5.58	5.71	5.75	5.68
Event-related targets	Cloze probability	0.00	0.00	0.00	0.00
	Log frequency	6.89	6.91	6.76	6.86
	Orthographic length	5.96	5.96	5.71	5.87
Event-unrelated targets	Event-relatedness score	91.17	89.71	96.21	92.36
Event-unrelated targets	Cloze probability	0.00	0.00	0.00	0.00
	Event-relatedness score	0.00	0.13	0.04	0.06

⁷Recall that the event-unrelated and event-unrelated targets consist of the same lexical items. Mean log frequency and orthographic length of the EuRAs is therefore equal to that of the ERAs and is not reported in the Table 1. Word frequencies were taken from the SUBTLEXus corpus of American English subtitles (Brysbaert & New, 2009).