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INTEGRATIVE EVENT PRIMING

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Abstract

The representation and organization of event concepts in semantic memory is an important issue in the domains of language processing and memory research. This thesis tested the hypothesis that pairs of words denoting events that can plausibly occur in sequence (*marinate-grill*) can prime a target that denotes a subsequently occurring, related event (*chew*). Experiment 1 showed that this type of priming occurs. I then tested whether such priming is contingent on presenting the primes in the order in which their referents occur in real life (*marinate-grill*), rather than in a temporally backward order (*grill-marinate*). Experiment 2 showed that priming was not contingent on prime order. Experiment 3 showed that individual primes (i.e., *marinate* and *grill* separately) did not prime their related event targets. Therefore, information from both primes must be integrated in order to sufficiently activate knowledge of the subsequently occurring target. This is the first study to demonstrate priming among words denoting sequentially occurring events. It is concluded that these results may provide support for perceptual simulation theory, but they cannot be accounted for by either spreading activation theory or Latent Semantic Analysis.

Keywords: Semantic memory, Expectancy generation, Event knowledge, Language comprehension, Semantic Priming

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I dedicate this thesis to Azadeh Erfanian, Masoud Khalkhali, and Örsi Tímár.

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Integrative Event Priming

Theories of human memory frequently express a fundamental distinction between episodic memory, the mental architecture that represents subjectively experienced events (Tulving, 2002), and semantic memory, which refers to more general knowledge of categories in the world as well as the words used to refer to them (Warrington, 1975). Given that language provides people with a common symbolic basis for referring to and discussing shared experiences of the world, it may be the case that how we process language bears some relation to how our minds represent related knowledge about the world. In particular, an important research question spanning the fields of language comprehension and semantic memory is the issue of how the processing of a word can automatically trigger activation of, or expectancy for, a related word/concept.

In terms of sentence processing, it is known that context can drive expectations for words later in the same sentence, as in *The day was breezy so the boy went outside to fly a* ____ (DeLong, Urbach, & Kutas, 2005), as well as for words in subsequent sentences (Federmeier & Kutas, 1999). Because sentences can evoke detailed scenarios or events, it may not be surprising that over their course, a single word can become highly anticipated, such as a suitable item that a typical boy might fly in the wind (*kite*). It is also interesting that the processing of single words, outside of a sentential context, can automatically generate expectancies for related concepts (de Groot, 1984). Indeed, lexical priming has often been observed between individually presented pairs of words. For example, the time it takes to recognize *nurse* as a word is reduced when it is immediately preceded by a related concept such as *doctor* as compared to being preceded by an unrelated concept such as *chair*, so *doctor* is said to prime *nurse* (Collins & Loftus, 1975; Neely, 1991). In the absence of form-based priming (e.g., *barin-brain*; Grainger, Kiyonaga, & Holcomb, 2006), priming between words is thus due to some semantic or associative relation between two lexical concepts.

Priming has played a significant role in testing theories of semantic memory. What is often called automatic semantic priming is thought to provide a window into the organization of conceptual representations. Priming is typically considered to be automatic if the stimulus onset asynchrony (SOA: the time between the presentation of the prime and the presentation of the target) is relatively short, such as 250 ms (Neely, 1991). Therefore, it has been and continues to be of considerable interest to investigate the types of semantic relations between words that produce priming.

The purpose of the present thesis is to examine whether semantic integration processes can drive automatic expectancy generation for words denoting events, given a limited linguistic context in the form of pairs of words. Specifically, I tested the hypothesis that word pairs denoting events that can plausibly occur in sequence (e.g., *marinate-grill*) can prime a target that denotes a subsequently occurring, related event (*chew*). In addition, I investigated whether such priming is contingent on presenting the primes in the order in which their referents occur in real life (*marinate-grill*), rather than in a temporally backward order (*grill-marinate*). Finally, to ensure that any obtained priming effects were not due to a single member of each prime pair, I tested whether each of the two primes on its own would prime the target (*marinate-chew*, *grill-chew*).

In the remainder of the Introduction, I first discuss the concept of semantic relatedness. Next, I review research that has investigated semantic relations that derive from people's knowledge of common events. Following that is a description of the present experiments, and a note about some existing research on integrative priming.

Semantic Relatedness

The construct of semantic relatedness has long held a prominent place in research on conceptual representations, owing to the fact that many categories of things in the world, and hence the words denoting them, intuitively seem related to each other, such as *hot-cold*, *eagle-hawk*, or *movie-popcorn*. As these examples show, there are many potential ways that two concepts can be related. It may be that the words denote contrasting aspects of the same phenomenon (*hot* and *cold* are perceptions of temperature), members of a common superordinate category (*eagle* and *hawk* are both birds), or elements of a common event (people eat *popcorn* while watching a *movie*).

Despite the fact that these and many other types of semantic relations exist between concepts denoted by single words, historically the term "semantic relatedness" was used to refer solely to category coordinates, as exemplified by *eagle* and *hawk*, or *truck* and *van* (Fischler, 1977; Lupker, 1984). The focus on category coordinates was related to research suggesting that natural concepts are structured hierarchically; for example, *truck* and *van* are members of the *vehicle* superordinate category (Rosch & Mervis, 1975). More recent research has defined semantic relatedness in terms of shared features (Shelton & Martin, 1992; McRae & Boisvert, 1998; Frenck-Mestre & Bueno, 2002; Vigliocco, Vinson, Lewis, & Garrett, 2004). Featural similarity priming effects have been simulated using computational models in which the strength or speed with which a concept (e.g., the target in a prime-target pair) is activated is influenced by the degree of overlap between its features and those of the concept that was activated previous to it, in this case the prime (Plaut, 1995; McRae, de Sa, & Seidenberg, 1997).

The other type of relatedness that has played a major role in theories of semantic memory and semantic priming is called associative relatedness, and is intended to account for the psychological association between concepts such as *peanut* and *butter*. Lexical association has been cited as a major source of automatic expectancy generation, being attributed to factors such as the co-occurrence of two words in speech or text, or the co-occurrence of the words' referents in the world (Fischler, 1977). The theoretical construct of association between lexical concepts has generally been operationalized by the empirical measurement of word association. The University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998) are the largest and most widely used set of word association norms. In Nelson et al.'s norms, participants were given a stimulus word such as *dock*, and asked to write down the first meaningfully related or associated word that came to mind. For example, according to these norms, given *dock*, 56% of participants (81/145) provided *boat* as a response.

Word association norms such as Nelson et al.'s (1998) have accounted for data in numerous studies of priming and other memory phenomena (Neely, 1991; Roediger, Watson, McDermott, & Gallo, 2001). However, even Nelson, McEvoy, and Dennis (2000), who are strong proponents of the use of word association as a research tool, acknowledge that a network of strengths of associations between words does not directly explain or describe the underlying semantic relations. For example, *boat* is the primary associate of *dock* most likely because boats are often found tied to docks; in fact, the primary function of a dock is to be a location at which boats can be housed safely. Furthermore, a number of other pairs of concepts are associated at 56% in Nelson et al.'s norms, such as *abdomen-stomach*, *adore-love*, *shears-scissors*, *stench-smell*, *above-*

below, *banker-money*, *bark-dog*, *cone-ice cream*, *enter-exit*, *gum-chew*, *herd-cow*, *job-work*, *nine-ten*, *proton-neutron*, and *quail-bird*. Two things should be apparent from this list of concept pairs. First, there are obvious semantic relations between each of these pairs of concepts; that is, they are not related due to an accident of contiguity. Second, although they are all associated to the same degree, there is a great deal of variability in the types of relations among them.

For a number of years, many semantic priming studies took the form of testing whether semantic relatedness, as defined by category coordinates, or normative association was the more important or basic organizational principle of semantic memory (Shelton & Martin, 1992; Thompson-Schill, Kurtz, & Gabrielli, 1998). However, it became apparent that this controversy may have been holding the field back because semantic relatedness is not limited to category coordinance or featural similarity, and pairs of associated concepts almost overwhelmingly share an obvious semantic relation. Thus, a better research strategy seemed to be to work toward defining, delineating, and testing various types of semantic relations. Therefore, over time, the definition of what constitutes a semantic relation has been expanded. One avenue that researchers have taken is to investigate what can be called event-based relations, such as the relations between events and the types of people and objects that tend to play some role in those events. Such investigations are discussed next to provide a relevant context for the present experiments.

Event-based Relations

The claim that people have extensive knowledge about events should come as no surprise, yet research on how such knowledge is represented in semantic memory or how it interacts with lexical processing during language comprehension clearly lags behind research on, for example, object concepts. Events can often be described in terms of the components that denote their various aspects. For example, if one considers *breakfast*, people have knowledge about typical locations (at the kitchen table, or in a diner), the things likely to be eaten, such as cereal and eggs, likely drinks such as orange juice and coffee, and likely objects such as a bowl, plate, glass, coffee cup, spoon, and fork.

In one of the first studies of how knowledge of events may be organized along multiple dimensions, Lancaster and Barsalou (1997) asked participants to recall short verbal descriptions of events, where each description included facts about the main activity (e.g., buying a boat), participants (Debra Winger), location (Hawaii), and time (Veteran's Day). The narratives were created such that some of them shared a common activity, participant, location, or time. Lancaster and Barsalou found that people's recall of the events were clustered by these shared dimensions, meaning that a participant might first remember all the events involving boat buying, then move on to events taking place on Veteran's Day, and so on. These results suggest that event memories are organized along multiple dimensions.

An important issue concerns whether event knowledge is automatically primed in the course of language comprehension. It is possible that the words denoting types of people or things at an event, or locations at which events typically occur, might prime one another because they are related through our everyday experience. The remainder of this section documents how activation between various components *within* an event has been studied, how knowledge of the temporal structure within events has been examined, and how one might go about studying anticipatory semantic processing across multiple event representations.

Various types of thematic relations have proven to be fertile ground for demonstrations of semantic processing. A verb's thematic roles consist of the roles played by event participants (broadly defined), such as agent, patient, instrument, or location. In the sentence, *Dave delivered fertilizer to Bruce with his pickup truck*, *Dave* is the agent who is doing the delivering, *fertilizer* is the patient (the thing being delivered), *Bruce* is the recipient of *Dave's* delivery, and the *pickup truck* is the instrument being used for delivery. Given that the concept of *deliver* is essentially the glue that binds the other sentential elements, Ferretti, McRae, and Hatherell (2001) addressed the question of what types of information are automatically activated by verbs. In a series of priming experiments, they showed that event verbs prime agents (*arresting-cop*), patients (*arresting-criminal*), and instruments (*stirred-spoon*), but not locations (*acted-theatre*).

Further evidence of the speed with which event-based concepts are activated by verbs comes from visual world studies. In a typical such study, a participant hears a spoken sentence while simultaneously attending to a visual display depicting entities described in the sentence, and possibly other distractor entities not mentioned. As the participant hears the sentence unfold, his or her eye movements are recorded. This paradigm allows researchers to test hypotheses about, among other things, the speed with which linguistic information is integrated and interpreted with respect to other information from the environment. The visual world paradigm has been used to show that people's eye movements correspond to the presence of information that is necessary to correctly anticipate plausible referents of the upcoming linguistic stream.

In a study showing that transitive verbs rapidly influence expectations for upcoming patients, Altmann and Kamide (1999) compared peoples' eye movements during sentences such as *The boy moved the ball* versus *The boy ate the cake*. When hearing *The boy moved the* while looking at an image depicting a cake and a ball, participants were equally likely to look at either because both are suitable moveable objects. In contrast, when hearing *The boy ate the*, participants were more likely to look at the cake. Altmann and Kamide attributed this pattern of eye movements to the fact that a cake and a ball can be moved with equal plausibility, but only a cake can be eaten. While such verb-based knowledge is easily retrieved and verbally described, Altman and Kamide showed that it is also used as the basis for making anticipatory, semantically guided eye movements.

Although events are often denoted by verbs, many nouns refers to events as well (*birthday, vacation*). Hare, Jones, Thomson, Kelly, and McRae (2009) showed that nouns denoting events can also prime words denoting types of people (*war-soldier*) and objects (*sale-clothes*) that typically are found at those events. Furthermore, if verbs or event nouns can activate relevant knowledge about common event participants, thus suggesting a relation between their concepts in semantic memory, then it may be the case that the opposite is also true. That is, agents, for example, may prime relevant verbs. Evidence of priming to verbs would bolster the position that relations between event concepts and their components are semantically coded and automatically activated. In fact, McRae, Hare, Elman, and Ferretti (2005) found that verbs can be primed by typical agents (*judge-sentencing*), patients (*guitar-strummed*), instruments (*oven-baking*), and locations (*razor-shaving*).

To add to the pattern of priming between words denoting events and associated thematic roles, studies have shown that components within an event can prime each other as well. Hare et al. (2009) found that locations prime people (*church-priest*) and objects (*barn-hay*) that are typically found at those locations, instruments prime patients of their actions (*scissors-hair*), and people prime types of instruments that they typically use (*janitor-broom*). Furthermore, in one of the first studies to examine the representation of event relations, Moss, Ostrin, Tyler, and Marslen-Wilson (1995) obtained priming for instrument relations and what they generically referred to as script relations (*restaurant-wine*). The finding that event knowledge-driven lexical anticipation occurs across a wide swath of relations is a testament to the necessity of such conceptual relations for understanding language efficiently.

Sentence comprehension requires the integration of multiple words to infer the situation that is being discussed, and so provides an experimental setting in which to study how event components, such as an agent and a verb, are combined to drive expectations for other components, such as a patient. In a visual world study considering the incremental nature of sentence processing, Kamide, Altman, and Heywood (2003) demonstrated that people rapidly activate patients of an action depending on the agent that is mentioned. For example, when a spoken sentence such as *The man will ride the motorbike* was paired with a visual scene depicting a motorcycle, a carousel, a man and a girl, people made more eye movements to the motorcycle than to the carousel upon hearing *will ride*. In contrast, *The girl will ride* elicited more eye movements to the carousel as a more likely patient. Studies such as this show that lexical concepts relating to events are activated and combined rapidly, and are used as a source of predictions for upcoming linguistic input. Moreover, they also demonstrate how quickly and automatically lexical knowledge is used to guide eye movements.

In summary, there is a great deal of research demonstrating that words denoting events and their common components rapidly activate one another both in isolation and in sentences. Importantly however, a key feature of events is that they unfold over time and that one event often leads to another. In all of the studies described above, the events were essentially treated as being static. That is, aside from the study by Lancaster and Barsalou (1997) showing that the off-line recall of events can be clustered by knowledge regarding when they occurred, nothing in the experiments reviewed above is dependent on, or provides insight into, temporal aspects of events, or whether any sort of temporal dimension is represented in semantic memory. The next section deals with the activation of temporal information within an event.

Accessing Temporal Structure Within Events

The studies mentioned so far have shown that processing information about an event leads to anticipatory activation of related concepts that are part of the same event. However, the types of relations discussed to this point do not necessarily relate to how an event unfolds over time. Although knowledge of an event's temporal structure is no doubt crucial to understanding the event, relatively fewer studies have shown how subtle manipulations of the linguistic context can alter the types of concepts that are anticipated, depending on the inferences that must be made about an event's temporal properties. In this line of research, the most common manipulation has been verb aspect. The grammatical category of aspect captures some ways in which language uses morphology to refer to the temporal structure of events (e.g., ongoing versus completed). For example, imperfective aspect (*is eating* or *was eating*) refers to the internal structure of events by focusing on their ongoing development, making no reference to their completion. Perfect aspect (*had eaten*) refers to some time period following the event, and focuses more on the resultant states. Note that aspect differs from tense in that, for example, imperfective aspect can be used to refer to an ongoing event that is either presently happening (*is eating*) or occurred in the past (*was eating*).

In sentence comprehension, the temporal properties of events and verb aspect interact to influence the activation of event-based knowledge during language comprehension. For example, Truit and Zwaan (1997) found that *hammer* (an instrument) was primed more strongly after *He was pounding the nail* than after *He pounded the nail.* That is, the instrument was more salient in an ongoing than in a completed event. In word-word priming, Ferretti, Kutas, and McRae (2007) examined whether the tendency of verbs to prime typical location nouns depends on the verb's grammatical aspect. Specifically, they compared priming effects for locations such as *arena* from past imperfective (*was skating*) and past perfect verbs (*had skated*) because the imperfective denotes an event that is still taking place (so that the location should be salient), whereas the perfect aspect suggests an already completed event (so that the location should not be salient). If the event knowledge associated with verbs is quickly activated, such that plausible candidates for upcoming input in the linguistic stream are predicted, it follows that an efficient language processor should demonstrate sensitivity to the specificities of the situation denoted by verb aspect. Ferretti et al. (2007) did in fact find that imperfective, but not perfect verbs primed the location associated with their activity. In summary, there is evidence, both from priming experiments and sentence processing, that people are sensitive to temporal information within events.

Semantic Relations Between Events

Given the evidence that people's knowledge of structure within events is encoded in semantic memory, there is reason to consider the possibility of rapidly activated semantic relations between words denoting separate events. Just as I mentioned was the case for people's knowledge of single events, it is not surprising that people are generally aware of the temporal order in which commonly perceived, multiple events tend to occur. For example, in addition to the rich knowledge people have about *breakfast*, they might also know that it tends to happen after waking up, and with too few exceptions is usually followed by going to work. Of course, the canonical order of some events is not as clear, such as whether showering tends to take place before or after breakfast. Nevertheless, it is interesting to consider what sorts of effects the repetitive exposure to events over the course of one's life has on the semantic representations of the temporal relations between events.

One way in which knowledge of event order has been studied is by examining how people process sentences containing temporal conjunctions such as *before* and *after*. Beginning a sentence with *after* signals to the reader that the order of events to be described in the sentence will reflect the order in which the events actually occurred in real life, as in *After the movie, they grabbed some drinks*. In contrast, *before* indicates a description of events in the opposite order to which they occurred, as in *Before going to the movie, they had dinner at home.* While it is generally believed that people understand sentences by constructing a mental representation of the situations described therein (Zwaan & Radvansky, 1998), an ongoing debate about language comprehension concerns the speed with which world knowledge is used to incrementally build a conceptual representation of a sentence as it unfolds in speech or text.

Münte, Schiltz, and Kutas (1998) hypothesized that if the mental representations created during on-line sentence comprehension are structured according to knowledge of how events unfold in real life, sentences that describe events counter to the default order should require greater cognitive processing. Since the use of *before* at the beginning of a sentence indicates a potential violation of expected order, Münte et al. predicted that the pattern of brain activity associated with reading such sentences, as recorded by event-related potentials measured on the scalp, would diverge early on from activity associated with reading sentences beginning with *after*. On the other hand, if event knowledge is not immediately used to construct a mental situation model during sentence comprehension, the presence of a single word at the beginning of a sentence should not immediately moderate brain activity. This is all the more likely if the sentences are otherwise identical (e.g., *Before she saw the movie, she had a drink* vs. *After she saw the movie, she had a drink*).

Münte et al. (1998) found that *before* sentences elicited greater negative changes in voltage, which has been shown to be a marker of the violation of semantic expectancies (Kutas & Hillyard, 1984; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005). Crucially, these differences emerged on average 300 ms after reading the first word in a sentence, indicating that the type of temporal conjunction had immediate effects on how the sentence was subsequently processed. As it relates to the goals of the present thesis, Münte et al.'s results provide an empirical basis for the hypothesis that knowledge of the temporal relations between events may be encoded in semantic memory.

The Present Study

I have so far considered some studies that examined how event nouns and verbs can activate other components that are part of the same event. That is, these studies focused on information that is internal to single events. A natural extension of this research, therefore, and an important step in understanding the organization of memory, is to consider whether semantic memory encodes the fact that some events typically follow one another. Given that the experiment reported by Münte et al. (1998) suggests that knowledge of event order is rapidly accessed during sentence processing, there is considerable justification for examining the nature of such knowledge in a semantic priming paradigm using words denoting events.

There are no published studies to my knowledge that have investigated priming across events that often follow one another in time. The remainder of this thesis presents experiments conducted to determine whether knowledge of the temporal relations between events is rapidly evoked by event words outside of a sentential context. I first tested whether two words denoting events that typically occur sequentially can prime another word denoting an event that might be expected to follow the first two (Experiment 1). I also sought to determine whether priming obtained in Experiment 1 was moderated by the order in which the primes were presented, thus indicating whether integration of primes and target is contingent on a temporally consistent presentation of the stimuli (Experiment 2). Furthermore, to ensure that any obtained priming was due to the integration of both primes, rather than activation from a single prime, I tested whether each member of a prime pair would individually prime its respective target (Experiment 3).

I began by conducting a norming study to construct stimuli on which to test priming. A pool of word pairs denoting two related, temporally contiguous events, were created, such as *marinate-grill.* These word pairs were then presented to participants, who were asked to respond with three events that could plausibly follow the first two. Event pairs that elicited a substantial proportion of similar responses across participants were chosen as items for the priming experiments. So as to bolster the claim that positive results in the subsequent priming studies were due to semantic integration processes, I chose stimuli with very weak word association values. This served to give credence to my claim of studying semantic processing, and hence mitigated the likelihood of the attribution of any obtained priming effect to non-semantic factors, such as associations arising from coincidental spatio-temporal proximity of words or their referents. Following the norming study, suitable items consisting of two primes and a target denoting events that follow each other (e.g., *marinate-grill-chew*) were included in Experiment 1, testing the hypothesis that two event words can prime another, subsequently occurring event.

After obtaining statistically significant results, Experiment 2 was then undertaken to see whether such integrative event priming only takes place when the primes are presented in the same order as that in which their referents would occur (i.e., *marinate-grill-chew*, rather than *grill-marinate-chew*). Although the integrative priming effect was replicated in Experiment 2, there was no evidence of an effect of order. Finally, Experiment 3 served to evaluate the possibility that the integrative priming previously found was due to direct priming from individual primes. The results from this experiment strongly indicate that such a mechanism cannot account for the results in Experiments 1 and 2.

A point worth mentioning is that although it may seem like an effect of event order can also be tested using two words, such that they are alternately used as prime and target (e.g., *marinate-chew* vs. *chew-marinate*), the potential for backward priming made this an undesirable option. Backward priming (Seidenberg, Waters, Sanders, & Langer, 1984) refers to the observation that a word (*beer*) can prime another word (*keg*) not because of a forward association between them (according to Nelson et al., 1998, the probability of providing *keg* as a response to *beer* is 0), but because of a word association in the backward direction (in Nelson et al.'s norms, *keg* elicits *beer* 89% of the time). Thus, any experimental design that is potentially sensitive to backward priming is not ideal for studying effects of order on semantic processing.

Integrative Priming

Before moving to the experiments, it is worth mentioning that there is one published study that demonstrates how reading two words that are not obviously related can prime a third word by virtue of the integration of all three into a meaningful context. Chwilla and Kolk (2005) tested whether two words presented simultaneously, and otherwise unrelated except when considered in the context of some broader event (e.g., *fries weight*) can prime another word (*diet*) that fits into the general situation being evoked. When compared to items that were not intended to evoke a consistent scenario (*chisel slate - diet*), related triplets elicited priming on the basis of the integrability of the words into a plausible situation.

Chwilla and Kolk's (2005) results are interesting because there was no consistency in the types of relations present among their stimuli, other than the fact that the items that they used did not contain strong word associations, ruling that out as an explanation of their findings. Their results are contingent on the integration of the primes with the target and thus speak to the rapid activation of people's knowledge of events and situations. However, their study is theoretically quite different from the present experiments that investigate integration of multiple sequentially-occurring events.

Event Norming Study

The goal of this study was to empirically derive sets of three events that follow one another. Participants were shown a pair of words denoting two events, and were asked to provide three responses, each corresponding to an event that might temporally follow the first two. The pairs of words given to the participants constituted the potential set of primes, whereas participants' responses represented potential targets.

Method

Participants

Forty undergraduate students at the University of Western Ontario participated for course credit. All participants in this experiment, as well as those in all other experiments reported herein, were native speakers of English and had normal or corrected-to-normal visual acuity. Furthermore, no participant took part in more than one experiment reported in this thesis.

Materials

A pool of 82 word pairs, such as *design-manufacture* or *borrow-read*, was created on the basis of intuition, such that the majority of the words were nouns or verbs denoting events. Some words appeared in more than one word pair, and an examination of the word pairs suggested that some could also be plausible responses to other pairs.

Therefore, two lists of 41 word pairs were created so that no word appeared more than once in a list, as well as to minimize potential overlap between prime words and plausible responses.

Procedure

Participants completed the norming study by signing on to a web-site. The instructions informed participants that they would be given pairs of words that describe the first two events of a sequence. They were then informed, "For each pair, please provide up to 3 other single words that each describe an event that you think should follow the first two." Thus, three responses were collected for each item from 20 participants per list. The entire task took less than 30 minutes to complete.

Results and Discussion

Responses were ranked based on the order in which a participant provided them. Thus, all the responses to a given stimulus item were weighted by taking into account the number of people who provided a response at each of the three ranks. Response weight was determined by

$$W = 3a + 2b + c,$$

where a, b, and c refer to the number of participants who provided that response in ranks 1, 2, and 3, respectively. In cases in which different responses to an item were synonymous or very closely related to one another, their weights were combined. For example, given *browse-try*, *buy* was produced nine times, *purchase* three times, and *pay* once, giving *buy* an amalgamated weight of 32. Thirty targets with high weights were chosen for the subsequent priming studies (see Appendix A for the 30 items). I also tried to ensure that the agent role applicable to each event word within an item remained constant (i.e., so that perspective did not change). For example, in the triplet *climb-slip-drop*, the same hypothetical person can be imagined climbing up a tree or rock face, slipping, and finally dropping down. There were some exceptions however, as in *fracture-operation-recover*: it is unclear who the agent responsible for the fracture is, and the people performing the operation and enjoying the recovery must also be distinct. Finally, forward and backward associative strength for each combination of the two primes and the target were taken from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998) to ensure that selected event triplets did not contain strong word associations between the primes and targets. As can be seen in Table 1, the mean and maximum word association between each prime and its corresponding target were extremely low. Thus, priming on the basis of word association would not be predicted.

Experiment 1: Relatedness Priming

Experiment 1 tested the hypothesis concerning the integration of otherwise weakly related event words (at least according to word association norms) to prime a subsequent event. Specifically, I predicted that the presentation of event primes in a temporally consistent order would elicit knowledge of an event that might follow in real life, thus priming the relevant target word. As mentioned in the Introduction, it is known that stimulus onset asynchrony (SOA) can moderate the types of processes that are responsible for the observed priming effects. At longer SOAs, the influence of strategic processing driven by task demands is often observed, whereas it is typically not present at SOAs of 250 ms or shorter. Thus, short SOAs are typically used to study automatic semantic priming (de Groot, 1984; den Heyer, Briand, & Dannenbring, 1983;

Table 1

Mean Word Association Probabilities (Range in Parentheses) between Primes and Targets for Experiment 1 Items

	Prime 1 and Target	Prime 2 and Target	Prime 1 and Prime 2
Forward	.004 (0 - .050)	.005 (0 - .092)	.005 (0 - .061)
Backward	.007 (0 - .169)	.001 (0 - .028)	.005 (0 - .126)

Stolz & Neely, 1995).

In the present experiment, priming was tested at two SOAs: 200 ms per prime (which means a 400 ms lag between the presentation of the first prime and the target) in Experiment 1a, and 500 ms per prime (1000 ms between the first prime and the target) in Experiment 1b. Because this experiment probed the organization of semantic memory, it would be ideal to obtain priming with an SOA of 200 ms. However, an SOA of 500 ms was included because as of yet there have been no published studies describing the conditions under which priming across events may be observed, and it is possible that such integration might take time.

Experiment 1a

Method

Participants. Forty-two undergraduate students at the University of Western Ontario participated; 18 for course credit, and 24 for $5.

Materials. The 30 event triplets from the norming study were used as related items. These were split into two rotation groups containing targets that were balanced on frequency and length. Unrelated event triplets were created by combining the prime pair from one item with an unrelated target from another item within the same rotation group (e.g., *borrow-read-return* and *digging-planting-return*). Two lists of 15 related and 15 unrelated critical items were constructed by pairing the related items from each rotation group with the unrelated items from the other group.

In addition to the 30 critical trials, 210 filler items were also included. These included 90 word targets that were unrelated to either prime, with the primes being unrelated to one another (*drag-expose-insure*), and 90 nonword targets preceded by primes unrelated to one another (*retire-modify-consulty*). Furthermore, so that relatedness between primes did not cue the lexical decision response, there were 30 nonword targets with primes that were related to each other (*fishing-catch-absarb*). In total, half the targets were words and half were nonwords. Among word targets, the proportion of related prime-target triplets was .14. Relatedness proportion has been shown to moderate the influence of strategy expectancy generation processes (Stolz & Neely, 1995). For the stimuli used in the present experiments, the relatedness proportion was quite low relative to other studies of semantic priming, meaning that prime-target relatedness could not be used as a reliable cue for making the lexical decision. Furthermore, the proportion of items containing related primes was .25, and was constant across word and nonword targets. As a result, prime-prime relatedness was also not a valid cue for making lexical decisions.

Prior to beginning the experiment, participants completed 24 practice trials. These consisted of three word targets with related primes (*stab-wound-blood*), nine word targets with unrelated primes (*back-venture-awake*), three nonword targets with related primes (*breath-lungs-starb*), and nine nonword targets with unrelated primes (*immigration-listen-fadder*).

Procedure. Stimuli were presented using E-Prime v1.1 (Schneider, Eschman, & Zuccolotto, 2002) on a PC with a 17-inch colour monitor. Decision latencies were recorded with millisecond accuracy using a Psychology Software Tools Model 200A serial-response box. Words and nonwords were displayed in lower case 18 point Courier New font in black, centered on a white screen. For each trial, participants were instructed to read and pay attention to the first and second primes, and decide as quickly as possible whether or not the target was an English word. Each trial began with a fixation point (+) for 250 ms followed by a blank screen for 250 ms. The first prime was then displayed for 200 ms. The second prime immediately followed the first, and was also presented for 200 ms. Finally, the target was displayed until the participant made a lexical decision. "Yes" responses were made with the dominant hand while "No" responses were made with the non-dominant hand. There were four breaks, one after every 39 trials.

Design. Decision latencies were analyzed separately with two-way analyses of variance. The factor of interest, relatedness (related vs. unrelated), was within both participants (F_1) and items (F_2). In all priming experiments reported in this thesis, list was included as a between-participants dummy variable in by-participants analyses (F_1), whereas item rotation group was a between-items dummy variable in by-items analyses (F_2). This was done to stabilize any variance caused by rotating items and participants across lists (Pollatsek & Well, 1995). The square root of the number of errors (Myers, 1979) was analyzed in the same manner. Decision latencies greater than three standard deviations above the grand mean were replaced by that value (5.6% of trials). In all priming experiments reported herein, trials on which an error was made were excluded from decision latency analyses.

Results

Decision latencies for related event triplets ($M = 595$ ms, $SE = 11$ ms) were 21 ms shorter than for unrelated triplets ($M = 616$ ms, $SE = 13$ ms), $F_1(1, 40) = 7.02, p < .02$, $F_2(1, 28) = 4.73, p < .04$. There was no significant difference in error rates between related ($M = 4.8\%$, $SE = 1.2\%$) and unrelated ($M = 3.7\%$, $SE = 0.8\%$) triplets, $F_1 < 1$, $F_2(1, 28) = 1.18, p > .2$.

Experiment 1b

Method

Participants. Forty undergraduate students at the University of Western Ontario participated; nine for course credit and 31 in return for $5.

Materials. The stimuli were identical to Experiment 1a.

Procedure. The procedure was identical to Experiment 1a, except that each prime was presented for 500 ms.

Design. The analyses were identical to Experiment 1a. Decision latencies greater than three standard deviations above the grand mean were replaced with that value (1.5% of trials).

Results and Discussion

Decision latencies for related event triplets (M = 576 ms, SE = 16 ms) were 37 ms shorter than for unrelated triplets (M = 613 ms, SE = 19 ms), $F_1(1, 38) = 10.34, p < .003$, $F_2(1, 28) = 13.63, p < .001$. Participants made significantly fewer errors on related (M = 1.8%, SE = 0.6%) than on unrelated triplets (M = 5.0%, SE = 0.9%), $F_1(1, 38) = 16.28, p < .001$, $F_2(1, 28) = 9.03, p < .006$.

Experiments 1a and 1b are the first demonstrations that pairs of event words can be integrated to prime a word denoting a subsequently occurring event, and this occurred at both SOAs of 200 ms and 500 ms per prime. Importantly, this effect cannot be attributed to associations between primes and targets individually because word associations show that they do not exist. Furthermore, the presence of priming at a 200 ms SOA can be taken as evidence of the automatic nature of the effect. Therefore, these studies indicate the existence of conceptual relations in semantic memory that encode knowledge of the temporal relations between multiple events.

Having established that temporally integrable event pairs can prime a word denoting a subsequent event, Experiment 2 sought to determine whether this priming effect is contingent on presenting the primes in the same order as that in which their referent events would typically occur.

Experiment 2: Relatedness and Order Priming

The present experiment was conducted to determine whether the integration priming observed in Experiment 1 is sensitive to the temporally consistent order of the primes, or if it can be obtained with primes that are presented in an unexpected order, such that the first prime denotes an event that would normally occur after the event denoted by the second prime, as in *chew-marinate-grill*.

It is known that words encountered over the course of a sentence are integrated to create a mental model of the verbally described situation; common experience suggests that comprehension can easily be made laborious by various types of violations of word order (e.g., *Fell the Jim cliff off*, *The cliff fell off Jim*, vs. *Jim fell off the cliff*). Although Experiment 1 used event triplets to test for semantic integration mechanisms given minimal contextual effects on processing, the three words in a triplet were nevertheless designed to evoke a meaningful scenario, not unlike the function of a sentence. And as regards the role of event knowledge in sentence comprehension, Münte et al.'s (1998) study clearly showed that knowledge of the temporal order of events is immediately evoked upon processing a single word. Accordingly, it may be the case that processing two primes in an order opposite to that in which their event referents are perceived results in a violation of semantic expectations, meaning that the primes cannot be as easily integrated to form a coherent mental model of a plausible situation. In consequence, the target that follows may have no basis, or a reduced basis, for being primed.

At first glance, it seems like order effects could also be tested by reversing the position of the second prime and the target rather than reversing the order of primes. In such a scenario, the two primes would always be presented in a temporally consistent order, whereas the target would appear out of place in the incorrect order condition (*marinate-grill-chew* vs. *marinate-chew-grill*). However, with this design, there would exist the possibility of backward priming in the reverse-order condition between the target and one of the primes, resulting in a priming effect that perhaps is not dependent on the semantic integration and expectancy generation mechanisms that I sought to investigate here.

The main hypothesis for Experiment 2 corresponded to a relatedness by prime order interaction. As in Experiment 1, two SOAs were used: Experiment 2a used 200 ms per prime, while Experiment 2b used 500 ms.

Experiment 2a

Method

Participants. Fifty-two undergraduate students at the University of Western Ontario participated; 26 for course credit and 26 for $5.

Materials. From the 30 event triplets from Experiment 1, 24 were chosen as stimuli. Items that included object words (e.g., *wine-carpet-stain*, *cold-blanket-heat*) were excluded, as were items including locations (e.g., *runway-takeoff-cruise*, *changeroom-warmup-play)*.

The 24 items were split into four rotation groups balanced on target length and frequency. As in Experiment 1, unrelated event triplets were created by combining a target with an unrelated prime pair from another item within the same rotation group. Backward order items were created by reversing the order of the primes in the forward condition. Four lists, each containing six related-forward triplets, six unrelated-forward triplets, six related-backward triplets, and six unrelated-backward triplets were constructed by combining the various versions of each rotation group.

To keep the same relatedness proportion as in Experiment 1 (.14), 168 fillers were included: 72 pairs of unrelated primes, followed by an unrelated word target (*stake-envelope-delete)*, 24 nonword targets preceded by primes that were related to each other (*rain-flood-gadroom*), and 72 pairs of unrelated primes, followed by a nonword target (*market-deploy-fugar*). As in Experiment 1, the proportion of items containing related primes was .25. Prior to beginning the experiment, participants completed the same 24 practice trials that were used in Experiment 1.

Procedure. The procedure was identical to that of Experiment 1, except that there were four breaks, one after every 38 trials. That is, each prime was presented for 200 ms.

Design. Decision latencies were analyzed separately with three-way analyses of variance. The factors of interest were relatedness (related vs. unrelated) and order (forward vs. backward order). Both factors were analyzed within participants (F_1) and items (F_2). The square root of number of errors (Myers, 1979) were also analyzed with three-way analyses of variance. Decision latencies greater than three standard deviations above the grand mean were replaced with that value (1.6% of trials).

Results

Mean lexical decision latencies by condition are presented in Table 2a. Decision latencies

Table 2a

Mean Decision Latencies (ms) and Percent Errors by Condition in Experiment 2a

	Forward		Backward	
	M	*SE*	*M*	*SE*
Latencies				
Unrelated	620	19	619	17
Related	597	15	600	14
Priming Effect	23		19	
Percent Errors				
Unrelated	5.1	1.3	4.8	1.2
Related	7.7	1.8	3.8	1.0
Priming Effect	2.6		1.0	

for related event triplets ($M = 598$ ms, $SE = 14$ ms) were 22 ms shorter than for unrelated triplets ($M = 620$ ms, $SE = 17$ ms), $F_1(1, 48) = 5.16, p < .03$, $F_2(1, 20) = 8.28, p < .009$. However, relatedness and order did not interact, $F_1(1, 48) < 1$, $F_2(1, 20) < 1$. Decision latencies for forward ($M = 608$ ms, $SE = 16$ ms) and backward order ($M = 610$ ms, $SE = 16$ ms) did not differ, $F_1(1, 48) < 1$, $F_2(1, 20) < 1$.

There was no significant difference in error rates between related ($M = 5.8\%$, $SE = 1.5\%$) and unrelated ($M = 5.0\%$, $SE = 1.2\%$) triplets, $F_1(1, 48) < 1$, $F_2(1, 20) = 1.49, p > .2$. Relatedness and order did not interact, $F_1(1, 48) = 1.59, p > .2$, $F_2(1, 20) = 3.54, p > .07$. There was a significant by-items difference in error rates between forward ($M = 6.4\%$, $SE = 1.6\%$) and backward order ($M = 4.3\%$, $SE = 1.1\%$) triplets, $F_1(1, 48) = 1.36, p > .2$, $F_2(1, 20) = 4.57, p < .05$.

Experiment 2b

Method

Participants. Fifty-two undergraduate students at the University of Western Ontario participated in return for \$5.

Materials. The stimuli were identical to Experiment 2a.

Procedure. The procedure was identical to Experiment 2a, except that each prime was presented for 500 ms.

Design. The analyses were identical to Experiment 2a. Decision latencies greater than three standard deviations above the grand mean were replaced with that value (2.2% of trials).

Results and Discussion

Mean lexical decision latencies by condition are presented in Table 2b. In contrast

Table 2b

Mean Decision Latencies (ms) and Percent Errors by Condition in Experiment 2b

	Forward		Backward	
	M	*SE*	*M*	*SE*
Latencies				
Unrelated	634	20	631	18
Related	623	20	625	17
Priming Effect	11		6	
Percent Errors				
Unrelated	7.1	2.1	7.7	1.7
Related	4.5	1.2	3.2	1.0
Priming Effect	2.6		3.5	

to Experiment 2a, there was no main effect of relatedness, as decision latencies for related (M = 624 ms, SE = 19 ms) and unrelated targets (M = 632 ms, SE = 19 ms) were not significantly different, $F_1(1, 48) < 1$, $F_2(1, 20) < 1$. Relatedness and order did not interact, $F_1(1, 48) < 1$, $F_2(1, 20) < 1$. Decision latencies on items containing forward (M = 628 ms, SE = 20 ms) and backward order primes (M = 628 ms, SE = 18 ms) did not significantly differ, $F_1(1, 48) < 1$, $F_2(1, 20) < 1$.

Error rates were lower for related (M = 3.9%, SE = 1.1%) than for unrelated (M = 7.4%, SE = 1.9%) triplets, $F_1(1, 48) = 3.68, p < .07$, $F_2(1, 20) = 13.51, p < .001$. Again, relatedness and order did not interact, $F_1(1, 48) = 1.74, p > .1$, $F_2(1, 20) < 1$. Error rates for forward (M = 5.8%, SE = 1.7%) and backward order (M = 5.5%, SE = 1.5%) did not differ, $F_1(1, 48) < 1$, $F_2(1, 20) < 1$.

Order effects were not found in any analysis. Interpretations of this finding, along with possible remedies, will be elaborated in more detail in the General Discussion. On the other hand, Experiment 2a clearly replicated the integration priming obtained in Experiment 1a, as is evidenced by the nearly identical magnitude of the priming effects (21 ms vs. 22 ms). An interesting question, then, is why Experiment 2b failed to reproduce the integration priming observed at the same SOA and with almost the same items as Experiment 1b.

It is unlikely that the absence of priming in Experiment 2b was due to the removal of a few items, because Experiment 2a showed a nearly identical priming effect to Experiment 1a. If specific items were responsible for the priming effect in Experiment 1, their removal would be expected to impact the short SOA results of Experiment 2a as well, which was clearly not the case. Thus, it is possible that the null effect in Experiment

2b was due to a Type II error, especially considering the priming effects found in the other experiments.

Importantly, three out of the four experiments presented so far have been consistent with our hypothesis on the integration of event knowledge. A plausible alternate interpretation of these results, however, is that what I have called integrative priming actually depends largely on priming from a single prime in each pair, rather than on event integration. Although such priming would not be predicted by the low word associations within the triplets, there are nevertheless potential event-based semantic relationships between our stimuli. To test the likelihood of this alternative interpretation, Experiment 3 was designed to assess priming from single primes to their respective target.

Experiment 3: Single Primes

To establish whether or not the priming effects in Experiments 1 and 2 were in fact due to one or the other prime on its own, thus precluding the interpretation of event integration, priming from each of the single primes separately within a triplet to the related target was tested. For example, the triplet *diagnose-treat-heal* was tested using the prime-target pairs *diagnose-heal* and *treat-heal*, in comparison to unrelated primes.

I predicted that no significant priming would result from the related single-word primes, in comparison to unrelated primes. Because each of the prime-target pairs derived from a given triplet share a common target, all pairs containing the first prime (*diagnose-heal*) were tested in Experiment 3a, whereas pairs containing the second prime (*treat-heal*) were tested in Experiment 3b. Because Experiments 1a and 2a successfully obtained priming using an SOA of 200 ms, and since such a short SOA has been shown to elicit automatic semantic processing, Experiments 3a and 3b were conducted using a 200 ms SOA.

Experiment 3a

Method

Participants. Twenty-four undergraduate students at the University of Western Ontario participated in return for $5.

Materials. Prime-target pairs were created by splitting up the 30 related triplets from Experiment 1 and pairing the first prime of a given triplet with its respective target, resulting in 30 pairs of items. For example, given the triplet *fracture-operation-recover*, the pair *fracture-recover* was used in Experiment 3a. Unrelated prime-target pairs were similarly created from the 30 unrelated event triplets from Experiment 1 (e.g., *digging-planting-recover*) by combining the first primes with their respective targets (e.g., *digging-recover*). The related items were split into the same two rotation groups (as defined by the targets they contain) as in Experiment 1, and these were then used to create two lists of 15 related and 15 unrelated items by pairing the related items from each rotation group with the unrelated items from the other group.

Since an absence of priming was the desired outcome, I included 30 items found to produce priming in McRae and Boisvert (1998). Obtaining priming with these items would ensure that there is nothing peculiar about either the participants or other aspects of the experiment that precluded finding a priming effect. The McRae and Boisvert stimuli consisted of 30 semantically similar pairs of concrete nouns (*shed-barn*) and 30 semantically dissimilar pairs (*cushion-barn*) split into two lists, with each list containing the similar and dissimilar counterparts of the targets on the other list (see Appendix B for the similar word pairs).

In addition to the 60 experimental trials, 420 filler items were also included: 180 unrelated word targets (*pudding-moral*) and 240 nonword targets (*tighten-pait*). This resulted in a relatedness proportion of .14, which was the same as in Experiments 1 and 2. Prior to beginning the experiment, participants completed 24 practice trials consisting of two related word targets (*crack-repair*), ten unrelated word targets (*embody-blow*), and 12 nonword targets (*recipe-tebephone*).

Procedure. The procedure was identical to Experiments 1 and 2, except for the following. For each trial, participants were instructed to read and pay attention to the prime, and decide as quickly and accurately as possible whether or not the target was an English word. Each trial began with a fixation point (+) for 250 ms followed by a blank screen for 250 ms. The prime was then shown for 200 ms. Next, the target was displayed until the participant made a lexical decision. There were eight breaks, one after every 53 trials.

Design. The analyses were identical to Experiment 1a. Decision latencies greater than three standard deviations above the grand mean were replaced by that value (3.6% of trials). Analyses on the McRae and Boisvert (1998) items were also identical to Experiment 1a, with the exception that the factor of interest was featural similarity. Decision latencies greater than three standard deviations above the grand mean were replaced by that value (4.2% of trials).

Results

Event pairs. Decision latencies were a non-significant 12 ms shorter for related (M = 587 ms, SE = 16 ms) than for unrelated targets (M = 599 ms, SE = 16 ms), $F_1(1, 22)$

= 1.23, $p > .2$, $F_2(1, 28) = 1.13$, $p > .3$. There was also no difference in error rates between related ($M = 1.9\%$, $SE = 0.6\%$) and unrelated ($M = 4.4\%$, $SE = 1.2\%$) targets, $F_1(1, 22) = 2.79$, $p > .1$, $F_2(1, 28) = 3.01$, $p > .09$.

McRae and Boisvert (1998) items. Decision latencies for similar pairs ($M = 637$ ms, $SE = 19$ ms) were 32 ms shorter than for dissimilar targets ($M = 669$ ms, $SE = 25$ ms), $F_1(1, 22) = 6.23$, $p < .03$, $F_2(1, 28) = 5.47$, $p < .03$. Error rates did not differ between similar ($M = 10.0\%$, $SE = 1.7\%$) and dissimilar ($M = 10.6\%$, $SE = 2.0\%$) targets, $F_1(1, 22) < 1$, $F_2(1, 28) < 1$.

Experiment 3b

Method

Participants. Thirty undergraduate students at the University of Western Ontario participated in return for $5.

Materials. Items were created in the same manner as in Experiment 3a, with the exception that the second primes from the Experiment 1 triplets were used as primes. For example, whereas *fracture-recover* and *digging-recover* were used in Experiment 3a, their counterparts *operation-recover* and *planting-recover* were tested in Experiment 3b. The same items from McRae and Boisvert (1998) were included as well, along with the practice and filler items used in Experiment 3a.

Procedure. The procedure was identical to Experiment 3a.

Design. The analyses were identical to Experiment 3a. Decision latencies greater than three standard deviations above the grand mean were replaced by that value (1.8% of event pair trials, and 1.9% of the McRae & Boisvert, 1998, trials).

Results and Discussion

Event pairs. Decision latencies were a non-significant 8 ms shorter for related (M = 601 ms, SE = 16 ms) than for unrelated targets (M = 609 ms, SE = 18 ms), $F_1(1, 28) < 1$, $F_2(1, 28) < 1$. There was also no difference in error rates between related (M = 3.1%, SE = 0.8%) and unrelated (M = 3.6%, SE = 1.0%) targets, $F_1(1, 28) < 1$, $F_2(1, 28) < 1$.

McRae and Boisvert (1998) items. Decision pairs for similar pairs (M = 624 ms, SE = 16 ms) were 31 ms shorter than for dissimilar pairs (M = 653 ms, SE = 19 ms), $F_1(1, 28) = 4.87$, $p < .04$, $F_2(1, 28) = 11.34$, $p < .002$. Error rates did not differ between similar (M = 8.4%, SE = 1.2%) and dissimilar (M = 8.7%, SE = 1.3%) items, $F_1(1, 28) < 1$, $F_2(1, 28) < 1$.

Reanalyses of Experiments 1 and 2. Although the 12 ms (from Experiment 3a) and 8 ms (Experiment 3b) priming effects on the event pairs were not statistically significant, I was concerned about the possibility that the priming effects found in Experiments 1 and 2 could be attributed to a small number of single primes that individually prime their respective targets. The plausibility of such an explanation was tested by first indentifying the targets with the greatest priming effects in each rotation group in Experiment 3, and then reanalyzing the decision latencies from Experiments 1 and 2 with those items removed.

After removing *greet* (rotation group 1) and *return* (rotation group 2) from Experiment 3a, there was a small 4 ms difference in decision latencies between related (M = 590 ms, SE = 17 ms) and unrelated targets (M = 594 ms, SE = 15 ms), $F_1(1, 22) < 1$, $F_2(1, 26) < 1$. Similarly, for Experiment 3b, there was a 4 ms difference in decision latencies between related (M = 603 ms, SE = 16 ms) and unrelated targets (M = 607 ms, SE = 18 ms), $F_1(1, 28) < 1$, $F_2(1, 26) < 1$.

Crucially, the reanalyses of Experiments 1 and 2 cast doubt on the hypothesis that the priming effects were due to a limited number of single primes, rather than integration across prime pairs and targets. After removing the same items from Experiment 1a (*greet* and *return*), decision latencies remained 18 ms shorter for related (M = 596 ms, SE = 11 ms) than for unrelated triplets (M = 614 ms, SE = 13 ms), which was significant by participants and marginally significant by items, $F_1(1, 40) = 5.39$, $p < .03$, $F_2(1, 26) = 3.53$, $p < .08$. The same reanalysis of Experiment 1b revealed that decision latencies for related triplets (M = 577 ms, SE = 17 ms) were 34 ms shorter than for unrelated triplets (M = 611 ms, SE = 19 ms), $F_1(1, 38) = 9.84$, $p < .003$, $F_2(1, 26) = 10.61$, $p < .003$. Finally, after removing *greet* and *return* from Experiment 2a, there remained an overall priming effect, with latencies being 22 ms shorter for related (M = 597 ms, SE = 14 ms) than for unrelated triplets (M = 619 ms, SE = 18 ms), $F_1(1, 48) = 5.31$, $p < .03$, $F_2(1, 18) = 8.47$, $p < .009$. Therefore, it appears that the results of Experiments 1a, 1b, and 2b truly reflect priming due to the integration of multiple event concepts.

General Discussion

The studies presented in this thesis are the first to show semantic priming across words denoting multiple events. While others have shown various forms of word-word priming, the finding that pairs of event words can be integrated to prime another event is a novel one, particularly considering the fact that individual primes produced no priming on their own. Although the prediction of an effect of prime order was not borne out, these results demonstrate not only that semantic memory encodes relationships between multiple events, but that semantic representations of such knowledge can be rapidly accessed given a minimal linguistic context.

The remainder of the General Discussion deals with theoretical interpretations of these findings, as well as potential avenues for further investigating the role of word order in event priming. Specifically, I discuss the fact that the construct of spreading activation (Collins & Loftus, 1975; Neely, 1991) does not seem to account for event-based conceptual integration on its own. I also demonstrate why a corpus-based model of lexical co-occurrence (Landauer & Dumais, 1997) does not satisfactorily explain the present findings. After discussing the lack of order effects, it is then suggested that the results can be accommodated by perceptual simulation theories of semantic memory (Barsalou, 1999).

A Note About Multiple Priming

The unusual priming paradigm used in this study, namely the use of two primes in place of the conventional single prime, resembles a paradigm used to assess the effects of multiple primes on a single target. As discussed by Lavigne, Dumercy, and Darmon (in press) in their meta-analysis of multiple priming, such studies investigate differences in priming as a function of whether both primes are related to the target (Related-Related: RR, *summer-snow-winter*), only the first prime is related (Related-Unrelated: RU, *summer-couch-winter*), or only the second prime is related (Unrelated-Related: UR, *couch-snow-winter*). In other words, these studies tend to consider how priming from a word that is known to prime the target on its own is affected by an additional prime.

According to Lavigne et al.'s (2010) meta-analysis, although RR priming is greater than either RU or UR priming, the two related primes tend to have a combined effect such that the magnitude of RR roughly equals the sum of the effects of RU and UR. Taking into consideration the effects that remained in the present experiments after removing two suspect items and reanalyzing them, it should be clear that the priming effect of the "RR" conditions (18 ms for Experiment 1a, 34 ms for 1b, and 22 ms for 2a) far exceeded the sum of the effects of the RU (Experiment 3a: 4 ms) and UR (3b: 4ms) priming.

Furthermore, multiple-prime studies deliberately use primes that show significant priming on their own, often include stimuli with word associations (Lavigne-Tomps & Vitu, 1992), and are not intended to produce integration between primes. Therefore, their relevance to the experiments presented in this thesis, which were designed to show priming due to the integration of words that do not prime on their own, is tenuous. In fact, Lavigne et al. (2010) selectively excluded the results of Chwilla and Kolk (2005) from their meta-analysis for this very reason, arguing that the latter's items were explicitly meant to elicit priming only when both primes were combined. Thus, in the context of the multiple priming research, the priming obtained in the present experiments can actually be considered a novel form of UU priming, given that neither of the primes within an item facilitated a response to the target on its own.

Spreading Activation

The construct of spreading activation (Collins & Loftus, 1975; McNamara, 1992) has been proposed as a mechanism of how lexical concepts can prime one another. According to spreading activation models of semantic memory, each concept is represented as a discrete node with the nodes of related concepts being connected by a link. Semantic memory is thus defined as the network formed by these interconnected nodes. When a concept is activated following perception of a word's phonological and/or orthographic form, activation from the concept spreads to related concepts, thus preactivating them which produces priming.

Given that I chose pairs of primes that seemed related to one another, and since participants in the norming study (under instructions to respond with an event that might come next) must have produced related targets on the basis of some perceived relation between the primes and the target, it stands to reason that a spreading activation model of semantic memory could account for event-based priming simply by claiming that the concepts in question are indeed related to each other in semantic memory with the requisite links. However, invoking spreading activation as the mechanism responsible for priming in the present experiments is problematic.

Often, when spreading activation is used to predict or interpret the results of priming studies, the strength of the link between two concepts is considered to be proportional to the strength of the normative word association between the words denoting them. Because normative word association in the present items was extremely low, spreading activation theory would correctly predict no priming from either prime on its own (Experiment 3), but incorrectly also predict no priming from pairs of words in Experiments 1 and 2. Thus, there appears to be no theoretical justification for positing spreading activation as the mechanism responsible for integrative event priming in my experiments. Generalizing from this, it must either be the case that spreading activation between discrete conceptual nodes is not a plausible mechanism of priming, or there are other mechanisms responsible for priming. In accord with this conclusion, a number of other studies have found priming in the absence of word association, such as Frenck-Mestre and Bueno (1999) with featurally-similar concepts and Hare et al. (2009) using event-based relations.

Corpus-based Co-occurrence Models

One potential reason for why the brain might form a mnemonic relation between two words is the words' co-occurrence in speech or text. Accordingly, one currently prominent view of semantics holds that a word's meaning is defined by the linguistic contexts in which the word tends to occur. As a result, researchers have created computational models for analyzing large corpora of text to mathematically symbolize the degree to which any two or more words tend to be found in the same context. By this token, one might predict *tree* and *branch* to be considered more related than *phone* and *branch*, considering that a document containing references to trees is probably more likely to refer to branches as well, rather than to phones. The issue of current import is whether the pattern of priming effects observed in Experiments 1, 2, and 3 can be explained as a function of the textual co-occurrence of the words used in those studies.

The various co-occurrence models, having common origin and purpose, are nevertheless distinguishable on the basis of the computational algorithms they each use to precisely define the notion of contextual similarity. While there are several such published models, including Latent Semantic Analysis (LSA, Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990; Landauer & Dumais, 1997), Hyperspace Analogue to Language (Burgess & Lund, 1997), and BEAGLE (Jones & Mewhort, 2007), I limit the discussion to how LSA informs the interpretation of the present results, as well as what the present results reveal about the strengths and shortcomings of LSA as a semantic model. To begin with, it is not unreasonable to expect that the words found within the related event triplets should tend to be mentioned near one another in written language, whereas the primes in unrelated items should not be expected to co-occur with the target to a large extent. That is, events that tend to occur in sequence may be mentioned together in text, either within a single sentence, as in "The thief *shattered* the glass, *entered* the home, and proceeded to *steal* some electronics", or across nearby sentences. Given that written language often describes meaningful events that are familiar to the reader, the pattern of co-occurrences among words within a language should to some extent reflect the pattern of co-occurrences of their referents in the world.

In the case of LSA, after a researcher has constructed the model on a given text corpus, the model initially represents each unique word in the corpus as a single vector with as many dimensions as there are documents in the corpus, where each document denotes one of the many individual articles, chapters, papers, etc., that comprise the corpus. Thus, each document represents a single context in which words may occur, and a word's vector codes the frequency of that word's occurrence in every document. As a result, words that tend to co-occur by virtue of their presence in a similar set of documents (e.g., articles and chapters discussing *branch* growth in *trees*), will also have similar vectors. The similarity between any two vectors can then be assessed by computing the cosine of the angle they subtend in hyperspace. Importantly, this method allows for computing the similarity between any two *sets* of words, not just between individual words. Cosine similarity can then be used to predict priming (Jones, Kinstch, & Mewhort, 2006).

For the 30 items used in Experiment 1, the mean cosine similarity between the two primes and the target for related items was .27, whereas mean cosine for unrelated items was .09. A paired *t*-test using the related and unrelated cosine for each item revealed that this difference is significant, $t(29) = 6.46$, $p < .0001$. For the 24 items used in Experiment 2, the mean cosine similarity for related items was .27, whereas mean cosine for unrelated items was .08. This difference was also quite significant, $t(23) = 5.59, p < .0001$. Thus, unlike word association measures, LSA correctly predicted priming for related event triplets.

However, LSA is known to overestimate priming effects (Hare et al., 2009; Jones et al., 2006) and it is interesting that such was the case for its prediction of the results of Experiment 3. The mean cosines between primes and targets for related and unrelated items in Experiment 3a were .20 and .06 respectively, and this difference was significant, $t(25) = 4.60, p < .0001$. As a side note, because *changeroom* and *wakeup* were not present in the LSA corpus, and were alternately used as related and unrelated primes in four items, these items could not be included in the analysis. For Experiment 3b, the mean cosines were .25 and .09 for related and unrelated items, and this difference was also significant, $t(29) = 5.68, p < .0001$. Thus, the priming effects in Experiments 1 and 2, as predicted by LSA, were not appreciably different than the priming effects predicted for Experiment 3. This finding casts doubt on the validity of using the co-occurrence based mechanism that drives LSA's predictions as an explanation of the semantic mechanisms driving the results in my Experiments.

Before moving on, a comment about LSA and order effects is warranted. As it stands, LSA cannot account for effects of word order on semantic processing. The cosine function used by LSA is commutative, meaning that the order in which the vectors are entered into the calculation has no bearing on the resulting angle, though in a footnote Landauer and Dumais (1997) indicate that there may be ways to produce asymmetric similarity effects. However, there presently are models that might be able to account for the order in which stimuli are processed (e.g., BEAGLE, Jones & Mewhort, 2007), which may suggest possibilities for future studies.

Interpreting the Non-effect of Prime Order

There are several issues with regard to the finding that prime order had no effect on the magnitude of priming. Starting with the premise that the priming effect for related event targets was due to integration of both primes into a coherent scenario with the target (which the results of Experiment 3 imply), it may have been the case that the pattern of semantic activation underlying the priming effect could be generated regardless of the order in which the primes were read. Although the order in which words are processed is clearly crucial to effective language comprehension in general, it could be that interpreting single words outside of a sentence does not provide sufficient context to constrain the types of representations that are primed.

Recall that one of the reasons behind the prediction that backward-order primes may not prime the target as effectively was that the events denoted by the primes are more plausibly encountered in the forward order. However, it is possible that the scenarios denoted by the primes can be understood in backward-order more easily than was intended when initially choosing items. For example, *shatter-enter* is assumed to prime *steal* because of underlying knowledge that someone may shatter a window, enter the house, and steal some electronics. On the other hand, it may be the case that the sequence *enter-shatter-steal* taps into knowledge that a person could plausibly enter a building, shatter a glass case, and then steal some jewelry.

A reasonable course of action given the non-significant effect of prime order in Experiment 2 is to use a different task that might be more sensitive to expectancy generation based on the temporally consistent integration of primes. That is, one solution might be to use a task that demands integration. A major reason why researchers use the semantic priming paradigm is that semantic relations influence people's performance on the task, but explicit integration of concepts is not required. That is, participants respond only to the target, are never asked about prime-target relations, and in fact, filler trials are used to obscure prime-target relationships. It is possibly the case that the influence of a subtle manipulation such as the order of the primes (events) might be found only when participants are asked to explicitly integrate the concepts. Thus, one could present each prime and the target in order for a short period of time, and ask participants to indicate whether the three concepts are related. In this case, the response should be "yes" for both forward- and backward-order items. However, presenting the primes in correct order could facilitate the integration of the words into a mental situation model, creating greater expectancies for event concepts that could follow, and thus leading to shorter decision latencies relative to backward-order items.

Event Semantics Grounded in Event Perception

The present findings potentially could be accounted for by a class of theories that claim that semantic representations are grounded in the perception of objects and actions in the world (for a review see Barsalou, 2008). According to perceptual simulation theory (Barsalou, 1999), the meaning of a word is accessed by simulating the pattern of neural activity responsible for the perception of the word's referent. Because understanding an event requires knowledge of many types of relations between various components, it is possible that the simulation prompted by reading an event word results in an accompanying simulation of related concepts.

Although reading a single event word (e.g., *shatter*) does not necessarily evoke a definitive representation (why is something shattering? where is the shattering taking place?), and therefore may not yield a particularly rich simulation, the addition of another event *(enter)* may serve to constrain the type of situation that is being denoted because of the additional information that is available (maybe someone is entering somewhere after shattering something). Thus, when two event words (i.e., the primes in Experiments 1 & 2) are processed in sequence, the simulations of each event independently may be integrated to yield a more conceptually coherent scenario. The simulation of a third event (*steal*) is subsequently facilitated because unlike the first event, it is encountered within a conceptually meaningful context. In fact, some important components of this third event may already have been activated by the time it is processed. To wit, the concept of stealing often involves gaining access to premises in an illicit manner, perhaps even by shattering the window beside a door, unlocking it, and entering. Simulating both *shatter* and *enter* thus sets the state for simulating *steal*, as a result of the appropriate context. By the time the target is read, a rich mental model has already been constructed on the basis of the two prior events, and if the overall scenario is meaningful, the target can be easily integrated within it. This account is, of course, quite speculative, and does not at the present time lend itself to the types of quantitative analyses that are provided by word association norms or LSA cosine values.

Conclusions

One of the underlying issues at the heart of this thesis concerns the degree to which the organization of word meanings reflects the immense amount of knowledge that people possess of those words' referents in the world. Given the observations that a large extent of our everyday lives involves perceiving and predicting common events, and that we frequently talk about these experiences via language, it follows that the semantic representations underlying world knowledge and language comprehension may be closely related. The priming studies presented in this thesis are the first to show that knowledge of event relations encoded in semantic memory is rapidly accessed to automatically generate expectancies from two event words to another.

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Appendix A

Event triplets and their weighted scores from the Event Norming Study

The first related prime was used in Experiment 3a, whereas the second related prime was used in Experiment 3b. The first 24 items were used in Experiment 2.

Related Prime 1	Related Prime 2	Target	Weight
dating	engaged	wedding	53
cook	sit	dine	50
climb	slip	drop	47
design	manufacture	sell	43
missing	search	discover	42
tailgate	brake	crash	42
knock	answer	greet	39
digging	planting	sprout	37
marinate	grill	chew	36
apply	interview	employed	35
browse	try	purchase	32
mix	pour	chug	32
lather	rinse	towel	32
check-in	boarding	flight	30
fracture	operation	recover	30
shatter	enter	steal	30
borrow	read	return	29

buy	assemble	enjoy	28
breakfast	traffic	work	26
eat	choke	death	26
defecate	wipe	wash	24
wakeup	shower	brush	24
diagnose	treat	heal	23
robbery	trial	jail	23

plate	fall	smash	52
drink	drive	accident	46
cold	blanket	heat	40
runway	takeoff	cruise	32
changeroom	warmup	play	31
wine	carpet	stain	28

Appendix B

Items from McRae and Boisvert (1998) used in Experiment 3

Related Prime	Target
goose	turkey
axe	tomahawk
slippers	sandals
bra	camisole
yacht	ship
shed	barn
hoe	shovel
bus	subway
radish	beets
cannon	bazooka
sword	spear
canoe	raft
crayon	pencil
coconut	pineapple
closet	dresser
file	sandpaper
cushion	pillow
slingshot	catapult
eagle	hawk

jeep	dunebuggy
finch	canary
peas	beans
plum	prune
microwave	toaster
tie	belt
missile	bomb
truck	van
moose	caribou
wagon	cart
pumpkin	squash

Appendix C

Ethics approval for Experiments 1 and 2

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Western

Use of Human Subjects - Ethics Approval Notice

Review Number	09 04 01	**Approval Date**	09 04 07
Principal Investigator	Ken McRae/Saman Khalkhali	**End Date**	09 04 06
Protocol Title	The role of event knowledge in semantic representations		
Sponsor	n/a		

This is to notify you that The University of Western Ontario Department of Psychology Research Ethics Board (PREB) has granted expedited ethics approval to the above named research study on the date noted above.

The PREB is a sub-REB of The University of Western Ontario's Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement and the applicable laws and regulations of Ontario. (See Office of Research Ethics web site: http://www.uwo.ca/research/ethics/)

This approval shall remain valid until end date noted above assuming timely and acceptable responses to the University's periodic requests for surveillance and monitoring information.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the PREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of research assistant, telephone number etc). Subjects must receive a copy of the information/consent documentation.

Investigators must promptly also report to the PREB:
a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to the PREB for approval.

Members of the PREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the PREB.

Clive Seligman Ph.D.

Chair, Psychology Expedited Research Ethics Board (PREB)

The other members of the 2008-2009 PREB are: David Dozois, Bill Fisher, Riley Hinson and Steve Lupker

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Appendix D

Ethics approval for Experiment 3

Western

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Use of Human Subjects - Ethics Approval Notice

Review Number	10 04 02	**Approval Date**	10 04 05
Principal Investigator	Ken McRae/Saman Khalkhali	**End Date**	11 04 04
Protocol Title	Event-based organization of lexical concepts		
Sponsor	n/a		

This is to notify you that The University of Western Ontario Department of Psychology Research Ethics Board (PREB) has granted expedited ethics approval to the above named research study on the date noted above.

The PREB is a sub-REB of The University of Western Ontario's Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement and the applicable laws and regulations of Ontario. (See Office of Research Ethics web site: http://www.uwo.ca/research/ethics/)

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