2007

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Your file Votre référence
ISBN: 978-0-494-26592-5
Our file Notre référence
ISBN: 978-0-494-26592-5

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Hemispheric Sensitivity to Thematic Role Information Derived from Active and Passive Verbs: An Event Related Brain Potentials Study

by

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THESIS

Submitted to the Department of Psychology

In partial fulfilment of the requirement for Master's of Science

Wilfrid Laurier University

2007

Abstract

Recent research examining differences in the way the left (LH) and right (RH) hemispheres of the brain process language have used the visual half-field (VHF) paradigm to examine whether each hemisphere can independently process information from sentences. The current study expanded upon such work by using event related brain potential (ERP) measures to examine how the comprehension of thematic role knowledge, a process essential to successful sentence comprehension (MacDonald, Pearlmutter, & Seidenberg, 1994), is undertaken in each hemisphere. During language comprehension, agents (entities that initiate action in an event) depicted by nouns (e.g. *cop*) have been shown to be associated with verbs presented in active voice (e.g., present participle – cop was *arresting*), whereas patients (entities that have action imposed upon them – e.g., *crook* for the event *arrest*) are associated with verbs presented in passive voice (e.g., crook was *arrested* – Ferretti, McRae, Elman, & Ramshaw, 2005). Thus, the current study examined how the cerebral hemispheres conjointly (Experiment 1) and independently (Experiment 2) process thematic fit (whether the noun and verb are thematically related) in conjunction with morphosyntactic information indicating whether a verb is in active (*arresting*), or passive (*arrested*) voice in order to further understand each hemisphere's sentence processing abilities. In Experiment 1, ERP responses to verbs (presented centrally) preceded by a common agent noun and presented in related-active (e.g., *The teacher was lecturing the man*), unrelated active (e.g., *The shepherd was lecturing the man*), related-passive (e.g., *The teacher was lectured by the man*) and unrelated passive (e.g., *The shepherd was lectured by the man*), sentences were analyzed in order to examine the effects of relatedness and voice on the processing of the critical verb. Experiment 1 results showed that brainwave amplitudes demonstrated greater semantic facilitation for related active than for unrelated active verbs. However, this effect did not occur as strongly for passive verbs, indicating that the congruency between the agent and verb form significantly affected processing. In Experiment 2, the exact same experimental design was employed with the procedural variation that the critical verbs were presented 2° to either the left or right of visual fixation, so only one hemisphere initially receives the information. Results from this experiment showed that with LH presentation, as with central presentation, related active verbs were processed more easily than unrelated active verbs and the magnitude of this effect was larger than that for analogous differences found with passive verbs (although sensitivity to relatedness for passive verbs was slightly larger than in Experiment 1). However, in the RH, differences in relatedness were found only for passive items indicating that sensitivity to relatedness differences in this hemisphere may be mediated more by frequency differences between verb forms than with LH processing (or central presentation). These results provide evidence against the theoretical contentions that the RH is only sensitive to simple word-level semantic relations (e.g., Faust, 1998), and are supportive of an 'expectancy' account of LH language processing (e.g., Coulson et al., 2005; Federmeier & Kutas, 1999).

Keywords: Event related brain potentials, visual half-field paradigm, hemispheric differences, thematic roles, event knowledge, active/passive verbs, sentence processing

Acknowledgements

The research presented in this thesis was carried out in the Language and Cognition Laboratory (a subdivision of the Centre for Cognitive Neuroscience) at Wilfrid Laurier University. The work was financially supported by the Canadian Foundation for Innovation (CFI) and the Natural Sciences and Engineering Research Council of Canada (NSERC).

First and foremost I would like to express my deepest gratitude to my advisor Dr. Todd Ferretti for his patience, encouragement, assistance and valuable insight over the past three years.

I am also thankful to Courtney Patterson for her assistance with experimental issues concerning the project, and Fariha Nafees for her assistance with data collection and analysis.

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Combining information derived from relatively unelaborated lexical cues such as words and clauses is necessary in order to successfully comprehend the intended meaning of sentences. The current study aimed to examine various aspects of this combinatorial processing during sentence comprehension. Specifically, the current study examined how each cerebral hemisphere independently, and jointly, processes verbs in active (e.g., The lifeguard *was rescuing* the swimmer) and passive (The swimmer *was rescued* by the lifeguard) voice. Examining the means by which each hemisphere participates in sentence processing is currently at the fore of neuropsychological linguistic research. The current experiments were undertaken with the intent of furthering this growing body of work by using event related brain potential (ERP) methodology to examine how thematic role knowledge is combined with morphosyntactic information in both the left hemisphere (LH) and right hemisphere (RH) during sentence comprehension.

Language Processing in the Cerebral Hemispheres

The predominance of the LH for the processing of language is perhaps the most renowned instance of cerebral hemispheric asymmetry in humans. In 1861, Paul Broca discovered that articulate, fluent speech was compromised by damage to the left frontal operculum. Consistent with this claim, early research investigating the neural basis of language in brain damaged subjects has predominantly found that phonological, semantic and syntactic processing are mainly undertaken by LH neural substrates (for a review, see Martin, 2003). The most prominent evidence for such assertions comes from dissociations demonstrating that damage to the LH can produce deficits in the most basic aspects of language processing, whereas homologous RH damage can leave basic processing relatively intact. Subsequently, researchers became so convinced that the LH was solely responsible for language processing that this region even became known as the putative 'verbal' hemisphere.

The LH dominance consensus has however been challenged by studies examining the functional effects of brain damage (e.g., Beeman, 1993; Brownell, Michel, Powelson, & Gardner, 1983; Joanette, Goulet, & Hannequin, 1990) and research using neuroimaging techniques (e.g., Bottini, Corcoran, Sterzi, Paulesu, Schenone, Scarpa, et al., 1994; Ni, Constable, Mencl, Pugh, Fulbright, Shaywitz, et al., 2000; St. George, Kutas, Martinez, & Soreno, 1999). For example, Beeman (1993) found that patients with RH damage who read paragraphs were impaired in correctly answering inference questions about the discourse, and were slower to respond to inference-related words pertaining to the passages they read during a lexical decision task (whereas a control group responded more quickly to inference-related words). In another study, St. George et al. (1999) used functional magnetic resonance imaging (fMRI) to demonstrate that both cerebral hemispheres are active during paragraph reading (specifically inferior frontal and temporal regions of both hemispheres), and that the RH is actually more active than the LH when more effortful integrative processes (reading untitled as opposed to titled paragraphs) are required to achieve global coherence during discourse processing. Such research has suggested that whereas some of the most fundamental, easily-recognizable aspects of language processing may be performed satisfactorily exclusively within the LH, the RH does play an important role in certain aspects of the common, everyday processing of language. Indeed, research involving brain damaged patients has suggested that the RH is necessary in order to understand figurative language (Brownell et al., 1983), produce socially appropriate, focused speech (Joanette et al., 1990), draw inferences from text (Beeman, 1993), and comprehend the main points of narratives and conversations (Gardner, Brownell, Wapner, & Michelow, 1983).

Behavioural Studies Examining RH Language Processing

Studies implicating the RH as integral to the processing of language have generated interest in investigating how RH language processing differs from (or is similar to) LH processing and how both hemispheres conjointly undertake normal, everyday language comprehension. In order to examine these issues using normal research populations, studies have employed the visual half field (VHF) technique (for a review of this technique, see Banich, 2002). This method utilizes the organization of the visual system to examine the processing abilities of each hemisphere independently in that stimuli presented to a particular side of space are only initially processed by the contralateral hemisphere (i.e., stimuli presented to the right visual field (rvf), are processed by the LH and left visual field (lvf) stimuli are processed by the RH). It is generally accepted that this technique reveals initial hemisphere specific computations. Moreover, ERP studies employing this method have shown (via measuring the latency for the onset of specific brainwave components) that inter-hemispheric transfer does not alter the elicitation of specific brainwave components (e.g., the N400 – a component that indexes semantic integration), in that the peak amplitude of waveforms is not delayed when presented to one hemisphere (Federmeier, Mai, & Kutas, 2005).

A large body of linguistic research has employed the VHF technique to examine many processes essential to successful language comprehension. For instance, this method has been used to examine how each hemisphere independently derives meaning from words (as gauged by results from semantic priming for word-word pairs). Research investigating such processing has generally found that patterns of semantic activation elicited from single words differ between the two hemispheres. For example, Chiarello, Burgess, Richards and Pollock (1990) used a priming paradigm to show that the hemispheres are equally sensitive to similar-associated words (e.g., *Doctor-Nurse*), but only lvf/RH presentation elicits priming for more distantly related words from the same semantic category (e.g., *Deer-Pony*). Additionally, Burgess and Simpson (1988) demonstrated that lvf/RH, but not rvf/LH presentation, elicits priming for the subordinate meaning of ambiguous words (e.g., *river-* vs. *money-BANK*). Such findings have led researchers to suggest that the hemispheres differ in the manner in which semantic information is represented with the RH characterized by diffuse semantic activation and 'loose' semantic coding, and the LH characterized by focused semantic activation which rapidly selects a particular meaning and suppresses others (Beeman & Chiarello, 1998). The broader range of meanings activated in the RH has been used to explain its reputed involvement in higher level language processing such as integrating pragmatic meaning from discourse.

In addition to examining the hemispheric processing of single words, studies using the VHF technique have also been used to examine if differences exist in the way each hemisphere processes information from sentence contexts (e.g., Chiarello, Liu, & Faust, 2001; Faust, 1998; Faust, Babkoff & Kravets, 1995; Faust, Kravets, & Babkoff, 1993). For example, Faust (1998) compared reaction times to sentence final words in both plausible (e.g., This restaurant serves French fries with *ketchup*) and implausible (e.g., This restaurant serves French fries with *cream*) sentences. The results showed that presentation to the LH but not the RH yields longer reaction times for sentence final words in implausible as opposed to plausible sentences, a finding consistent with preliminary behavioural work examining RH multi-word integration (e.g., Faust et al., 1993; Faust et al., 1995). More recent findings have also provided evidence which suggests that the RH may be insensitive to message-level incongruity. For instance, Faust, Bar-Lev, and Chiarello, (2003) showed that sentence final words can be primed equally by lexical associates in congruent (e.g., *The mother quickly took the sick child to the Doctor*), non-sensical (e.g., *The devoted mother fed the sick child to the Doctor*), and scrambled (e.g., *To took the quickly mother child the sick to Doctor*) contexts. Such findings have led researchers to argue that the LH is generally responsible for integrating syntactic, semantic, and pragmatic information to formulate the meaning of sentences whereas the capabilities of the RH extend only to word level priming mechanisms.

More recent VHF behavioural examinations however have suggested that the RH may in some way be sensitive to multi-word sentential information. For instance, Chiarello et al. (2001) examined lexical decision times to sentence final words for incongruous (e.g., *The weary campers devoured the tent*) and congruous (e.g., *The weary campers set up the tent*) sentences containing a word related (e.g., *campers*) to the sentence final word or a word unrelated (e.g., *husband*) to the final word. When a related word appeared in the prior sentence context, both hemispheres showed differences in final-word reaction times, with facilitation for the related ending (this effect was larger for the LH however). When no related word appeared in the prior context, inhibition was present for both hemispheres. For example when the sentence *The weary husband* *devoured the tent*, was read, inhibited responses occurred for sentence final words relative to a neutral baseline. Such results provide evidence that suggests both hemispheres may be sensitive to a message level context.

ERP Studies Examining the Hemispheric Processing of Sentence Information

Although behavioural tasks can be informative when investigating hemispheric processing asymmetry, some researchers have claimed that results using this task may not wholly represent the semantic capabilities of the RH. For instance, studies involving aphasic patients have suggested that lexical decision and semantic classification are subserved by different processes (Bub & Arguin, 1995). Additionally, studies involving commisurotomy patients have shown that lexical decision and naming tasks can underestimate the RH's semantic processing capabilities (Baynes & Eliassen, 1998; Zaidel, 1990). For example, patients have demonstrated an ability to read words presented to the lvf/RH for meaning even though lexical decision accuracy can be low (Baynes & Eliassen, 1998). To avoid such drawbacks, researchers have begun to use the VHF paradigm in conjunction with ERP methodology to examine asymmetries in neurologically intact participants.

An ERP is the term used to describe a small voltage fluctuation in an electroencephalogram that is time-locked to the onset of particular stimuli. ERPs are electrical potentials recorded at the scalp that represent synchronous cortical synaptic activity in response to the processing of stimuli. Importantly, they afford researchers several advantages over standard behavioural methods when examining responses to lateralized (hemispheric) stimuli. Firstly, ERPs provide a more precise way to confirm that stimuli are initially processed only by the intended contralateral hemisphere. This is typically accomplished by using occular electrodes to provide a physiological index to unambiguously indentify (and subsequently remove from analysis) lateral eye movements. When these movements occur, the visual field shifts and stimulus information potentially reaches both hemispheres. In behavioural experiments the identification of lateral movements is less precise; in such studies an experimenter simply watches a participant and notes when eye-movements occur. Additionally, ERPs are able to provide topographic confirmation of stimulus lateralization in that stimuli presented to a particular visual field typically elicit more negative ERPs at electrode sites over the cerebral hemisphere contralateral to the visual field of presentation, indicating that this hemisphere has an increased processing load relative to the ipsilateral hemisphere (e.g., Federmeier et al., 2005). Secondly, by using this method, brainwave amplitudes can be recorded in real time while participants simply read for comprehension. This allows researchers to gain a precise, moment-by-moment physiological index of independent hemispheric processing and avoids the previously mentioned confounds of competency differences in task performance (e.g., response and decision making tasks – see Bub & Arguin, 1995) which can manifest as insensitivity to the properties of experimental stimuli. Thirdly, ERPs have certain well-established components that are typically associated with specific perceptual, syntactic and semantic processes (e.g., the N400 reputedly indexes the process of semantic integration). Thus ERPs provide a functionally specific measure that is able to inform how each hemisphere is able to undertake particular linguistic operations. For the purposes of the current study, it can be assumed that more positive amplitudes for one experimental condition relative to another index a relatively greater ease of performing the mental operation that is examined by a particular brainwave component. Several of these components were investigated in the current study.

One such ERP waveform commonly examined in both linguistic and non-linguistic studies is the N1 component. The N1 is a negative going potential that is typically elicited 100-200 ms after the onset of a stimulus and is thought to reflect extrastriate visual processing. Amplitudes for the N1 are typically more negative when a visual stimulus is detected and can be used to confirm stimulus lateralization by examining differences between lvf/RH and rvf/LH presentation at contralateral electrodes. Typically, greater negativities are elicited and sustained at electrode sites contralateral to the visual field of presentation (e.g., Federmeier et al., 2005). Thus, examining amplitudes in the N1 time window provides physiological confirmation that stimuli reached have indeed their intended targets. This component can also be used to examine early differences in language processing. For instance, the N1 has been found to vary with differences in word frequency (high frequency words elicit more positive amplitudes – Sereno, Rayner, & Posner, 1998), and can index when people distinguish words from non-words (words elicit more positive amplitudes – Sereno & Rayner, 2003).

The P2 is a positive going deflection in the ERP that typically occurs between 200-300 ms post stimulus onset. This wave has been linked to both perceptual analysis (e.g., the detection and analysis of visual features in selective attention tasks – Hillyard & Munte, 1994; Luck & Hillyard, 1994), and differences in processing linguistic stimuli both in centrally presented (e.g., Ferretti et al., 2007) and hemispheric studies (e.g., Coulson, Federmeier, Van Petten, Federmeier, & Kutas, 2005; Federmeier et al., 2005). For studies investigating hemispheric language processing, more positive P2 amplitudes have been found for stimuli that are congruent with a sentential context, and effects have typically been strongest with rvf/LH presentation (e.g., Federmeier et al., 2005). Thus, by examining P2 amplitudes, an index of early attentional processing differences for linguistic stimuli can be examined.

Another commonly examined waveform used in ERP investigations of language processing is the N400. This is the most well known component for indexing the ease of semantic integration between individual words and their preceding contexts (Kutas & Hillyard, 1980). It is a negative potential that peaks at approximately 400 ms after the onset of a stimulus and is largest when a word is semantically incongruent or difficult to integrate with its preceding context (e.g., van Burkum, Hagoort, & Brown, 1999). Typically, N400 effects are largest over central-parietal scalp locations. This component is elicited in response to any item that is potentially meaningful (e.g., written, spoken or signed words as well as pictures), and is inversely correlated with the ease of integrating an item with its context (Kutas & Hillyard, 1984). The N400 component is often followed by a late positivity complex (LPC) which onsets between approximately 500-900 ms post stimulus. This waveform is a positive going component in the ERP that has been thought to reflect semantic encoding including elaborative semantic processing based on information in long-term memory (Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991).

Visual half field studies using ERP methodology have commonly utilized the N400 to gain insight into each hemisphere's sensitivity to sentential information. For instance, a study by Federmeier and Kutas (1999) presented participants with pairs of sentences (e.g., *He caught the pass and scored another touchdown. There was nothing he* *enjoyed more than a good game of…*) ending in either an 'expected exemplar' (*FOOTBALL*), a 'within category violation' (*BASEBALL*) or a 'between category violation' (*CHESS*). The results showed larger N400s in the RH to 'between category violations' and 'within category violations' relative to 'expected exemplars', providing evidence to suggest that sentence congruity can be processed in the RH (as well as in the LH). In addition to this finding, Coulson, et al. (2005) examined ERP responses to associated (e.g., *spare-tire*) and unassociated (e.g., *spare-pencil*) words presented in both a word-word priming paradigm, and also in congruous (*They were truly stuck since she didn't have a spare tire*; *During the test Ellen leaned over and borrowed my spare pencil*) and incongrouous sentence contexts (*During the test Ellen leaned over and borrowed my spare tire*; *They were truly stuck since she didn't have a spare pencil*)). Isolated pairs elicited more positive amplitudes for associated words and large sentential context effects were found with presentation to both visual fields, further demonstrating each hemisphere's sensitivity to lexical associations generated from both single word and multi-word contexts. Additionally, Federmeier et al. (2005) examined ERP responses to sentence-final words that were not preceded by a lexically associated word. In such a context, readers could only utilize multi-word contextual information to facilitate semantic processing. The items used in the experiment were designed so that sentence final words were either weakly or strongly constrained by the entire preceding context. For example, the sentence "*She was suddenly called back to New York and had to take a cab to the AIRPORT*" was considered strongly constraining for the final word, whereas the sentence "*She was glad she had brought a book since there was nothing to read at the AIRPORT*" was considered weakly constraining – note that neither context preceding the final word contains a lexical associate. N400 responses to final words in these contexts were largest for weakly constraining sentences in both hemispheres. Thus this result demonstrates convincingly that both hemispheres are able to utilize semantic information generated from multiple words to constrain processing.

Although ERP studies examining lateralized sentence processing have been very useful in elucidating the understanding of each hemisphere's sensitivity to sentential context, many fundamental aspects of sentence comprehension have yet to be duly examined. Thus the current study intended to extend previous work by examining hemispheric processing of thematic relatedness and verb morphology. Understanding thematic relations is essential for successful sentence comprehension (MacDonald, Pearlmutter, & Seidenberg, 1994), and examining the interaction between thematic fit in conjunction with different verb forms can help to elucidate each hemisphere's independent role in this fundamental aspect of language processing.

Thematic Roles

A thematic role (sometimes analogously referred to as a theta role) denotes the semantic role a given entity, such as an agent or a patient (denoted by nouns), plays in relation to events (denoted by verbs) in sentences (Carlson & Tannenhaus, 1988; Tannenhaus, Carlson, & Trueswell, 1989). For instance, *agents* are individuals that are typically conceptualized as the initiators of action in an event and *patients* are entities that have an action imposed upon them, or typically undergo some change of state. For example, in the sentence *The judge sentenced the defendant to life in prison*, the conceptual information linked to *judge* is consistent with typical agent characteristics for the specific event, whereas the *defendant* is consistent with typical patient role qualities.

Thematic role assignment is essential to successful sentence comprehension, as it enables readers to determine who is doing what to whom (MacDonald, et al., 1994; McRae, Ferretti & Amyote, 1997). Thus, thematic role assignment is an important process to study in order to learn how each hemisphere is able to carry out sentence comprehension.

The Nature of Thematic Assignment during Language Processing

There are a variety of theoretical approaches to sentence processing and such perspectives present opposing viewpoints regarding whether thematic role assignment is initially driven only by syntactic information or also by detailed conceptual knowledge of the world. Two competing types of theories currently dominate the debate over the types of information used to initially guide thematic assignment (Frazier, 1987). Two stage models posit that sentence parsing proceeds by first relying upon only a single source of information to make initial sentence parsing decisions and then using additional sources of information to 'check' the initial interpretation. The most well known types of two-stage accounts are known as garden path models. These models posit that in the first stage of processing, decisions are made on the basis of syntactic information alone and, during the second stage thematic information is used to verify initial syntactic parsing decisions (Ferreira & Henderson, 1990; Frazier, 1987). Contrastingly, constraint-based accounts of sentence processing hold that when a sentence clause is first read, thematic role assignment is determined by the relative strength of different sources of information (e.g., lexical, semantic, syntactic, pragmatic) for different (syntactically viable) alternatives that compete for activation (e.g., active versus passive interpretations – e.g., McRae, Spivey-Knowlton, & Tannenhaus, 1998). Thus, these two approaches differ fundamentally on whether detailed conceptual knowledge can be utilized to influence the early stages of syntactic processing, with two stage approaches positing a later role for such information and constraint-based models claiming conceptual information immediately guides syntactic processing (e.g., McRae et al., 1998).

Currently, a large body of evidence suggests that detailed conceptual knowledge about a verb's thematic roles is made available and utilized immediately upon encountering those verbs during language processing (e.g., Boland, Tanenhaus, Garnsey, & Carlson, 1995; Ferretti, McRae, & Hatherall, 2001; McRae et al., 1998). Such studies have used semantic priming paradigms (Ferretti et al., 2001), syntactic ambiguity resolution (McRae et al., 1997; McRae et al., 1998), and filler-gap constructions (Boland et al., 1995) to demonstrate immediate utilization of thematic role information during language processing. The current study intends to extend such work by examining how a particular information source, that being verb morphology, can affect sentence processing. By examining how the processing of different verb forms is influenced by the thematic relationship between entities, a further understanding of how sentence processing occurs during typical reading (inter-hemispherically – Experiment 1) and independently in each hemisphere (Experiment 2) will be gained.

The inflectional properties of verbs have been shown to be crucial constraints on thematic role assignment during sentence processing (Garnsey, Pearlmutter, Meyers, & Lotocky, 1997; McRae et al., 1998; Morrow, 1986). For example, the activation of event knowledge can be influenced by present (*-ing*) and past (*-ed*) participle inflections (Ferretti et al., 2003), verb aspect (Ferretti, Kutas, & McRae, 2007; Madden & Zwann, 2003) and voice (Ferretti et al., 2001; 2005). The voice of a sentence refers to the verb form which expresses the relation of a sentence's subject to a particular action (i.e., voice denotes which thematic role the subject of a sentence is assuming). For example, when verbs are presented in *active* voice, they typically denote that the subject of a sentence is an agent that is initiating or performing the action that the verb depicts; usually this action is carried out on some entity (e.g., *The cop arrested the crook*). When verbs are presented in *passive* voice, the form of the verb serves to indicate that the subject is the thematic patient of the event denoted by the verb and that the agent is likely to appear in an upcoming *by* phrase (e.g., *The crook was arrested by the cop*). The present research focused on voice because it is a grammatical category that leads to very clear expectations for agents and patients in sentences. Manipulating the voice that verbs are presented in has been shown to be useful in examining mechanisms of sentence processing. For example, research by Ferretti et al. (2001) used cross-modal priming techniques to demonstrate that the active and passive forms of verbs differentially influence the activation of event knowledge and concordantly, the expectation for the role of a subsequently read noun. Sentence fragments presented in their active form (e.g. *She arrested the*) more easily prime common patient fillers for the verb (e.g., *crook*), whereas passive sentence fragments (e.g., *She was arrested by the*) facilitate common agents (e.g., *cop*) relative to unrelated control conditions (Ferretti et al., 2001).

The findings from Ferretti et al. (2001) have been further supported by work, which has demonstrated that expectations for specific events can be activated from common thematic role fillers of the events. For example, agent (e.g., *doctor*), patient (e.g., *patient*), instrument (e.g., *needle*) and location (e.g., *hospital*) nouns have been found to sufficiently prime verbs depicting events (e.g., *cure*) of which the nouns are common fillers of thematic roles (McRae, Hare, Elman, & Ferretti, 2005). More specifically, agent nouns have also been shown to activate knowledge of specific aspects of events related to the agent role (e.g., Ferretti et al., 2005). For instance, both naming and lexical decision latencies for the verb *arresting* are enhanced following the presentation of *cop was* as relative to *crook was* (Ferretti et al., 2005). These results suggest that when common agent nouns are presented, readers quickly generate expectancies for the role that they play in thematically related events. However, such an effect has only been demonstrated using fragments of sentences or priming pairs and has not been indexed using modern neuro-imaging methods. Thus, the current study intended to further this work by examining ERP responses to active and passive verbs preceded by related and unrelated agent nouns at the initial noun phrase in sentences (for examples see Table 1). Such a paradigm serves to further research that has investigated expectations for grammatical voice based on common agents (i.e., Ferretti et al., 2005), as well as research that has used ERPs to examine how sentential processing is lateralized in the brain (Coulson, et al., 2005; Federmeier & Kutas, 1999; Federmeier, et al., 2005). Importantly, this research is the first to examine how thematic role knowledge influences the processing of inflected verbs in the two cerebral hemispheres.

Thematic Assignment, Verb Morphology and Theories of Semantic Activation

Another benefit of examining the processing of different verb forms based on thematic relatedness is that it facilitates a critical evaluation of established theories of semantic memory organization. For instance, Spreading Activation (SA - Collins & Loftus, 1975) in semantic networks has been the most commonly used explanation of results from automatic (SOA 250 ms or less) word-word priming (see Neely, 1991). This theory holds that semantic memory is represented via a network of interconnected nodes that correspond to specific concepts or words. A specific node is connected to other conceptually related nodes through a series of links that are weighted in accordance with the degree of relatedness between concepts. The theory originally served to explain results from studies where noun targets in priming paradigms (such as in lexical decision tasks) are activated more quickly when paired with semantically related noun primes (e.g., Meyer & Schvaneveldt, 1971). Thus, it is supposed that when a prime word is encountered, its concept node is activated and this activation automatically spreads outward in all directions. The more closely a related node is located to the concept in the semantic architecture, the more quickly and strongly it will be activated (manifested experimentally as priming effects).

Originally, semantic networks focused primarily on noun representations (e.g., Collins & Loftus, 1975). Verb meaning was later incorporated into the network and included thematic links from verbs to nodes that stood as thematic role place holders (Rumelhart & Levin, 1975). However, the links and nodes in this organization included only negligible semantic content, limited to general selectional restriction information (e.g., the agent link only carries with it information that the noun must be animate). Recent work that has examined the processing of common locative nouns preceded by verbs presented in different aspect has challenged this theory (Ferretti et al., 2007). Aspect is a grammatical category which indicates whether an event denoted by a verb is in a completed or ongoing state. Ferretti et al. (2007) demonstrated that common locations for events (e.g., *arena*) are pronounced more quickly when preceded by related (relative to unrelated) verbs with imperfective (e.g., *was skating*) but not perfect (e.g., *had skated*) aspect. These findings show that aspect modulates activation of common locations for events and consequently that SA theories do not accurately account for variations in the spread of semantic activation based on verb form. This is because SA predicts that the verb *skate* would prime common locations (e.g., *arena*) regardless of aspect, because only the relatedness between concepts determines the degree of facilitation.

In order to surmount shortcomings of SA models, alternative explanations of semantic activation claim that human memory is structured so that when a verb is read, event-specific information is made immediately available from a schematic representation of a situation (e.g., Ferretti et al., 2001; McRae et al. 1997). This view supposes that thematic role concepts are generated through everyday experience where people learn the types of participants that are commonly involved in events. This 'everyday' episodic knowledge about events is accumulated and used on-line to aid the comprehension and production of language. For example, the agent role for the event of *rescue* is formed from hearing and witnessing rescuing events (e.g., someone may have witnessed a lifeguard rescuing someone and thus this entity may be conceptualized as an agent for the event) as well as being exposed to linguistic descriptions of the event. This knowledge is utilized immediately to guide on-line thematic assignment after encountering the word *rescue*. This account hypothesizes that syntactic information, such as the grammatical inflections placed on verbs, interacts immediately to constrain the activation of situation specific knowledge. Thus, the results of Ferretti et al., (2007) are not adequately captured by SA models because this theory cannot account for the interaction between verb morphology and thematic role knowledge that constrains the processing of nouns and verbs. Accounts based on the activation of specific world knowledge (e.g., Ferretti et al., 2001; Ferretti et al., 2007; McRae et al., 1997) however, can sufficiently describe priming results that differ based on the form of the verb. Thus one of the purposes of the current study was to further assess these theories by using ERPs to examine if the same pattern of results is apparent for brainwave amplitudes to active and passive verbs presented to both hemispheres simultaneously and individually.

Purpose of the Current study

As discussed above, the current experiment utilized sentences designed to examine how the thematic knowledge associated with nouns (*agents*) interacts with different verb forms (i.e., verbs in active and passive voice) to constrain comprehension during sentence processing both conjointly and between the two cerebral brain hemispheres. Examples of sentences in each experimental condition used in the study can be seen in Table 1. Overall these items were employed to examine three purposes: Firstly, the current study intended to utilize ERP brainwaves to provide a neurocognitive index of how the cerebral hemispheres conjointly and independently undertake the processing of specific active and passive verb forms after reading related and unrelated *agent* nouns. This measure was employed to afford a more detailed index of the processes underlying the utilization of thematic information than has previously been revealed from experiments examining priming results (e.g., Ferretti et al., 2005; McRae et al., 2005). ERPs provide an unprecedented temporal index of the brain mechanisms underlying cognitive processes (millisecond resolution) and also provide a topographical depiction of the cortical regions involved in undertaking such processes. By examining components thought to be involved in both syntactic and semantic language processing (e.g., P2 and

N400), it was intended that an electrophysiological depiction of how agent nouns generate expectations for specific verbs be obtained for each hemisphere.

A second purpose of this study was to examine theoretical contentions regarding the semantic activation of event knowledge from memory. Using ERPs provides another measure whereby the differential claims of SA networks (e.g., Collins & Loftus, 1975) and models positing verb-specific activation of event knowledge (e.g., McRae et al., 1997) could be evaluated by examining whether the inflectional information interacts with the thematic relatedness between the noun and verb. Using the current paradigm to examine these models was used to expand upon previous work that has investigated such contentions using behavioural (e.g., Ferretti et al., 2005) and ERP methodology (e.g., Ferretti et al., 2007). It was intended that, by using the VHF paradigm, an assessment of how well different theoretical models explain processing of both centrally and laterally presented targets could be gained. This was the first study to examine these particular theories of facilatory semantic activation with ERPs for joint (Experiment 1) and independent (Experiment 2) hemispheric processing.

Finally, the main purpose of the experiments was to expand upon previous hemispheric ERP work (e.g., Federmeier et al., 2005) that has examined the nature of sentence processing in the cerebral hemispheres. By using the VHF paradigm to examine brainwave responses to critical active and passive verbs preceded by related and unrelated agent nouns, an understanding of hemispheric sentence processing could be advanced in a number of different ways. One advantage of the current experiment was that a neurocognitive index of orienting to thematic role information during both joint and hemispheric sentence processing could be gained. Studies investigating the mechanisms by which the LH and RH processes linguistic information are central to current neurocognitive language research. Whereas ERP studies in this field have been very useful in elucidating the understanding of each hemisphere's ability to process a sentential context, they have not, prior to the current work, examined some basic aspects of sentence comprehension such as assigning thematic roles, a process that has been shown to be an essential part of successful sentence comprehension (e.g., Frazier, 1987; MacDonald et al., 1994).

Also, using the current experimental design allowed for an examination of joint and independent hemispheric ERP responses to variability in the syntactic structure of sentence clauses. Hemispheric ERP research has generally focused on examining only semantic constraints on the processing of critical noun targets in order to investigate LH and RH sentence processing capabilities. Although such work has been informative, there has been a surprising paucity of ERP research employing any experimental syntactic variables or examining verb processing in general. Whereas hemispheric behavioural work has begun to employ non-semantic variables (e.g., word-class – Arambel & Chiarello, 2006), to examine LH and RH sentence processing capabilities, the current work was the first to examine the interplay between event specific thematic role knowledge and verb morphology using ERP measures.

Another way in which the current work expanded previous ERP studies of hemispheric sentence processing was by examining responses to verbs during the early moments of sentence reading. Typically studies (both behavioural and ERP) have used only sentence-final words (e.g., Federmeier et al., 2005) as critical items for examining sensitivity to a sentence context. In the current study, the critical noun-auxiliary-verb combinations were embedded at the beginning of plausible sentences, allowing investigation into how a sentence context is established for further processing. The current research provided a paradigm where a smaller amount of contextual elaboration is allotted to readers. Thus, the individual power of the thematic elements could be assessed as they are used conjointly (Experiment 1), and by each hemisphere (Experiment 2), to generate an initial sentential clause.

Experiment 1: Central Presentation

Previous research has demonstrated that reading a common agent noun (e.g., *cop*) for a particular event (e.g., *arrest*), activates the conceptual representation of that event (McRae et al., 2005) and further, this information has shown to be specific for a particular morphological form of a verb depicting the event (i.e., *arresting* for good agents – Ferretti et al., 2005). Such results have typically been found using reaction time measures in priming paradigms. In Experiment 1, it was intended that ERP responses be recorded to active (e.g., was *lecturing*) and passive (e.g., was *lectured*) verbs that are preceded by related (e.g., *teacher*) and unrelated (e.g., *shepherd*) agents embedded at the beginning of sentence contexts (see Table 1). Based on results from semantic priming measures (e.g., Ferretti et al., 2005), it was expected that the N400 component will be more negative in response to thematically unrelated verbs, indicating a greater integration difficulty with the preceding sentential context. It was thought that this effect however, should be stronger for active (e.g., *lecturing*) verbs because expectations for this form are more salient when common agent nouns precede the verb (McRae et al., 1997). Thus, it was expected that such an amplitude pattern would be manifested as an interaction between voice and relatedness.

Additionally, it was thought that early effects in the P2 (200-300 ms) time window may also be detected in response to the critical verbs. However, unlike what was expected for N400 responses, additional sources of information such as word frequency may influence P2 brainwave amplitudes. Active sentences are by far the most frequent type in the English language with approximately 95% of sentences presented in this voice (McRae et al., 1998). However, the most frequent form of an active sentence is the simple past-tense form (e.g., *The cop arrested the man*). In the current study a less frequent form was employed to make active sentences (e.g., *The cop was arresting…*). Contrastingly, passive sentences were presented in a common form (e.g., *The cop was arrested…*) which is actually more frequent than the specific active form presented in the experiment. Additionally, the specific words used as verbs for passive sentences appear much more frequently in the English language than the words used as *active* verbs both individually and when the words are paired with the auxiliary *was* (see Methods section below). Note that the two forms of the verbs were employed because it enabled the number of words in the context preceding the verbs to be controlled and because it enabled examination of verb forms that vary in their different suffixes (i.e., *ing* and *ed* verbs).

When people read sentences, they generally are expecting an active sentence (which is the most frequent form in English), however because the active sentences used in this study contained the less frequent *ing* form of verb, it was thought that there may be an initial greater processing difficulty for these verbs relative to the more frequent *ed* verbs used in passive sentences. Thus, it was expected that, independent of relatedness, P2 responses would generally be less positive in response to the active verbs (relative to passive), indicating greater processing difficulty for the lower frequency verb forms. In addition to frequency, it was hypothesized that sensitivity to the thematic relatedness between noun and verb may also be affected in the N1 and P2 time windows. Previous work has shown that P2 amplitudes can vary based on such factors as sentential constraint (e.g., Federmeier, 2005) as well as verb form (Ferretti et al., 2007). Thus it was expected that amplitudes for related verbs would be more positive than amplitudes for unrelated verbs, but this effect may only be observable for active verbs. Importantly, relatedness may also interact with voice in that good agent nouns in the patient role of passive verbs (e.g., *The cop was arrested*) should be unexpected and may even have less positive amplitudes than unrelated verbs in the same role (e.g., *The headmaster was arrested*).

Such a pattern of results would be consistent with theories positing that verb-specific event knowledge interacts with the morphological form of verbs during sentence processing. The results were also intended to provide support for previous work, which has shown that the grammatical inflections placed on verbs (e.g., *ing* and *ed*) can interact with event-specific knowledge (Feretti et al., 2001). Thus when an agent noun is encountered, activation (or expectancy) increases for the specific form of the verb that is consistent with the role depicted by the noun (active verbs reference agents and are thus connected with that specific role). These results would also be consistent with previous work which has shown priming advantages for processing active verbs when they are congruent with a related agent (Ferretti et al., 2005). Conversely, the results would be problematic for spreading activation theories (e.g., Collins & Loftus, 1975) which posit that the degree of semantic relatedness between concepts would be the sole determinant of the ease with which the critical items are processes. Thus, SA theories predict that N400 amplitudes would only vary with the degree of relatedness between agent (noun) and event (verb – with less positive amplitudes for unrelated verbs) and that such effects would not be modulated by voice.

Method

Participants.

Thirty-two (10 male and 22 female) right handed, native English speaking undergraduate psychology students from Wilfrid Laurier University participated in the study for course credit. Participants did not take part in Experiment 2 or in the norming procedure discussed below.

Materials.

One hundred and four target sentences were generated from noun verb combinations derived from previous experiments (McRae et al., 1997) as well as novel combinations generated from the experimenter's intuition. Each sentence began with the initial clause format *The agent-noun was verbing/verbed*, and was combined with another clause in order to generate a plausible sentence completion. Each verb was paired with both a thematically related (e.g., *cop* for *arrest*) and unrelated (e.g., *headmaster* for *arrest*) agent noun and presented in either active (*ing*) or passive (*ed*) form between the experimental conditions. Examples of each of the four types of sentences used in the experiment can be seen in Table 1 (for all sentences used in the study see Appendix A).

In order to assess whether the nouns could indeed be classified as good agents (poor patients) for the events denoted by the verbs, a series of normative ratings was collected from 20 participants (10 rated agenthood and 10 rated patienthood). The thematic fit of each noun (both related and unrelated) for the verb's agent and patient roles was measured by means of a role-typicality norming procedure (McRae et al., 1997). This norming method indexes the plausibility of entities denoted by nouns as fillers for specific thematic roles by asking participants for a subjective judgement about how commonly a denoted situation occurs in the real world. This typicality was measured by having participants provide ratings capturing a noun's agenthood (e.g., "How common is it for a ______ to cure someone?") or patienthood ("How common is it for a _____ to be cured by someone?") on a 7-point scale ranging from 1 (very uncommon) to 7 (very common). For each event, four ratings for nouns were collected; the agenthood and patienthood ratings for the related agent noun and agenthood and patienthood ratings for the unrelated noun.

The agenthood and patienthood ratings were compared to examine the appropriateness of each noun for its depicted thematic role. The mean Likert ratings for each rating collected can be seen in Table 2. For each comparison of interest, a one-way ANOVA with factor thematic role (agenthood versus patienthood) was performed on the Likert ratings. The agenthood ratings for the related nouns were rated as sufficiently higher ($M = 6.32$) than the patienthood ratings for the same nouns ($M = 3.23$), $F(1, 206) = 494.02$, $p < .01$, indicating that the related nouns can be thought of as good agents and poor patients for the events denoted by the verbs. The agenthood ratings for the related nouns were also rated as sufficiently higher ($M = 6.32$) than the agenthood ratings for the unrelated nouns ($M = 2.6$), $F(1, 206) = 962.94$, $p < .01$, indicating that the related nouns can be thought of as more common agents for the events than the unrelated nouns. The related nouns were also rated significantly better as patients ($M = 3.23$) than the unrelated nouns (*M* = 2.85) $F(1, 206) = 9.50$, $p < .01$. However the actual numerical difference in ratings between these two means is quite small (.38) when compared to differences between the agenthood and patienthood ratings for related nouns (3.09), and to the difference between agenthood ratings for related and unrelated nouns (3.72). The unrelated nouns were rated as marginally better patients (*M* = 2.85) than agents (*M* = 2.61), $F(1, 206) = 2.84$, $p = .07$, however, again this difference was numerically quite small (.24). Overall, related nouns were given the highest typicality ratings for filling the agent role in the events denoted by the verbs and were rated as much better agents than patients. They were also rated as considerably better agents than unrelated nouns. Thus, these ratings indicate that the item set employed in the study captured the desired thematic relatedness between agent nouns and events denoted by the verbs. The mean agenthood and patienthood ratings for both the related and unrelated nouns for each verb/event can be seen in Appendix B.

To examine how commonly each word in the item set is encountered in English text, the frequency of each verb per million words in its isolated form (e.g., *arresting* and *arrested*) and the frequency of each verb form when preceded by the auxiliary *was* (as it appears in the experiment) were analysed. The overall mean frequencies for the isolated verbs as well as the auxiliary-verb combinations can bee seen in Table 3. Frequency data for each of the isolated verbs was found by using an index of the frequency of a particular word per million written words in English (Kucera & Francis, 1967). A one-way ANOVA with variable word (ing versus ed) was performed on these frequency values. Results showed there were significant differences in the mean frequencies of active verbs and passive verbs, $F(1, 189) = 7.38$, $p < .01$. This occurred because a significantly higher frequency was found for passive verbs (*M* = 36.71) relative to active verbs (*M* = 17.22). Frequency data for the verbs preceded by the auxiliary *was*, was attained by searching the internet with *Google*. To conduct this search, a *Google Advanced Search* which reported the number of internet pages containing a particular item was performed. The parameters set for this search specified that only results for the exact auxiliary-active verb pairing (e.g., *was arresting*) or auxiliary-passive verb pairing (e.g., *was arrested*) be returned. Only English pages were included in the search. As with frequencies for individual verbs, a one-way ANOVA with the factor voice (two levels: active and passive) was performed on the log frequency values. Log frequencies were used instead of the raw *Google* frequency values so that the distribution of results would not be skewed by exceedingly large or small values. Results showed frequencies for the different auxiliary-verb pairs differed significantly, $F(1, 206) = 37.59, p < .01$. This difference occurred because the auxiliary-passive verb pairs were found more frequently (*M* = 5.79) than auxiliary-active verb pairs (*M* = 5.19). All individual frequency values can be seen in Appendix C.

Using the aforementioned items, four experimental lists were constructed, each contained 26 related-active sentences (e.g., *The teacher was lecturing the man*), 26 unrelated active sentences (e.g., *The shepherd was lecturing the man*), 26 related-passive sentences (e.g., *The teacher was lectured by the man*), and 26 unrelated passive sentences (e.g., *The shepherd was lectured by the man*). Each item appeared once in each condition between the four lists and no noun or verb was seen more than once on any given list. Note that unrelated items were formed by re-pairing the related noun/verb pairs so that they were now unrelated. In addition to the 104 target trials, 104 filler trails were included in the lists. Filler items consisted of short (6 word), plausible, easily comprehensible sentences (e.g., *The trees have lost their leaves.*). These items appeared in a variety of syntactic structures which included roughly an equal number of active and passive sentences. All sentences in each list were presented in pseudorandom order to participants under the constraint that no more than three target sentences be presented consecutively.

Procedure.

Participants sat in a chair in front of a computer monitor located in an electrically shielded room. They were instructed to read sentences one word at a time on the screen and then answer a yes-no comprehension question about the sentences they read using a button box. Participants were instructed not to blink, move their eyes laterally, or move their body during sentence reading. The presentation of each sentence was preceded by a series of plus-signs presented for 2000 ms (with a 2500 ms SOA) to orient gaze to the center of the screen. Sentences were then presented in the center of the monitor one word at a time for a duration of 200 ms with an SOA of 500 ms. After each sentence, a 'yes-no' comprehension question appeared on the screen and remained until the participant answered the question. Breaks were given after approximately every 10 minutes of testing.

EEG Recording.

Figure 1 shows a schematic diagram of the electrode layout and labels on the 64 channel electrode cap used in the experiment. The electroencephalogram (EEG) was recorded from 64 silver-chloride plated electrodes referenced on-line to a mid-sagital/mid-coronal electrode site. Eye movements and blinks were monitored via occular electrodes place on the intraorbital ridge and outer canthus of each eye. Electrode impedances were kept below 5KΩ, and the EEG was processed through a neuroscan Synamps2 amplifier set at a bandpass of 0.05 – 100 Hz, and was digitized at 250 Hz.

Data Analysis.

Data was re-referenced offline to the average of the left and right mastoids. ERPs were computed for epochs extending 100 ms before and 1000 ms after stimulus onset. The pre-stimulus baseline amplitudes were subtracted before data was analysed. Trials that were contaminated by blinks, lateral eye movements or excessive muscle activity were rejected offline before averaging. A total of 18.64 % of trials were removed because of such artifacts. Additionally, 2.48 % of questions were answered incorrectly and also not included in the analysis. After such artifacts were removed, an average for all remaining trails for each condition was made for each participant. Mean amplitudes for each time window corresponding to a particular waveform of interest were then calculated from these averages. The calculated averages for each participant were then subsequently analysed in an ANOVA. All *p* values were reported after epsilon correction (Greenhouse-Geiser) for measures with greater than one degree of freedom.

Results

Artifact-free ERP responses were measured and analysed in four different time windows: N1 responses were measured from 100-200 ms post stimulus onset, the P2 component was measured from 200-300 ms post stimulus onset, the N400 was examined in the 300-500 ms post stimulus onset, and the LPC was measured from 500-900 ms post stimulus onset. Brainwave amplitudes for each latency window were initially analysed in a 2 (voice: active and passive) x 2 (relatedness: related and unrelated) x 62 (electrode site) repeated measures ANOVA. Results were always collapsed across electrode location since this provided the most theoretically neutral examination of ERP waveforms. Because evidence of topographic variance was needed before an examination of where different brainwaves occur was undertaken, an analysis broken down by electrode location was to only be performed when the interaction between the experimental variables and electrode site was significant. A summary of all results for effects involving the variables of interest at each epoch can be seen in Table 4. For a schematic diagram of grand average ERPs at each electrode site to target verbs in all conditions, see Figure 2.

N1 (100-200 ms). Results for this epoch showed a significant main effect of voice, $F(1, 28) = 4.43, p < .05$, which occurred because amplitudes for passive verbs were significantly more positive ($M = 0.31$ μV) than amplitudes for active verbs ($M = -0.04$ μV). No main effect of relatedness was found ($F < 1$). Additionally, the analysis revealed a significant two-way voice x relatedness interaction, $F(1, 28) = 12.57, p < .01$. Planned comparisons revealed a significant difference between amplitudes to related and unrelated verbs in their active form, $F(1, 28) = 12.71, p < .01$, with significantly more positive amplitudes for related ($M = 0.38$ μV) versus unrelated ($M = -0.45$ μV) items. Contrastingly, differences between the passive form of related ($M = 0.14$ μV) and unrelated ($M = 0.48$ μV) verbs were found to be non-significant, $F(1, 28) = 2.11, p = .16$. No other interactions examined were found to be significant (all F's < 1.22).

P2 (200-300 ms) Results for this time window also showed a marginally significant main effect of voice, $F(1, 28) = 3.24, p = .08$, which occurred because amplitudes for passive verbs were more positive ($M = 2.68$ μV) than amplitudes for active verbs ($M = 2.36$ μV). No main effect of relatedness was observed ($F < 1$). As with

N1 component, the two-way voice x relatedness interaction was also significant, $F(1, 28) = 12.57, p < .01$. Planned comparisons investigating this interaction revealed significantly more positive amplitudes for related ($M = 2.78$ μV) than for unrelated ($M = 1.93$ μV) active verbs, $F(1, 40) = 7.53, p = .01$. Conversely, differences in amplitude were reversed for passive verbs with related verbs being less positive ($M = 2.36$ μV) than unrelated verbs ($M = 3.00$ μV), $F(1, 40) = 4.40, p = .05$. No other interactions examined were found to be significant (all F's < 1.60).

N400 (300-500 ms). Unlike the previous analyses for earlier components, the results in the N400 time window revealed a significant main effect of relatedness, $F(1, 28) = 13.56, p < .01$, but not voice $F(1, 28) = 1.05, p = .32$. The main effect of relatedness occurred because amplitudes for related items were significantly more positive ($M = 0.80$ μV) than those elicited to unrelated items ($M = -0.18$ μV). Although the two-way voice x relatedness interaction was found to be non-significant, $F(1, 40) = 1.44, p = .24$, planned comparisons revealed that amplitudes for related/active verbs were significantly more positive ($M = 0.83$ μV) than amplitudes for unrelated/active verbs ($M = -.44$ μV), $F(1, 40) = 13.91, p < .01$. Differences between related ($M = 0.77$ μV) and unrelated ($M = 0.08$ μV) passive verbs also reached significance, however the effect was much smaller than with active verbs, $F(1, 40) = 4.12, p = .05$. All other interactions were found to be non-significant (all F's < 1.80).

Late Positivity Complex (500-900 ms). LPC effects were measured at later time intervals in order to examine the effects of integrating the critical verb into sentence contexts. A significant main effect of relatedness was found, $F(1, 28) = 7.40, p < .01$, as amplitudes elicited in response to related items were significantly more positive ($M =$

1.73 μV) than those elicited to unrelated items (*M* = 0.92 μV). The main effect of voice was not significant, $F < 1$. Although the two-way interaction between voice and relatedness was found to be non-significant $F(1, 28) = 1.34$, $p = .26$, planned comparisons again revealed that active/related verbs were found to be significantly more positive (*M* = 1.81 μV) than active/unrelated verbs (*M* = 0.69 μV), $F(1, 40) = 8.65$, $p < .01$. Contrastingly, the differences between related passive (*M* = 1.65 μV) and unrelated passive (*M* = 1.15 μV) verbs was non-significant, $F(1, 28) = 1.70$, $p = .20$. No interactions with electrode were found to be significant (all *F*'s < 1.43).

For a visual representation illustrating differences between all conditions across the recording epoch at a single central parietal electrode site, see Figure 3. For specific comparisons of related and unrelated verbs at each level of voice for at this same central parietal electrode, see Figure 4.

Discussion

The results of this experiment demonstrate how amplitudes for both early (i.e., N1 and P2) and late (i.e., N400 and LPC) brainwave components can document changes in sensitivity to morphosyntactic information across the processing of a verb. Results from the N1 time window show that even at the very early moments of processing a stimulus, the brain is sensitive to modulations in linguistic information. This is evidenced by the variations in responses to different morphological verb forms; specifically, brainwave amplitudes indicate that passive verbs (e.g., *arrested*) were generally processed more easily than the active form of the same verb (e.g., *arresting*). This result can be explained by the noted frequency advantage for the specific set of passive items relative to the active items used in the experiment. Frequency effects have been shown to influence the processing of linguistic stimuli at early time windows; with high frequency words being typically associated with more positive amplitudes than low frequency words (e.g., Sereno, Rayner, & Posner, 1998).

Additionally, results in the N1 time window revealed how processing difficulties for related and unrelated verbs vary as a function of voice. Specifically, brainwave amplitudes for related active verbs were more positive than amplitudes for unrelated active verbs, whereas no significant differences were found between related and unrelated passive verbs. Such an effect suggests that people are sensitive to the thematic fit between agent noun and verb form during the very early moments of processing after reading the noun-verb combinations. Whereas such a result is consistent with predictions made for the interaction between voice and relatedness, it is somewhat surprising that such an effect occurred so early during processing. This is because there are few examples in ERP research that have shown relatedness effects for the N1 component (but see Soreno et al., 1998)

In the P2 (200-300 ms) time window, planned comparisons revealed a cross-over interaction for differences between related and unrelated verbs at each level of voice. For active verbs, amplitudes were found to be more positive for related relative to unrelated verbs suggesting that the brain is more easily able to attend to verbs having congruent thematic fit with preceding agent nouns. Thus when an agent noun is read, the brain is more prepared to process information consistent with that entity's specific role in events. Conversely, for passive verbs, the opposite pattern of amplitudes was observed; unrelated verbs elicited more positive amplitudes than did related verbs, indicating the brain was more prepared to process the unrelated relative to the related form of the verbs. This effect illustrates that when the verb form is incongruent with the preceding agent, the brain needs to devote additional attentional resources to process the verb depicting the noun in a role that is opposite to that which it typically assumes. Overall these results demonstrate that both frequency and congruency between thematic fit and subsequent verbs influence the ease with which verbs are integrated into a sentence context following the presentation of agent nouns. Such a pattern of results is consistent with predictions made for effects in this time window and also complement previous work that has shown that such early effects can vary based on verb morphology (Ferretti et al., 2007) and word frequency (Dambacher et al., 2006; Soreno et al., 1998).

In addition to early effects, results for the N400 (300-500 ms) and LPC (500-900 ms) converged to show that expectations for verbs after reading typical agent nouns vary as a function of voice. As expected, for the N400 component, robust differences between related and unrelated active verbs were observed, suggesting that related words were more easily integrated with the context containing the preceding agent noun. For passive verbs, differences between related and unrelated items were also found. However, as expected, the magnitude of the effect was greatly reduced. A similar pattern of effects also occurred in the later (500-900 ms) LPC time window indicating that this pattern of semantic integration difficulties was sustained beyond the N400 time region. These results show that common agent nouns lead to the generation of expectations not only for the thematically related verb, but for the specific congruent morphological form of the verb. Because verbs presented in active voice are congruent with good agent nouns, expectations for this form of verb are stronger than for passive verbs. The pattern of results are consistent with the hypothesized effects for the experiment supports previous work that has demonstrated that the inflectional properties of verbs influence the activation of event knowledge (e.g., Ferretti et al., 2003; Feretti et al., 2007). The findings also complement previous behavioural work using priming which has shown that expectations for specific events can be activated from common thematic role fillers of the events (McRae et al., 2005) and more specifically, work that has demonstrated that agent nouns are able to prime the congruent, active form of a thematically related verb in semantic priming tasks (Ferretti et al., 2005).

Overall, the results of the experiment are consistent with the expected pattern of brainwave amplitudes. Facilitation for processing thematically related as opposed to unrelated items was clearly influenced by whether verbs were presented in their active or passive voice. This influence was evident not only at later latency windows used to examine components which index the ease of semantic integration (i.e., N400 and LPC), but also during earlier time windows (i.e., N1 and P2) suggesting that goodness of thematic fit is recognized at the early moments of processing a word. These results are consistent with theoretical accounts which claim that event specific information is utilized quickly to constrain on-line sentence processing (McRae et al., 1997): Because agents are associated with the initiation of action in an event and are referenced as such by verbs presented in active voice, then the specific active verb form (relative to the passive or any other form) should be made more salient from reading good agent nouns. This increased expectancy for active verb forms is precisely what was documented by differences in brainwave amplitudes in this experiment. Conversely, this variation in sensitivity to specific verb forms is very problematic for theories of spreading activation (e.g., Collins & Loftus, 1975). These models suggest that the degree of semantic relatedness between concepts in memory is predominantly what determines facilitation between related items. Thus SA models would predict that no interactions between voice and relatedness should have occurred and consequently, amplitude differences between related and unrelated items should not vary simply by altering the grammatical morphemes placed on verbs. Thus, only effects of relatedness would be expected to result regardless of verb form. However, facilitation for related items was observed to vary as a function of voice and thus, because SA models do not adequately account for factors that substantially constrain semantic processing during language comprehension. In order for such models to more accurately semantic processing, a mechanism for inflections to influence the spread of semantic activation would need to be incorporated.

Experiment 2: Lateral Presentation of Critical Verbs

In Experiment 2, the exact same experimental design and method used in Experiment 1 was employed with one key procedural difference between experiments; in this experiment, critical verbs (in either active or passive form) were presented 2° horizontal visual angle to either the left or right of central fixation so that only the contralateral cerebral hemisphere was presented with the word. This key manipulation allows the linguistic processing load to be assumed by the hemisphere initially presented with the stimulus (Banich, 2002). Thus, by employing brainwave recordings while participants read lateralized stimuli, an electrophysiological index of each hemisphere's ability to process thematic role information in conjunction with morphosyntactic information could be attained.

This work was designed to expand upon recent ERP investigations of hemispheric sentence processing that have provided evidence that the RH is able to process message-level information (Coulson et al., 2005; Federmeier & Kutas, 1999; Federmeier et al., 2005). As in Experiment 1, an examination of both early and late waveforms was conducted to assess the influence of the variables voice (active and passive) and relatedness (related and unrelated) on perceptual, attentional, and semantic processing. When stimuli are presented in the VHF paradigm, brainwaves responses to rvf/LH presentation often parallel those found with central presentation (e.g., Federmeier & Kutas, 1999). However, some studies have found that an increased sensitivity to semantic relatedness between words in a sentence context can sometimes occur with rvf/LH presentation (e.g., Coulson et al., 2005). Thus, it was expected that amplitude differences in waveforms for rvf/LH presentation should vary as a function of voice and relatedness in a manner similar to that observed in Experiment 1, although potentially with slightly larger relatedness effects.

Although LH processing often can resemble that of conjoint hemispheric processing (i.e., central presentation), the effects of lvf/RH presentation can often be more difficult to predict. Because this work is the first of its kind to examine how the individual hemispheres process thematic fit in conjunction with the morphosyntactic properties of verbs, the effects of RH presentation were difficult to anticipate. Specifically, it was hard to gauge whether the RH would be sensitive to manipulations in verb morphology in a manner similar to that of the LH. Early investigations (involving commisurotomy patients) of RH language ability have suggested that the RH is incapable of grammatical or syntactic processing (Gazzaniga & Hillyard, 1971; Zaidel, 1983). For instance, Gazzaniga and Hillyard (1971) demonstrated that after viewing pictures of visual scenes, split-brain patients were unable to select appropriate sentences for the images that distinguish between future and past tense (e.g., *The girl is drinking* vs. *The girl will drink*) or sentences with singular or plural nouns (e.g., *The dog jumps over the fence* vs. *The dogs jumped over the fence*). As a result of such findings, researchers have speculated that grammatical and syntactic processing facilitate the LH's ability to focus its meaning activation, a characteristic consistent with the LH's postulated fast, narrow and integrative linguistic processing capabilities (e.g., Arambel & Chiarello, 2006; Faust et al., 2003). Thus, it was hypothesized that the effects of varying the verb forms may be attenuated with RH processing. However, previous results that are the basis for such conclusions were not based on ERP recordings, which have been shown to reveal RH processing capabilities that are thought to be undetectable with behavioural measures (e.g., Coulson et al. 2005; Federmeier et al., 2005).

Overall, it was expected that amplitudes to verbs presented to the lvf/RH would be sensitive to modulations in voice and relatedness. However, it was thought that these effects may present differently than those found with rvf/LH presentation. In this experiment, it was hypothesized that effects of voice would again be evident in early components; however, it was also thought that this effect may not be as pronounced in the RH. This prediction was based on findings from previous hemifield ERP studies which have found either that P2 effects are smaller for lvf/RH presentation (Federmeier et al., 2005), or that this component is insensitive to modulations in experimental variables such as expectancy for a particular sentence ending (Federmeier & Kutas, 1999). Additionally, it was expected that later semantic ERP components (e.g., N400) would show effects of semantic relatedness for lvf/RH presentation, with amplitudes to related verbs being more positive than those to unrelated verbs. This finding would follow from previous ERP work that has found that the RH (like the LH) is sensitive to sentential congruity (Coulson et al., 2005; Federmeier et al., 2005), as well as lexical associations between words (Coulson et al., 2005; Federmeier & Kutas, 1999). Although, it was thought that the RH may be insensitive to syntactic manipulations (e.g., Arambel & Chiarello, 2006), it was expected that the RH would demonstrate some sensitivity to this aspect of language comprehension, based on the assumption that syntactic processing is a part of comprehending sentence-level contextual information. This prediction was made based on findings from recent ERP work which has shown that the RH may indeed have the ability to processes sentential context in manner comparable to the LH (e.g., Federmeier et al., 2005). Although, it was thought that the pattern of waveform effects for lvf/RH presentation may be attenuated relative to those found for rvf/LH presentation (Coulson et al., 2005; Federmeier & Kutas, 1999).

Method

Participants.

Forty-eight (13 male and 35 female) right handed, native English speaking psychology undergraduate students from Wilfrid Laurier University participated in the study for course credit. None of the students in this study participated in Experiment 1.

Materials.

The items used in Experiment 2 were the same as those used in Experiment 1. Eight lists were constructed using the same experimental variables as in Experiment 1 plus an additional visual field variable (two levels – lvf/RH and rvf/LH presentation). Thus each list contained the same conditions as in Experiment 1 (see above) with half the target verbs for a given condition laterally presented to the lvf/RH and half presented to the rvf/LH. Each item appeared once in each condition between eight lists and no noun or verb appeared more than once on any given list. In addition to the 104 target trails, 104 filler trails were included in the lists. All sentences in each list were presented pseudorandomly to participants with the condition that no more than three target sentences be presented consecutively.

Procedure.

Participants sat in a comfortable chair in front of a computer monitor located in an electrically shielded room. They were instructed to read sentences one word at a time on the screen and then answer a yes-no comprehension question about the sentences they read using a button box. Participants were instructed not to blink, move their eyes, or move their body during sentence reading. The presentation of each sentence was preceded by a series of plus-signs presented for 2000 ms (with a 2500 ms SOA) to orient gaze to the center of the screen. The target sentences were then presented one word at a time for a duration of 200 ms with an SOA of 500 ms. All non-target words were presented centrally but target verbs were presented pseudorandomly to either the left or right visual field with the inner edge of the word subtended 2° horizontal visual angle from central fixation. Throughout the presentation, a central fixation point (small plus-sign) was positioned 0.40° below the bottom edge of centrally presented words. This was positioned as such to help participants fixate their eyes centrally during the presentation of lateralized words. After each sentence, participants answered a 'yes-no' comprehension question about the contents of the sentence. Breaks were given after approximately every 10 minutes of testing.

EEG Recording and analysis.

The parameters for recording and analysing the electroencephalogram were the same as those used in Experiment 1.

Data Analysis.

As in Experiment 1, data was re-referenced offline to the average of the left and right mastoids. Trials that were contaminated by blinks, eye movements or excessive muscle activity were rejected offline before averaging. Such artifacts comprised 25.05 % of experimental trials. Additionally, a total of 3.57 % of comprehension questions were also removed because they were answered incorrectly. ERPs were computed for epochs extending 100 ms before and 1000 ms after stimulus onset. All *p* values are reported after epsilon correction (Greenhouse-Geiser) for measures with greater than one degree of freedom.

Results

Artifact-free ERP responses were measured and assessed in the same four time windows analysed in Experiment 1 (N1,100-200 ms; P2, 200-300 ms; N400, 300-500 ms; LAN, 500-900 ms). For each latency region, a 2 (visual field: lvf/RH and rvf/LH) x 2 (voice: active and passive) x 2 (relatedness: related and unrelated) x 62 (electrode site) repeated measures ANOVA was conducted for the dependent variable mean amplitude (see Table 5 for a summary of the ANOVA results for all four time windows). When amplitudes for a voice x relatedness interaction were modulated by an interaction with electrode site, distribution analyses were conducted to investigate this interaction across scalp locations. Note that only electrode interactions that included the voice and relatedness variables were investigated as these are of primary theoretical interest. For the distribution analysis, only a select group of electrodes (that are representative of various topographical scalp regions) consisting of sites F7, FT7, P7, CB1, FP1, F1, P3, O1, F8, FT8, P8, CB2, FP2, F2, P4, and O2 were included in the analysis. For the distribution analyses, a 2 (visual field: lvf/RH and rvf/LH) x 2 (voice: active and passive) x 2 (relatedness: related and unrelated) x 2 (hemisphere: left and right) x 2 (laterality: lateral and medial) x 4 (anteriority: prefrontal, frontal, parietal, occipital) ANOVA was conducted. Grand average ERPs to target verbs at all electrode locations for both lvf/RH and rvf/LH are shown in Figure 5 and Figure 6 respectively.

N1 (100-200 ms). The N1 is thought to reflect extrastriate visual processing and is typically largest for electrode locations contralateral to the VF where a stimulus was presented (Hillyard & Anllo-Vento, 1998). As in previous research (e.g., Federmeier et al., 2005), these brainwave components were analysed in order to confirm the lateralization of stimuli to the intended visual field of presentation as well as to examine any early influences of voice and relatedness. A significant two-way visual field x hemisphere interaction confirmed that the target words were processed in the intended hemispheres $F(1, 40) = 27.65$, $p < .01$. As expected, comparisons for this N1 effect showed that lvf/RH presentation amplitudes were less positive over right ($M = -.13$ μV) than left ($M = .52$ μV) hemisphere electrode locations, $F(1, 40) = 16.81$, $p < .05$. Analogously, when the target verbs were presented to the rvf/LH, amplitudes were less positive over left ($M = .30$ μV) than right ($M = .82$ μV) electrode sites, $F(1, 40) = 11.13$, $p < .05$). Such effects demonstrate that stimuli were properly received more prominently at the intended contralateral scalp sites (see Figure 7 for an illustration of this effect).

Previous studies measuring ERPs to lateralized visual stimuli have also reported a sustained negative-going effect over scalp sites contralateral to the VF of stimulus presentation (e.g., Federmeier & Kutas, 1999; Federmeier et al., 2005). This selection negativity further verifies that the balance of processing remained biased to the contralateral hemisphere throughout the duration of the recording epoch. Such an effect was also elicited in the current study. To characterize this negative-going process, mean amplitudes measures from 300-900 ms were subjected to a distribution analysis (where effects of experimental variables were not of interest). Results from this analysis showed that the main effect of visual field was non-significant, $F < 1$, as was the main effect of hemisphere, $F(1, 40) = 1.66, p < .22$. As expected, visual field and hemisphere interacted $F(3, 40) = 72.50, p < .01$. This interaction occurred because greater negativity was detected over scalp sites contralateral to the VF of presentation: For lvf/RH presentation amplitudes were less positive over right ($M = 1.33$ μV) than left ($M = 2.27$ μV) hemisphere electrode locations, $F(1, 40) = 57.18, p < .01$. Conversely, when the target verb was presented to the rvf/LH, amplitudes were less positive over left ($M = 1.65$ μV) than right ($M = 2.21$ μV) electrode sites, $F(1, 40) = 20.07, p < .01$). These effects demonstrate that a larger contralateral processing load persisted over the duration of the recording epoch (see Figure 7).

The ANOVA results for all electrode locations revealed a main effect of visual field, $F(1, 40) = 6.20, p < .05$, which occurred because amplitudes for verbs presented to the rvf/LH were more positive ($M = .63$ μV) than amplitudes for verbs presented to the lvf/RH ($M = .13$ μV). There were no main effects or two-way interactions involving either the voice or relatedness variable (all F's < 2.11). There was however a significant three-way voice x relatedness x electrode interaction, $F(1, 61) = 3.44, p < .05$, and these effects were modulated by a significant four way visual field x voice x relatedness x electrode interaction, $F(1, 61) = 3.44, p < .01$. To examine the nature of this effect, a distribution analysis was performed to investigate the early influence of experimental variables across different topographical scalp regions.

The distribution analysis revealed a significant three-way voice x relatedness x hemisphere interaction, $F(5, 40) = 7.28,\ p = .01$, and, importantly, a significant four-way visual field x voice x relatedness x laterality interaction, $F(7, 40) = 4.02,\ p = .05$. Comparisons revealed that this effect occurred because of several differences between related and unrelated verbs in both active and passive form in the two visual fields: For rvf/LH presentation, amplitudes elicited to related verbs in active voice were significantly more positive ($M = .381$ μV) than amplitudes for unrelated active verbs ($M = -.01$ μV) at lateral electrodes, $F(1, 40) = 17.33,\ p < .01$. At medial electrode sites, related active verbs were also more positive ($M = 1.01$ μV) than unrelated active verbs ($M = .35$ μV), $F(1, 40) = 52.13,\ p < .01$. Alternatively for passive verbs presented to the rvf/LH related verbs also elicited significantly more positive amplitudes ($M = .44$ μV) than unrelated verbs ($M = .22$ μV) at lateral electrode sites, $F(1, 40) = 5.52,\ p < .05$, but no significant differences were found at medial sites, $F(1, 40) = 2.33, p = .14$. This pattern of effects was not detected with lvf/RH presentation; for the RH, related active verbs were only found to be marginally more positive ($M = -.02$ μV) than analogous unrelated verbs ($M = -.18$ μV) only at lateral electrode sites, $F(1, 40) = 3.27,\ p = .08$. All other comparisons were non significant (all other F's < 1.89).

Additionally the same distribution analysis demonstrated a significant four-way visual field x voice x relatedness x anteriority interaction, $F(7, 40) = 9.31, p < .01$. Comparisons revealed that this effect occured due to several topographic differences between conditions: For active verbs presented to the rvf/LH, amplitudes elicited to related verbs were significantly more positive (M = 1.21 μV) than amplitudes to unrelated verbs (M = .09 μV) at prefrontal electrodes, $F(1, 40) = 32.86, p < .01$, and frontal electrodes (related active verbs, M = .94 μV; unrelated active verbs, M = -.01 μV), $F(1, 40) = 23.27, p < .01$. These effects did not occur at parietal or occipital electrode sites (both F's < 1). For passive verbs presented to the rvf/LH, amplitudes for related items were marginally more positive (M = .50 μV) than for unrelated items (M = .10 μV) at parietal electrodes, $F(1, 40) = 4.20, p = .07$, and at occipital electrodes, (related, M = .63 μV; unrelated, M = .26 μV), $F(1, 40) = 3.48, p = .09$. However, there were no differences in relatedness for passive verbs at prefrontal or frontal electrode locations (both F's < 1). For lvf/RH presentation, related active verbs elicited amplitudes that were only marginally more positive (M = .15 μV) than unrelated active verbs (M = -.28 μV) at parietal locations, $F(1, 40) = 4.72, p = .06$. No other differences were found at any other scalp location (all other F's < 1.70).

P2 (200-300 ms). The P2 component is thought to index higher order perceptual and attentional processes such as the perception of visual features in selective attention tasks (Hillyard & Munte, 1984; Luck & Hillyard, 1994) and has been shown to vary with hemispheric presentation of linguistic stimuli (e.g., Federmeier, et al., 2005). Thus, the P2 was analyzed in order to examine the influence of the experimental variables on higher-level perceptual processes. The overall ANOVA for this component revealed a significant main effect of visual field, $F(1, 40) = 9.07, p < .01$, which occurred because amplitudes for verbs presented to the rvf/LH were more positive (M = 2.87 μV) than amplitudes for verbs presented to the lvf/RH (M = 2.20 μV). A main effect of relatedness, $F(1, 40)$ =

1.83, $p = .05$, which occured due to more positive amplitudes for related ($M = 2.71$ µV) versus unrelated ($M = 2.36$ µV) verbs was also found. The main effect of voice was found to be non-significant, $F(1, 40) = 1.83$, $p = .18$. However, the three-way visual field x voice x relatedness interaction was found to be significant, $F(1, 61) = 5.57$, $p < .05$. To more closely examine the nature of this interaction separate 2 (voice: active and passive) x 2 (relatedness: related and unrelated) x 62 (electrode site) repeated measures ANOVAs were calculated for each visual field (lvf/RH and rvf/LH).

With lvf/RH presentation, no main effects, interactions or comparisons were found to be significant. However, with rvf/LH presentation a significant main effect of voice was found, $F(1, 40) = 4.02$, $p = .05$. As in Experiment 1, this effect occurred because responses to passive verbs were more positive ($M = 3.12$ µV) than responses to active verbs ($M = 2.60$ µV). The main effect of relatedness was also significant, $F(1, 40) = 5.08$, $p < .05$. This effect occurred because amplitudes for related verbs were more positive ($M = 3.16$ µV) than for unrelated verbs ($M = 2.58$ µV). Although the interaction between voice and relatedness did not reach significance, planned comparisons demonstrated that, for active verbs, amplitudes for related verbs were found to be significantly more positive ($M = 3.08$ µV) than amplitudes for unrelated verbs ($M = 2.13$ µV), $F(1, 40) = 8.67$, $p < .01$. However, for passive verbs, no differences were found between related and unrelated items ($F < 1$).

N400 (300-500 ms). In the N400 window, a main effect of visual field was found, $F(1, 40) = 4.82$, $p < .05$. This effect occurred because amplitudes for verbs presented to the rvf/LH were more positive ($M = 2.14$ µV) than amplitudes for verbs presented to the lvf/RH ($M = 1.71$ µV). A robust main effect of relatedness, $F(1, 40) = 13.56$, $p < .01$, was also detected. This effect occured because amplitudes for related items were more positive (M = 2.24 μV) than amplitudes for unrelated items (M = 1.60 μV). No main effect was found for voice, $F(1, 40) = 1.70, p = .20$. Additionally, a significant two-way visual field x relatedness interaction was detected, $F(1, 40) = 4.10, p < .05$. This effect occurred because responses to related items were significantly more positive (M = 2.61 μV) than responses to unrelated (M = 1.66 μV) verbs presented to the rvf/LH, $F(1, 40) = 19.09, p < .01$, whereas amplitudes to related verbs (M = 1.88 μV) did not differ significantly from amplitudes to unrelated verbs (M = 1.55) with lvf/RH presentation, $F(1, 40) = 2.27, p = .14$. No other interactions involving visual field, voice and relatedness occurred (all F's < 1).

Similar to the previous analysis, separate ANOVAs for the variables of interest in each hemisphere were again conducted. The results of these analyses demonstrated that for lvf/RH presentation, no significant main effects or interactions of interest were observed. However, with rvf/LH presentation, a significant main effect of voice was found, $F(1, 40) = 5.62,\ p < .05$. This effect occurred because amplitudes to passive verbs (M = 2.47 μV) were more positive than amplitudes to active verbs (M = 1.80 μV). A significant effect of relatedness was also found, $F(1, 40) = 16.35,\ p < .01$. This effect occurred because amplitudes for related items were more positive (M = 2.61 μV) than amplitudes for unrelated items (M = 1.66 μV). Although the voice x relatedness interaction was not significant (F < 1), planned comparisons demonstrated that, for active items, amplitudes for related verbs were found to be more positive (M = 2.36 μV) than for unrelated verbs (M = 1.23 μV), $F(1, 40) = 9.70,\ p < .01$. There was also a significant, yet considerably smaller difference found between related and unrelated passive verbs,

$F(1, 40) = 4.46$, $p < .05$. This effect was due to more positive amplitudes for related (M = 2.87 μV) relative to unrelated (M = 2.09 μV) verbs.

Late positivity complex (500-900 ms). LPC effects were measured at later time intervals in order to examine the effects of integrating the critical verb into sentence contexts. For the main ANOVA analysis, a large main effect of relatedness, $F(1, 40) = 37.33$, $p < .01$, was detected. This effect was due to more positive amplitudes for related (M = 2.76 μV) relative to unrelated (M = 1.75 μV) verbs. Alternately, no main effect of voice was found, $F(1, 40) = 2.03$, $p = .16$. A significant two-way visual field x relatedness effect was also observed in the main analysis, $F(3, 40) = 5.30$, $p < .05$. This effect occurred because responses to related items were significantly more positive (M = 2.98 μV) than responses to unrelated (M = 1.55 μV) verbs presented to the rvf/LH, $F(1, 40) = 30.87$, $p < .01$, whereas amplitudes to related verbs (M = 2.55 μV) also differed significantly from amplitudes to unrelated verbs (M = 1.96) with lvf/RH presentation, yet the effect was much smaller, $F(1, 40) = 5.29$, $p < .05$. No other interactions involving visual field, voice or relatedness reached significance (all F's < 1.74).

As with the previous analysis, separate ANOVAs were conducted for the variables in each hemisphere. The results of the ANOVAs demonstrated that, for lvf/RH presentation, a significant main effect of relatedness was found, $F(1, 40) = 5.58$, $p < .05$. This effect occurred because amplitudes for related items were more positive (M = 2.55 μV) than amplitudes for unrelated items (M = 1.96 μV). No significant effect of voice or voice x relatedness interaction was detected ($F < 1$). Planned comparisons were conducted to examine differences between related and unrelated verbs at each level of voice. For active verbs there were no significant differences between amplitudes for related ($M = 2.38$ μV) and unrelated ($M = 1.94$ μV) verbs, $F(1, 40) = 2.55, p = .12$. For passive verbs however, a significant difference between related ($M = 2.72$ μV) and unrelated ($M = 1.97$ μV) items was elicited, $F(1, 40) = 7.42,\ p < .01$.

For rvf/LH presentation, a significant main effect of voice was elicited, $F(1, 40) = 3.99,\ p = .05$. This effect occurred because amplitudes for passive verbs were more positive ($M = 2.54$ μV) than amplitudes for active verbs ($M = 1.99$ μV). A significant main effect of relatedness was also found, $F(1, 40) = 35.11,\ p < .01$. This effect was due to more positive amplitudes for related ($M = 1.55$ μV) as opposed to unrelated ($M = 2.98$ μV) verbs. Additionally, both a significant two-way voice x electrode interaction, $F(61, 2440) = 3.13,\ p < .01$, and a marginally significant two-way relatedness x electrode interaction, $F(61, 2440) = 2.29,\ p = .07$, were also detected. No other significant interactions occurred (all F's < 1). Planned comparisons were employed to examine differences between related and unrelated verbs at each level of voice. For active verbs, a significant difference between related and unrelated verbs was found, $F(1, 40) = 13.10, p < .01$. This result occurred because amplitudes were more positive for related ($M = 2.70$ μV) than unrelated ($M = 1.30$ μV) verbs. Additionally, a significant difference was found between related and unrelated passive verbs, $F(1, 40) = 13.94,\ p < .01$. This result also occurred because amplitudes for related verbs were more positive ($M = 3.26$ μV) than amplitudes for unrelated verbs ($M = 1.80$ μV).

To see all conditions plotted at a single central/parietal electrode site to illustrate amplitude differences in both the rvf/LH and lvf/RH, see Figures 8 and 9 respectively. For amplitude differences between related and unrelated verbs at each level of voice with rvf/LH presentation see Figure 10. For the same comparisons with lvf/RH presentation see Figure 11.

Discussion

This experiment was the first to examine hemispheric processing of thematic role information and morphosyntax. Because successful sentence comprehension depends on correct thematic role assignment (i.e., understanding who is doing what to whom), examining this basic linguistic function provides insight into each hemisphere's individual sentence processing capabilities. By using ERP measures, a temporally precise electrophysiological index of how variations in voice and thematic relatedness affect sentence processing was gained. Specifically, by utilizing ERP methodology, this experiment provided insight as to how the factors of voice and relatedness effected perceptual, attentional and semantic processing of critical verbs.

For early components, large differences in brainwave amplitudes at different levels of visual field (rvf/LH and lvf/RH presentation) emerged: Overall, the N1 component was largest for electrode locations contralateral to the visual field of stimulus presentation. Following the N1 a similar contralateral negative potential emerged and was sustained throughout the entire epoch (see Figure 7), suggesting that neural activity continued to depend on the initial visual field of stimulus presentation. This result replicated previous hemispheric ERP work which has also shown that negativity is sustained for electrodes contralateral to the visual field of stimulus presentation (Coulson et al., 2005; Federmeier & Kutas, 1999; Federmeier et al. 2005). Based on such an effect, it could be inferred that lvf/RH presentation resulted in a greater degree of RH processing whereas rvf/LH presentation had a homologous effect.

When examining the effects of voice and relatedness on the N1 component, different results that varied across electrode locations for rvf/LH and lvf/RH presentation were found: This is a very interesting finding in that it demonstrates how perceptual processing of critical verbs varies topographically as a function of both visual field of presentation and verb form. For rvf/LH presentation, as with central presentation, voice and relatedness had a reliable influence on brainwave amplitudes. For verbs presented in the active form, more positive brainwave amplitudes were dispersed across lateral and medial electrode sites whereas this difference occurred only at medial sites for passive verbs. Additionally, a topographical difference occurred between posterior and anterior electrode locations: Increased positive amplitudes for related active verbs relative to unrelated active verbs occurred only at the most frontal electrode locations whereas the same positive advantage for related passive items occurred only at the most posterior electrodes. This work is the first of its kind to find such topographic effects in the N1 time window with hemispheric presentation and as such the results are somewhat difficult to interpret. It may be speculated that for rvf/LH presentation, at parietal scalp sites, amplitude differences between related and unrelated passive verbs may represent an increased ease of lexical access for thematically related and most frequent items with rvf/LH presentation. This finding is supported by previous work (using central presentation) which has found both context and frequency can influence lexical access (Sereno, Brewer, & O'Donnell, 2003). For differences between active words at anterior electrodes it may be difficult to argue that higher order visual perception processes (thought to be indexed in this time window) is stronger at these electrode locations since anterior regions are thought not to be advantaged for such processing. Instead, it is possible the results may represent some form of attentional modulation for preparing the congruent verb form for subsequent use in working memory. This idea is based on the finding that attentional linguistic processing can be biased towards anterior electrodes (e.g., Federmeier et al., 2005) and that effects at frontal sites have been proposed to be indicative of differences in short term memory processing (e.g., King & Kutas, 1995). However, because this study is the first to find such effects with lateral presentation, interpretations of effects at this time are somewhat speculative.

For lvf/RH presentation, more positive amplitudes for related active vs. unrelated active items were found as well (although only at parietal locations). These parietal differences may again be indicative of variations in lexical access for the congruent active verb form, although comparisons for related and unrelated verbs at different topographic locations did not interact as reliably as with rvf/LH presentation. Coupled with the fact that this work is the first of its kind to find such early RH differences any conclusions drawn about lexical access for RH processing should be made with caution. Overall, additional research is eventually required to further understand the nature of the topographic variability of such early effects elicited with lateral presentation. It can however be contended that because the amplitude patterns for the differences (related more positive than unrelated) are similar to findings for centrally presented verbs, the findings converge to demonstrate that neural resources are recruited quickly and are constrained by factors such as frequency and voice to process thematically related verbs. This finding is important in that it is one of very few that has found effects of linguistic variables in such an early time window (see Soreno & Rayner, 1999), and is the first to elicit such effects hemispherically using the VHF paradigm.

As with central presentation, P2 amplitudes once again demonstrated sensitivity to the most frequent verb form in that, overall, passive verbs were processed more easily than active verbs, although this effect was only detected for rvf/LH presentation. This overall advantage for passive verbs demonstrated that, in the same manner as conjoint processing, the LH orients attention to the most frequent form of a word. Amplitudes for the P2 latency window also demonstrate that the brain is sensitive to the thematic fit between agent nouns and active verbs with rvf/LH presentation. In the LH, related items elicited significantly more positive amplitudes than did unrelated items for active, but not passive, verbs, an effect similar to that found with central presentation. However unlike central presentation, no cross-over interaction showing a processing advantage for unrelated passive verbs in the same time window was found.

For the N400, differences between related and unrelated items in the left hemisphere were similar to those found with central presentation: Overall, amplitudes for related verbs were more positive than amplitudes for unrelated verbs. Additionally, when comparisons examined this difference at each level of voice, active verbs showed larger differences between amplitudes for related relative to unrelated items compared to passive verbs. One difference between lateral and central presentation however, was that when verbs were presented to the LH, the main effect of voice was also present in the N400 time window, whereas with central presentation, the effect of voice was only present for early ERP components. This contrasting effect indicates the most frequent form of verb remains advantaged throughout the N400 processing window. Surprisingly, only small, non-significant effects of relatedness were found with lvf/RH presentation. Although it was anticipated that the RH may not process information connected to the verbs in the same manner as in the LH, it was expected that significant differences in amplitudes for related versus unrelated items would be detected in this time window (Coulson et al., 2005; Federmeier et al., 2005).

The LPC also showed more pronounced positive amplitude advantages for related items with rvf/LH presentation. As in Experiment 1, comparisons revealed that large differences between unrelated and related active verbs occurred because amplitudes were significantly more positive for related relative to unrelated verbs. Additionally, large differences in the same direction were also found for passive verbs, a finding which differs from central presentation of the items where no relatedness effects were found for these items. Also, as with N400 effects, there was still an overall advantage for passive verbs. This may indicate that passive verbs were more salient with rvf/LH than with central presentation and may also explain why there was an increased sensitivity to relatedness for passive items with rvf/LH as opposed to central presentation. Recall that in Experiment 1, overall advantages for the passive verbs were not found after the P2 component and thus with independent LH processing, the advantage of the most frequent morphological form of the verb persists for a much longer duration. Additionally, the LPC was the only component to show overall relatedness difference with lvf/RH presentation, although such differences were found only for passive verbs. These results indicate that, although evidence was provided that indicates the RH distinguishes between related and unrelated active verbs at the early moments of processing (see N1 results), it remains sensitive to relatedness differences only the most frequent (passive) verb form. Specifically, the RH is only showing relatedness effects for contexts containing related words in incongruent thematic conditions (e.g., *The cop was arrested*), whereas the LH shows relatedness effects for both forms of the verbs. This suggests that the RH is not competently processing the active verb form and is more sensitive to high frequency information than congruency between noun and verb form. Thus, the RH only seems to use relatedness information to aid processing when the particular most frequent form of the verb is made salient. Although this result does provide evidence to support the contention that each hemisphere utilizes different mechanisms to comprehend sentential information (e.g. Coulson et al., 2005), the pattern of results does not indicate that the RH is sensitive to the congruency between an entity's thematic role and morphosyntactic information. Even so, the results are the first of their kind to examine the processing of thematic roles in conjunction with morphosyntactic information in the RH. Future research is required to understand the exact nature of the cognitive processes that underlie this effect.

Overall, it is apparent that the cerebral hemispheres can independently combine different sources of information (such as frequency, semantic and syntactic information) to subsequently process active and passive verb forms. These results are the first to examine how the thematic relatedness between a noun and verb interacts with morphosyntactic information to constrain hemispheric sentence processing. Additionally the findings are the first to provide an electrophysiological index of thematic role processing to expand earlier ERP work which has shown that hemispheric responses to critical words are sensitive to sentential constraint (Coulson et al., 2005; Federmeier et al., 2005).

Although the results of this study do further the understanding of hemispheric sentence processing, there was a paucity of effects elicited from lvf/RH presentation.

Generally, evidence from these experiments may suggest that the RH is not as able as the LH to integrate multiple information sources and generate sentential context. However, the results for RH processing are surprising in that previous ERP work has found relatedness effects that are as strong as (or at least comparable to) those for LH processing (e.g., Coulson et al., 2005). It would be expected that some relatedness effects would be detectible in the N400 time window. However, the item set employed in this study is quite different from that used in previous ERP or behavioural work and there may be several reasons for the relative paucity of RH results: Firstly, the fact that verbs were used as target words distinguishes this work from the vast majority of past VHF research which has typically examined responses to nouns in order to draw conclusions about intra-hemispheric processing (e.g., Chiarello et al., 2001; Coulson et al., 2005; Faust et al., 1995; Faust et al., 2003; Federmeier & Kutas, 1999; Federmeier et al., 2005). Previous work using priming to examine the difference between the hemispheric processing of nouns and verbs has shown that verbs are processed more slowly in the RH than in the LH (Sereno, 1999). Such a finding is consistent with effects found in the current study which show that the RH was not sensitive to relatedness between noun and verb until a much later point in processing compared to the LH (i.e., in the LPC region). Previous priming results also show that this delay for verbs may have varied based on the frequency of the particular phrases (advantages for more frequent words – Sereno et al., 1999). Additionally, it is fair to propose that the words used in the current study were more 'information heavy' than words used in previous work (Soreno et al., 1999). For instance, the verbs employed by Soreno et al., (1999) in a previous experiment were very basic, short items (e.g., *sing*) and were not suffixed with morphemes that altered the verbs congruency with a preceding concept. Therefore, it is conceivable then that the processing load for the current items was substantially larger. Thus, because of these reasons, it may not be surprising that delays for semantic effects occurred in the RH relative to the LH.

Secondly, another possible explanation for a lack of N400 effects for lvf/RH presentation is that the degree of relatedness between target items and the previous context was much stronger in previous work. In prior ERP studies, semantic differences between associated (e.g., *olive-oil*) and unassociated items (e.g., *olive-shoes*) as well as congruous (e.g., *The Italian cook always added too much olive* oil) and incongruous (e.g., *They were hard to walk in, but she loved her olive* oil) items can be thought of as larger relative to differences between thematically unrelated (e.g., *fireman was lectured*) word pairs. Typically, previous work has demonstrated distinctly larger N400 (and sometimes earlier) responses to items that form anomalous, improbable concepts relative to plausible items. Such items are ideal for eliciting N400 effects which index the degree of semantic relatedness between a word and its context along a continuum (e.g., Fedemeier & Kutas, 1999).

Third, even when N400 differences have been found between plausible sentence endings in previous work (e.g., Federmeier et al., 2005), a large, elaborated semantic context has been established in each hemisphere prior to responses to final words. In the current study, only plausible sentences were constructed and N400 effects were analysed at words appearing early in the sentence. Although this manipulation was strong enough to detect N400 differences with LH (and central) presentation, the RH was not satisfactorily able to process the thematic fit between nouns and verbs. Thus, based on differences in each hemisphere's verb processing capability (delayed for the RH – Sereno 1999), as well as more subtle semantic differences between the current items and those employed in previous work (e.g., Coulson et al., 2005), it may not be surprising that RH semantic sensitivity to relatedness may have been decreased in the current work. However, despite this disparity, at later stages of word processing, the RH shows reliable sensitivity to semantic relations between the head noun and subsequent (passive) verb.

General Discussion

Overall, by presenting critical verbs both centrally (Experiment 1) and laterally (Experiment 2), evidence as to how thematic role processing is undertaken conjointly and in each hemisphere independently was gained. Particularly, the main experimental goals proposed for the experiment were achieved: First, by using ERP methodology, a precise physiological index of how active and passive verbs are processed in each hemisphere was attained. By employing this methodology, some of the drawbacks inherent with using basic behavioural paradigms were circumvented. For instance, ERPs allow for millisecond temporal resolution to examine language processing and thus reputed waveforms corresponding to perceptual, attentive and semantic functions provided insight into how the processing of critical verbs unfolded. When using standard behavioural measures, separate cognitive operations can often confound results intended to investigate a single process (Bub & Arguin, 1995). Also, by using ERP methodology it was unequivocally demonstrated that lateralized stimuli were received more prominently by the contralateral cerebral hemisphere. Additionally, by recording horizontal and vertical eye-movements trials contaminated by such artifacts could be unambiguously identified and removed from analysis. Such advantages are not afforded when employing standard behavioural measures.

Secondly, the experimental design employed in the current study allowed for the examination of theories addressing the semantic activation of event knowledge from memory. Using ERPs to examine thematic role processing produced strong evidence against SA theories in that the facilitation for related relative to unrelated verbs was strongly mediated by voice. Several key findings from the first experiment in this study highlight the strong interaction between voice and relatedness: P2 effects revealed that amplitudes for related active verbs were more positive than for unrelated active verbs. Conversely, P2 amplitudes for unrelated passive verbs were significantly more positive than amplitudes for related passive verbs. This finding indicates that the brain is not prepared to process the specific passive form of thematically related verb in relation to the agent noun. This modulation in amplitudes suggests that attentional resources are being taken away from processing the particular verb based on its incongruence with the role of the preceding noun and thus making subsequent integration of this word more difficult. This crossover interaction is indeed very interesting and exemplifies the importance of congruency between a head noun and an appropriate verb for facilitated processing. The reliability of this effect is bolstered by results from unpublished data examining the processing of agent nouns preceded by a thematically related or unrelated participle (e.g., *The arresting cop...*), which have elicited a similar interaction (Ferretti & Schwint, unpublished data). Additionally in Experiment 1, amplitude differences between related and unrelated verbs in the N400 and LPC epochs also varied between active and passive voice. Particularly, larger relatedness effects were observed only for active verbs, a finding that illustrates that the brain was more attuned to process the thematically congruent verb form.

Thirdly, the results of the current study provide the first known electrophysiological evidence which informs how thematic role processing in undertaken in both the LH and RH. Several interesting findings emerged from these results: First, it was demonstrated that with presentation to both visual fields, linguistic features such as frequency information are recognized at early moments after stimulus presentation. Both hemispheres demonstrated sensitivity to the verb form congruent with the preceding agent noun at these early moments (although this effect was much stronger in the LH). This suggests that the brain's perceptual scrutiny was able to distinguish between features of the related and unrelated active verbs more strongly than passive verbs. Such a result was also observable in Experiment 1 and serves to bolster the reliability of hemispheric N1 differences. This early effect of linguistic variables is a very notable finding in that it has only been previously documented in a small number of instances (Soreno & Rayner, 2003; Soreno et al. 1998).

Consistent with Experiment 1, P2 amplitudes were also found to again illustrate the interaction between voice and relatedness with rvf/LH presentation. Even though there was no crossover interaction with voice (as found in Experiment 1), the lack of this result is not totally unexpected in that is was found that LH presentation elicited a greater overall sensitivity to relatedness relative to central presentation. This effect is similar to disparities between results for central and lateral presentation found in previous work (e.g., Coulson et al., 2005). This may explain why amplitudes did not differ significantly between related and unrelated passive verbs (based on Experiment 1 findings it is expected that unrelated verbs be more positive), even though attentional resources may be allocated in a manner similar to that which occurs with conjoint hemispheric processing.

Finally, N400 and LPC effects for hemispheric processing also serve to demonstrate how amplitude differences between related and unrelated items can vary based on voice. With rvf/LH presentation, as with central, sensitivity to relatedness differences was more pronounced for active verbs. In the LH, there were stronger relatedness differences for passive verbs than found with central presentation, however, as with P2 amplitudes, this may be due to an overall increased sensitivity to relatedness differences with rvf/LH presentation. As mentioned previously, this increased sensitivity has also been observed in previous work where even in incongruent conditions the brain was still sensitive to lexical association between individual words (Coulson et al., 2005). In the RH, sensitivity to relatedness differences did not occur until approximately 500 ms post stimulus and were more pronounced for passive verbs (i.e., verbs that were thematically incongruent with the preceding noun). Although such a finding did not correspond exactly to the hypothesized results, it nevertheless demonstrates that the RH is sensitive to relatedness differences and that effect may be mediated by frequency information rather than verb morphology. However, caution must be exercised when interpreting such results because such ERP findings in response to the congruency between thematic relatedness and verb morphology are preliminary in the hemispheric literature. To decipher the exact nature of this RH effect, future research examining different aspects of thematic role processing is required.

Overall such findings provide the first evidence documenting how thematic role processing occurs between the two cerebral hemispheres. These results successfully further the finding of previous work that has examined the comprehension of sentence information within both the LH and RH by demonstrating that each hemisphere is active during early sentential processing (e.g., Coulson et al., 2005; Federmeier et al., 2005). More importantly, in addition to advancing results from particular studies, these findings further inform theories that have proposed mechanisms by which each hemisphere is able to understand linguistic information.

Implications for Theories of Hemispheric Laterality for Language

The results of this study contribute to debates regarding the nature of the linguistic processing capabilities of each hemisphere. As mentioned previously, an influential model of functional asymmetry between to the two cerebral hemispheres posits that there is a disparity between each hemisphere's ability to utilize message-level information from sentences (Chiarello, 2000; Faust et al. 1998; Faust et al., 1995). In this model, the LH has the ability to integrate syntactic, semantic and pragmatic information to form conceptual representations from sentential information, whereas the RH is primarily only capable of bottom-up activation of semantic information established from incoming words. This hypothesis has been proposed based on results from priming studies where the RH has been shown to be insensitive to multi-word contexts in the form of summation primes (e.g., Faust et al., 1993) and message level incongruity (e.g., *The patient parked the medicine* – Faust et al., 1995). When applied to the current study, such a model of lateralized processing would predict that in the RH, only the relatedness between the head agent noun and subsequent verb would affect brainwave amplitudes since a broad range of semantically related items would be activated upon reading the noun. This semantic activation would spread diffusely but would not be modified based on the morphological form of the verb (since syntactic information would not be integrated).

However, the results for lvf/RH presentation in the current experiment showed that amplitude differences between related and unrelated items may have been modulated based on the frequency of the verb form. Specifically, sensitivity to differences between thematic relatedness in the LPC region was detected only for passive verbs. Although such results do not mimic the sensitivity to voice found in the LH, amplitude differences for related items seem to have been affected by information other than the semantic relatedness between noun and verb (i.e., the specific verb form). Although further research is required to determine the specific processes that can account for such effects, results indicate that word-word priming mechanisms based solely on semantic relatedness do not account for the elicited pattern of results. Generally, these findings are consistent with previous hemispheric ERP work that has demonstrated that the RH is sensitive to more than simply the word-level relatedness between priming pairs and may be able to combine information from multiple words (Federmeier et al., 2005).

As discussed previously, the findings of the current study are also problematic for SA theories which propose that the strength of activation for a particular concept in memory is dictated solely by the degree of semantic relatedness between words (Collins & Loftus, 1975). Consequently, the present findings also provide evidence against the assertion that such models adequately describe the nature of semantic processing in the LH. For instance, Deacon and colleagues have proposed that semantic memory is represented in different memory systems between the two cerebral hemispheres (Deacon, Grose-Fifer, Yang, Stanick, Hewitt, & Dynowska, 2004). This model of hemispheric asymmetry contends that in the LH semantic concepts are represented in distinct nodes and this system of nodes is connected by associative links as in SA models. Additionally, this model also contends that a wholly different memory system in the RH utilizes information from words in a completely different way. In the RH semantic memories are stored in a distributed system (e.g., Masson, 1995) where activation of concepts is dependent upon similarity between semantic features. Thus, when a word (e.g., *APPLE*) is read, it immediately activates an aggregate of semantically related features (e.g., is a fruit, tastes pleasant, is healthy, etc.) and when a word is read that shares a number of those features (e.g., *ORANGE*) semantic facilitation occurs based on featural overlap. When an unrelated item is read, it resets the configuration of the activated feature set because comparisons reveal no featural match, and thus, activation becomes weaker. This hypothesis is predicated upon ERP results that have shown that associatively related items that do not share semantic features (e.g., *DOG-BONE*) produce ERP advantages (relative to unrelated pairs) presented to the rvf/LH but not the lvf/RH. Conversely, items that share semantic features but were neither associates nor from the same semantic category (e.g., *BROCCOLI-TREE*) produced ERP advantages with lvf/RH, but not rvf/LH presentation (Deacon et al., 2004).

The findings of the current study are problematic for this model for processing in both hemispheres. In the LH, if semantic concepts are represented holistically and activation spreads as a function of the associative relatedness between items, then the activation of a concept from memory should be unaffected by varying the morphological linguistic properties representing that concept. Thus for the current study, it would be expected that facilitation would depend solely on the degree of thematic relatedness between items (as in Experiment 1). However, it was clearly demonstrated that with rvf/LH presentation, as with central presentation, relatedness effects for verbs varied based on the congruency between the agent noun and specific morphological verb form. In the lvf/RH a different pattern of results would be expected: It can be thought that a semantically encoded feature of a particular agent noun may be that they initiate a certain action (e.g., for *cop, arrests criminals*) rather than have that action imposed upon them (e.g., *cop* would not have the feature *arrested by*___). This would suggest that the nouns used in the current study share more features with active than with passive verbs. Thus, it would be expected that only active verbs would show any facilitation for related relative to unrelated items because the action represented by the verb in this form would be a common semantic feature that is representative of the particular agent noun. Alternatively, it would be expected that no facilitation at all occurs for passive verbs because these items could be construed as having little to no featural overlap with preceding agents. The results for lvf/RH presentation demonstrate that facilitation was strongest for verbs presented in the passive voice and this result is contrary to the notion that facilitation for related items is based solely on featural similarity.

Thus, overall, this experiment provides evidence against the two aforementioned theories (Faust et al., 1995; Deacon et al., 2004) that have proposed particular, differential semantic processing mechanism between each brain hemisphere. Conversely, the results of the current experiment are supportive of models based on ERP findings which posit an ‘expectancy account’ of the LH’s language processing abilities

(Federmeier & Kutas, 1999). This model has been posited to account for ERP results in which the pattern of semantic integration for final words after participants read pairs of sentences (e.g., *He caught the pass and scored another touchdown. There was nothing he enjoyed more than a good game of…*) ending in either an 'expected exemplar' (*FOOTBALL*), a 'within category violation' (*BASEBALL*) or a 'between category violation' (*CHESS*), did not support common theoretical contentions (based on priming studies) about each hemisphere's semantic processing capabilities. Recall that, based on results from behavioural studies examining hemispheric semantic processing capabilities (e.g., Chiarello, 1990), researchers typically thought the LH was characterized by quickly selecting a particular meaning of a word and suppressing others, whereas the RH is given to diffuse ('loose') semantic activation (Beeman & Chiarello, 1998). Based on such an contention, one would predict that responses to both type of 'violations' would show equally less positive ERP amplitudes relative to the expected ending in the LH because they would both be suppressed and equally difficult to access. Whereas in the RH, one may think that responses to 'within category violations' may be facilitated relative to 'between category violations' since the diffuse spread of semantic activation may be more likely to activate a distant category member related to the expected ending. In fact, the opposite pattern of results occurred; LH responses presented with a gradient of amplitudes that were directly correlated with the degree of contextual semantic relatedness between endings (i.e., largest ERPs for 'between category violations', medium ERPs for 'within category violations' and smallest for 'expected exemplars') and RH responses differed between exemplars and violations but did not differ between the violation types. Thus the authors proposed that LH semantic activation may be based on featural similarity.

In this account, when reading sentence information, the context in which a word is processed is assumed to activate the semantic features of the item most strongly consistent with (i.e., predicted by) the context. It is these predictive features that are then compared with the target item, with the amount of facilitation for this word a function of the extent of semantic overlap between the actual word and the word that the LH has actively predicted. In the previous work (Federmeier & Kutas, 1999), 'within category' violations share more semantic features with the 'expected exemplar' than the 'between category violations' and thus, ERP responses show this facilitation accordingly. In the case of the current study then, the active form of verb would be most consistent with the properties of the previously read agent noun (e.g., 'arrests people' is a feature of cop), whereas the passive verb would be less likely to be activated (gets arrested is not a semantic feature). Thus it would be postulated that the LH is actively generating a prediction as to what the next word in a sentence will be based on information from the agent noun. Previous work using priming has also shown that such expectations can be generated from congruent noun-verb form information (Ferretti et al., 2005). With the current item set, based on the consistency between agent noun and verb form, the related active verb would be most strongly predicted. This account correctly predicts the pattern of the P2 and N400 results in that strong differences were found between related and unrelated active verbs, whereas much weaker (yet still significant) differences were found with passive verbs. This pattern of results demonstrates the gradient of facilitation that the LH 'expectancy' account would predict.

Additionally, the results of this study also demonstrate some typical characteristics of lvf/RH processing. For instance studies employing computational modelling methods (e.g., Burgess & Lund, 1998) as well as priming studies (e.g., Burgess & Simpson, 1988) have shown semantic information builds more slowly in the RH relative to the LH, a result consistent with the delayed relatedness differences for passive verbs with lvf/RH presentation. This slower processing of semantic information in general coupled with the finding that verbs specifically are processed more slowly in the RH (Soreno, 1999), may further explain why differences in semantic relatedness did not appear until later in the recording epoch relative to the LH. Additionally, such work has shown that semantic processing in the RH can be facilitated by frequency information (Burgess & Simpson, 1998). It has also been suggested that the RH can maintain larger amounts of information over longer periods of time than can the LH (Kirshner, 1980; Kirshner & Brown, 1981). Such a characteristic would help to explain why the RH maintained the sensitivity to relatedness differences for the most frequent verbs until the later stages of the recording epoch.

However, although the results of the current study are consistent with some reputed RH processing characteristics, no currently relevant model of RH sentence/semantic processing appears to fully account for the observed pattern of results. Even so, the finding of a late sensitivity to more frequent verb forms as well as qualitatively different results than elicited with rvf/LH presentation warrant further examination of RH semantic capabilities. While, the findings of the current study do not indicate the RH is sensitive to the congruency between thematic fit and morphosyntactic information, presentation to this hemisphere did however show interesting early and late effects which provides a basis for investigation into the types of information the RH utilizes when processing nouns and verbs.

Limitations of the Current Study and Future Research

Although the results of the current study are greatly informative with regard to how thematic role processing occurs in each hemisphere, there are potential limitations to the generalizability of conclusions drawn from the findings. Particularly, it is uncertain whether the effects elicited in the study that varied as a function of voice can wholly be attributed to this factor. One potential confound in the experiment is that verbs presented in different voice were also presented in different aspectual form. Aspect is a grammatical category that uses morphology to refer to the temporal structure of event (e.g., ongoing vs. completed). In the current study, items presented in active voice were also presented with ongoing, imperfective aspect, whereas items in passive voice were presented in a complex perfective aspect (i.e., denoting a completed event). Thus, it could be contended that modulations in amplitudes based on variations in voice could also be attributed to differences in aspect because variations in this factor has been shown to affect ERP waveforms (Ferretti et al., 2007). Thus, future research designed to examine the effects of modulations in voice would benefit from controlling for this factor.

Although the results of this study greatly inform how active and passive verbs are processed based on the thematic fit with a preceding agent noun, further research is required to more intricately understand how thematic role knowledge is utilized as an initial sentence context progresses from three words to four words to five words, etc. Based on a survey of past research that has examined thematic role processing (e.g., Ferretti et al., 2003; Ferretti et al., 2001), there are several possible experiments which may further inform how sentence processing occurs between cerebral hemispheres. For instance using adjectival participle-noun combinations as initial sentence clauses (e.g., *The arresting cop…/ The arrested cop…*) would (like the current study) demonstrate how interpreting thematically related and unrelated concepts can be modified based manipulating the inflections placed on participles. Based on results from the current experiment as well as previous behavioural work that has examined the processing of these word combinations (Ferretti et al., 2003), it would be hypothesized that present participles (e.g., *arresting*) combine more readily with good agent nouns (e.g., *cop*) than do past participles (e.g., *arrested*). This experiment would examine how information from the inflected participles would affect the processing of critical noun targets. Thus such an experimental design would compliment the current work by showing how information from participles (which are derived from verbs) affect the processing of agent nouns, rather than showing how reading nouns affects the processing of verbs. Note that preliminary data collection for such an experiment has begun (for central presentation) and data has thus far resembled that of Experiment 1.

Another possible experiment that could be implemented to examine hemispheric thematic role processing would also examine active and passive sentences but would employ the more frequent simple past tense form of active verbs (e.g., *The man arrested the*___). In such an experiment, ERP responses would be recorded to nouns presented at the end of the aforementioned active sentences as well as their counterpart passive sentences (e.g., *The man arrested by the*___). This paradigm would more closely resemble that used in previous hemispheric ERP research in that sentence final nouns would be used as the critical words. Such an experiment would resolve some limitations of the current work by controlling for the frequency of specific words, as well as verb aspect, and would expand upon previous behavioural work that has employed a similar item set (Ferretti et al., 2001). Using this experimental design, it would be expected that ERP responses to critical agent nouns would be modified based on a greater congruency with the active form of sentence and thematic relatedness to the preceding verb.

By employing these new types of sentences in addition to the item set used in the current study, an examination of how thematic role processing proceeds with increased sentential context can be gained: First, by using participle noun combinations (e.g., *The arrested cop…*) early sentence processing based on responses to nouns preceded by an inflected participle can be examined. Secondly, in the current study, responses to verbs preceded by a common agent noun and the auxiliary *was* (e.g., *The cop was arrested…*) were examined, and demonstrated how expectations for specific verb forms were modified based on congruency with the preceding noun. Thirdly, by examining responses to nouns preceded by a more developed sentence context (e.g., *The man was arrested by the*___) the processing of thematic role information at sentences final words can be gauged. Thus, whereas the current study was successful in demonstrating how thematic fit between nouns and verbs can influence ERP responses to critical verbs, future work is needed to more comprehensively understand how thematic role processing proceeds at various points in the development of a sentence context in conjunction with different morphological forms of verbs. The results of the current research are encouraging and demonstrate that a more detailed understanding of how sentence comprehension is undertaken by each hemisphere can be gained using ERP methodology to examine the processing of thematic role information.

Table 1

Examples of target sentences used during testing for all experimental conditions.

Voice	Relatedness	Example sentence
active	*related*	The teacher was lecturing the man. The tourist was visiting the museum in Cuba. The thief was swindling the unsuspecting woman.
passive	*related*	The teacher was lectured by the man. The tourist was visited by his best friend while in Cuba. The thief was swindled by his colleague.
active	*unrelated*	The shepherd was lecturing the man. The student was visiting the museum in Cuba. The inspector was swindling the unsuspecting woman.
passive	*unrelated*	The shepherd was lectured by the man. The student was visited by his best friend while in Cuba. The inspector was swindled by the smooth talking restaurant owner.

Table 2

Mean Likert agenthood and patienthood ratings for both related and unrelated nouns.

	Agenthood rating	Patienthood rating
Related	6.32	3.23
Unrelated	2.61	2.85

Table 3

Left) Mean frequency ratings for target verbs in both 'ing' and 'ed' forms. Right) log of mean frequency of target verbs preceded by 'was' according to google.

	Frequency		Log Google Frequency
verb'ing'	17.22	was verb'ing'	5.19
verb'ed'	36.71	was verb'ed'	5.79

Table 4

Experiment 1: Summary of results for all epochs of interest

Effect	Latency Region N1 100 – 200 Vs	P2 200 – 300 Vs	N400 300 – 500 Vs	LPC 500 – 900 Vs
Voice (V)	$F(1, 28) = 4.43$*	$F(1, 28) = 3.24$ [a]	$F < 1.05$	$F < 1$
Relatedness (R)	$F < 1$	$F < 1$	$F(1, 28) = 13.45$**	$F(1, 28) = 7.40$**
VxR	$F(1, 28) = 12.57$**	$F(1, 28) = 11.72$**	$F < 1.44$	$F < 1.34$
Vx electrode (E)	$F < 1$	$F < 1$	$F < 1$	$F < 1$
RxE	$F < 1$	$F < 1$	$F < 1.80$	$F < 1.43$
VxRxE	$F < 1.22$	$F < 1.60$	$F < 1$	$F < 1.37$

*p < or = .05
** p < or = .01
[a] $p > .05$ and $< .10$

Table 5

Experiment 2: Summary of results for all epochs of interest

	Latency Region			
Effect	N1 100 – 200 Vs	P2 200 – 300 Vs	N400 300 – 500 Vs	LPC 500 – 900 Vs
Visual field (VF)	F(1, 40) = 6.20*	F(1, 40) = 9.07**	F(1, 40) = 4.82*	F < 1
Voice (V)	F(1, 40) = 2.10	F < 1.82	F < 1.70	F(1, 40) = 2.03
Relatedness (R)	F < 1.87	F(1, 40) = 4.03	F(1, 40) = 13.56**	F(1, 40) = 37.33**
VFxV	F < 1	F < 1.26	F(1, 40) = 2.67	F < 1
VFxR	F < 1	F < 1.45	F(1, 40) = 4.10*	F(1, 40) = 5.30*
VxR	F < 1	F < 1	F < 1	F < 1
VFxElectrode (E)	F(61, 2440) = 12.25**	F(1,61) = 11.91**	F(1,61) = 11.79**	F(1,61) = 13.80**
VxE	F < 1.81	F < 1.38	F < 1.55	F < 1.32
RxE	F < 1	F < 1.53	F < 1.69	F < = 1.74
VFxVxR	F < 1	F(61, 2440) = 5.57*	F < 1	F < 1
VFxVxE	F < 1	F < 1	F < 1.05	F < 1.46
VFxRxE	F < 1	F < 1	F < 1	F < 1
VxRxE	F(61, 2440) = 2.37*	F < 1	F < 1	F < 1
VFxVxRxE	F(61, 2440) = 3.44**	F < 1.39	F < 1	F < 1

*p < or = .05
** p < or = .01
[a] p > .05 and < .10

Figure Captions

Figure 1. Schematic diagram showing electrode sites with labels representing the electrode caps used in the study.

Figure 2. Grand average ERPs to target verbs in Experiment 1 (central presentation). The layout of electrode sites in the figure approximates their spatial location on the scalp. Mean amplitudes for all experimental conditions at each electrode site are shown in the array. Negative amplitudes this figure and all analogous figures are plotted up.

Figure 3. Mean amplitudes for target verbs in all four conditions at a central parietal electrode site (CPZ) in Experiment 1. Negative amplitudes for this individual electrode site and all subsequent sites displayed are plotted up. Responses to unrelated active verbs were least positive throughout the duration of the recording epoch, followed by responses to unrelated passive verbs.

Figure 4. (A) Mean amplitude differences between related and unrelated active verbs at a central parietal electrode site (CPZ) in Experiment 1. Unrelated active items are least positive throughout the duration of the recording epoch. (B) Mean amplitude differences between related and unrelated passive verbs at a central parietal electrode site (CPZ) in Experiment 1. Initially, in the P2 (200-300 ms) region related passive verbs are least positive. This effect reverses during the N400 (300-500 ms) time window. Differences between related and unrelated active verbs are much larger than differences between related and unrelated passive verbs.

Figure 5. Grand average ERPs to target verbs in Experiment 2 for rvf/LH presentation. The layout of electrode sites in the figure approximates their spatial location on the scalp.

Mean amplitudes for all experimental conditions at each electrode site are shown in the array. Negative amplitudes are plotted up.

Figure 6. Grand average ERPs to target verbs in Experiment 2 for lvf/RH presentation. The layout of electrode sites in the figure approximates their spatial location on the scalp. Mean amplitudes for all experimental conditions at each electrode site are shown in the array. Negative amplitudes are plotted up.

Figure 7. (A) Responses to target verbs for all conditions are shown at a left (PO5) parietal/occipital scalp sites. N1 (100-200 ms) and sustained negativity (300-900 ms) are larger for rvf/LH presentation. (B) Responses to target verbs for all conditions are shown at a right (PO6) parietal/occipital scalp sites. N1 (100-200 ms) and sustained negativity (300-900 ms) are larger for lvf/RH presentation. These effects demonstrate that lateralized stimuli were processed more prominently over contralateral electrode locations.

Figure 8. Mean amplitudes elicited to target verbs presented to the rvf/LH for all four conditions at a central parietal electrode site (CPZ) in Experiment 2. Responses to unrelated active verbs and unrelated passive verbs were least positive throughout the duration of the recording epoch.

Figure 9. Mean amplitudes elicited to target verbs presented to the lvf/RH for all four conditions at a central parietal electrode site (CPZ) in Experiment 2. A greater positivity begins for active related verbs relative to active unrelated verbs at later latency periods (500-900ms) than with rvf/LH presentation.

Figure 10. (A) Mean amplitude differences between related and unrelated active verbs at a central parietal electrode site (CPZ) for rvf/LH presentation in Experiment 2. Unrelated

active items are least positive throughout the duration of the recording epoch. (B) Mean amplitude differences between related and unrelated passive verbs at a central parietal electrode site (CPZ) for rvf/LH presentation in Experiment 2. Differences between related and unrelated active verbs were found to be larger than differences between related and unrelated passive verbs.

Figure 11. (A) Mean amplitude differences between related and unrelated active verbs at a central parietal electrode site (CPZ) for lvf/RH presentation in Experiment 2. No significant differences were found between amplitude differences for related and unrelated active verbs at later latency windows. (B) Mean amplitude differences between related and unrelated passive verbs at a central parietal electrode site (CPZ) for lvf/RH presentation in Experiment 2. Differences between related and unrelated passive verbs were significant in the LPC (500-900 ms time window.

Figure 1

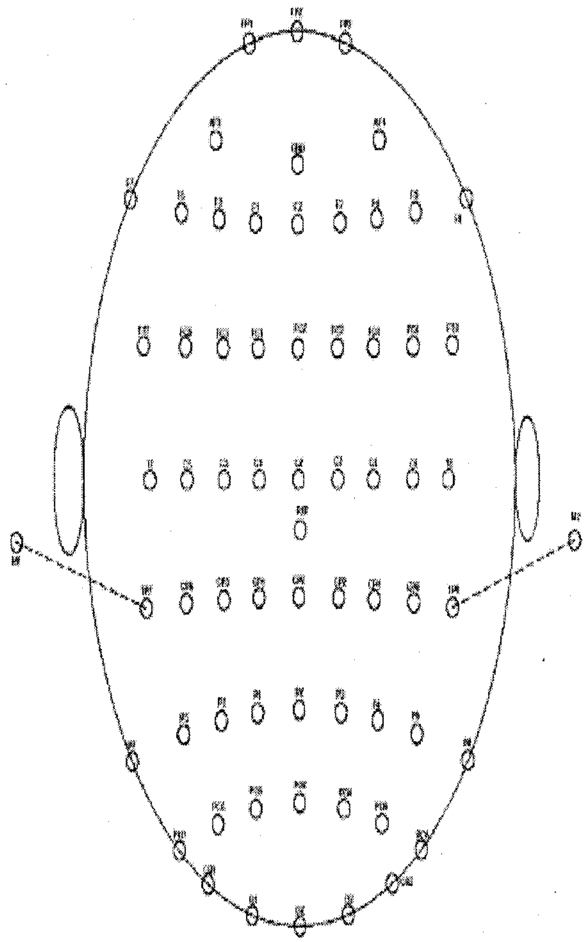


Figure 2

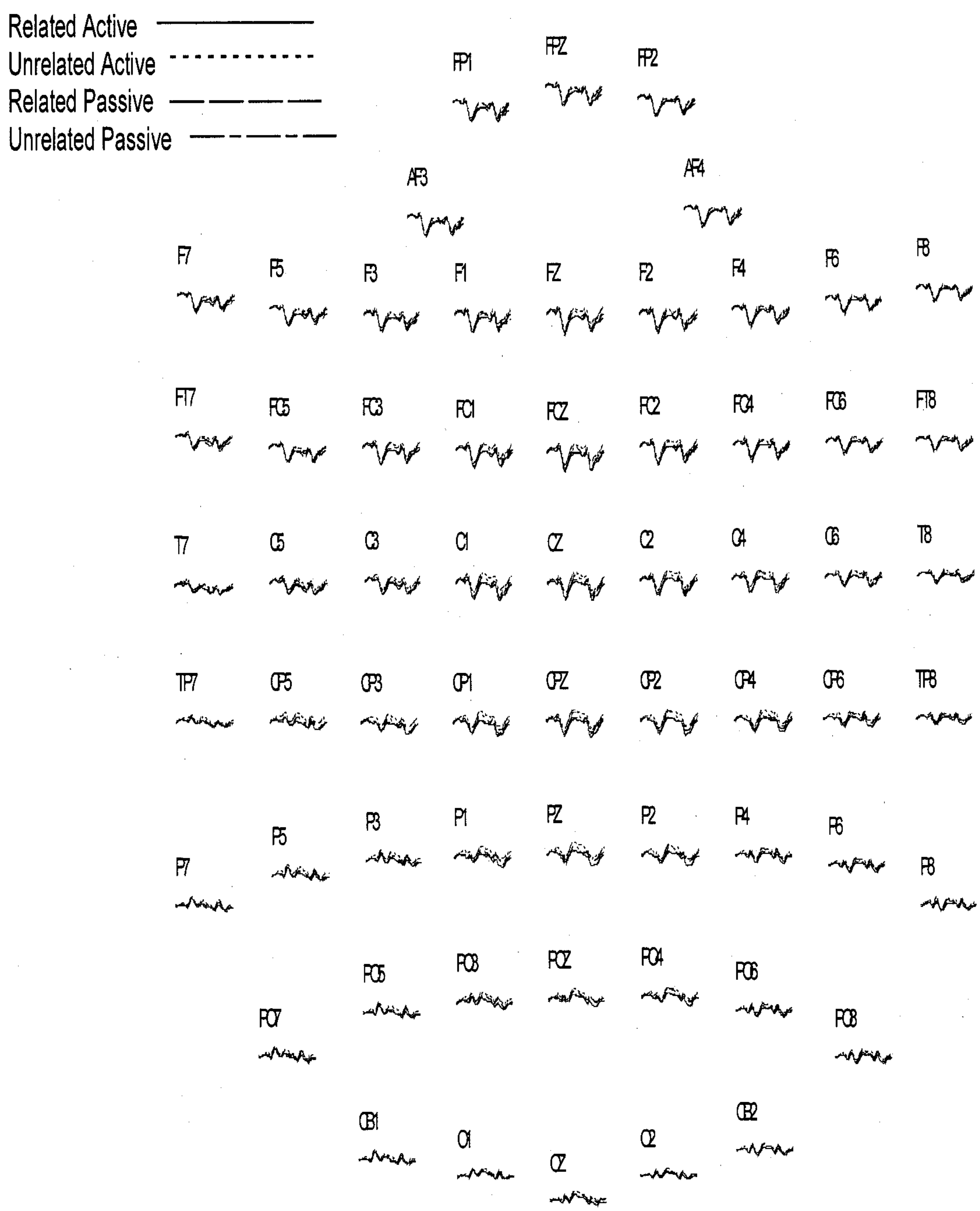

Related Active
Unrelated Active
Related Passive
Unrelated Passive
FP1
FPZ
FP2
AF3
AF4
F7
F5
F3
F1
FZ
F2
F4
F6
F8
FT7
FC5
FC3
FC1
FCZ
FC2
FC4
FC6
FT8
T7
C5
C3
C1
CZ
C2
C4
C6
T8
TP7
CP5
CP3
CP1
CPZ
CP2
CP4
CP6
TP8
P7
P5
P3
P1
PZ
P2
P4
P6
P8
PO7
PO5
PO3
POZ
PO4
PO6
PO8
CB1
O1
OZ
O2
CB2

Figure 3

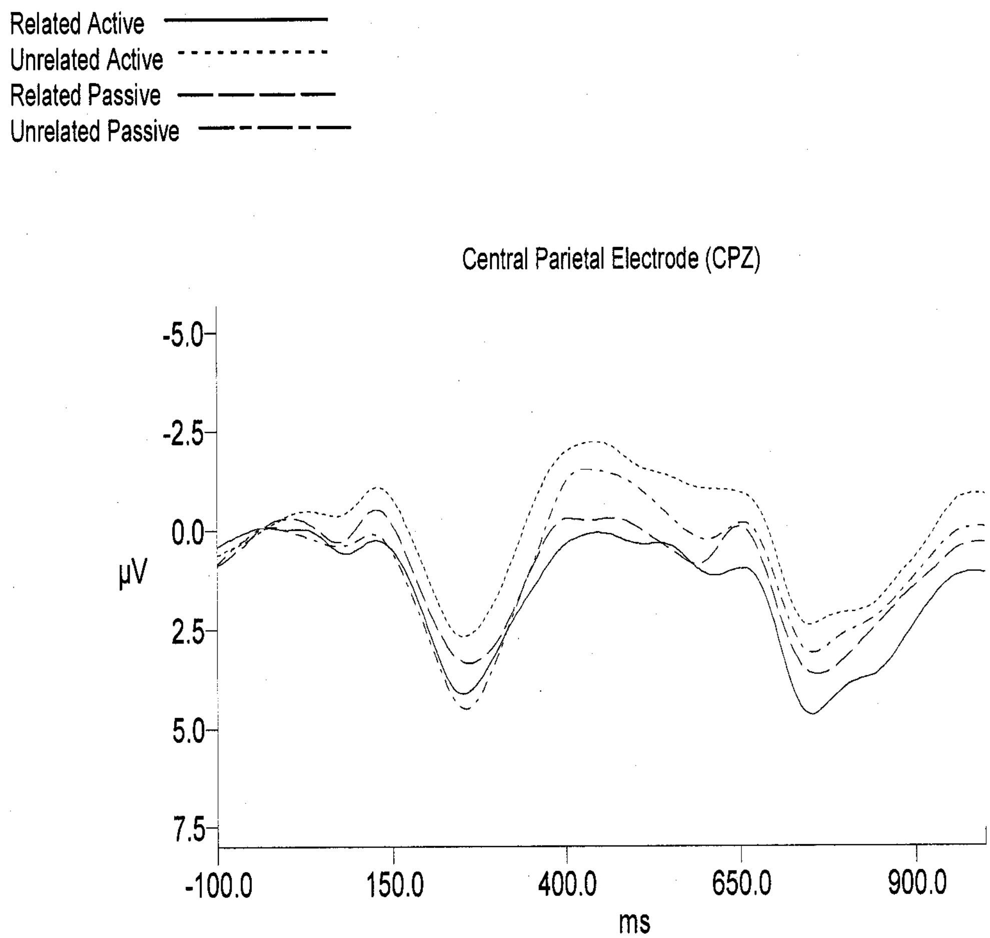
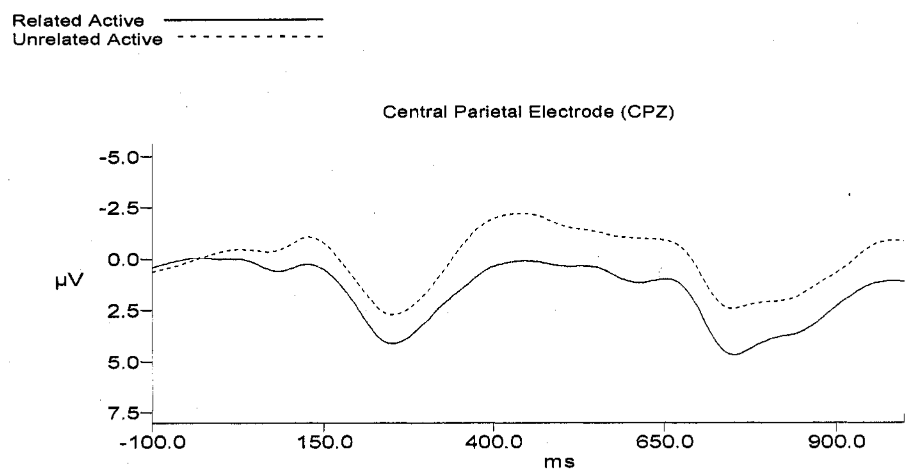

Related Active
Unrelated Active
Related Passive
Unrelated Passive
Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
2.5
5.0
7.5
µV
-100.0
150.0
400.0
650.0
900.0
ms

Figure 4

(A)


Related Active
Unrelated Active
Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
2.5
5.0
7.5
µV
-100.0
150.0
400.0
650.0
900.0
ms

(B)

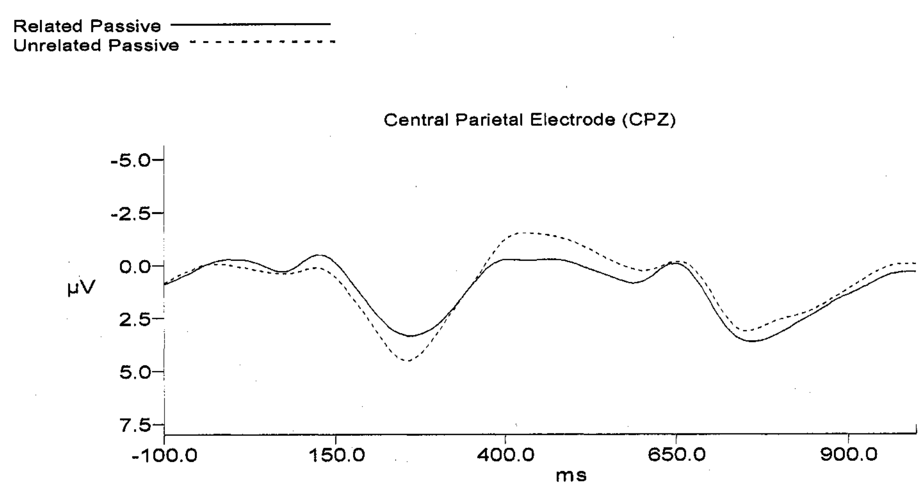

Related Passive
Unrelated Passive
Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
2.5
5.0
7.5
µV
-100.0
150.0
400.0
650.0
900.0
ms

Figure 5

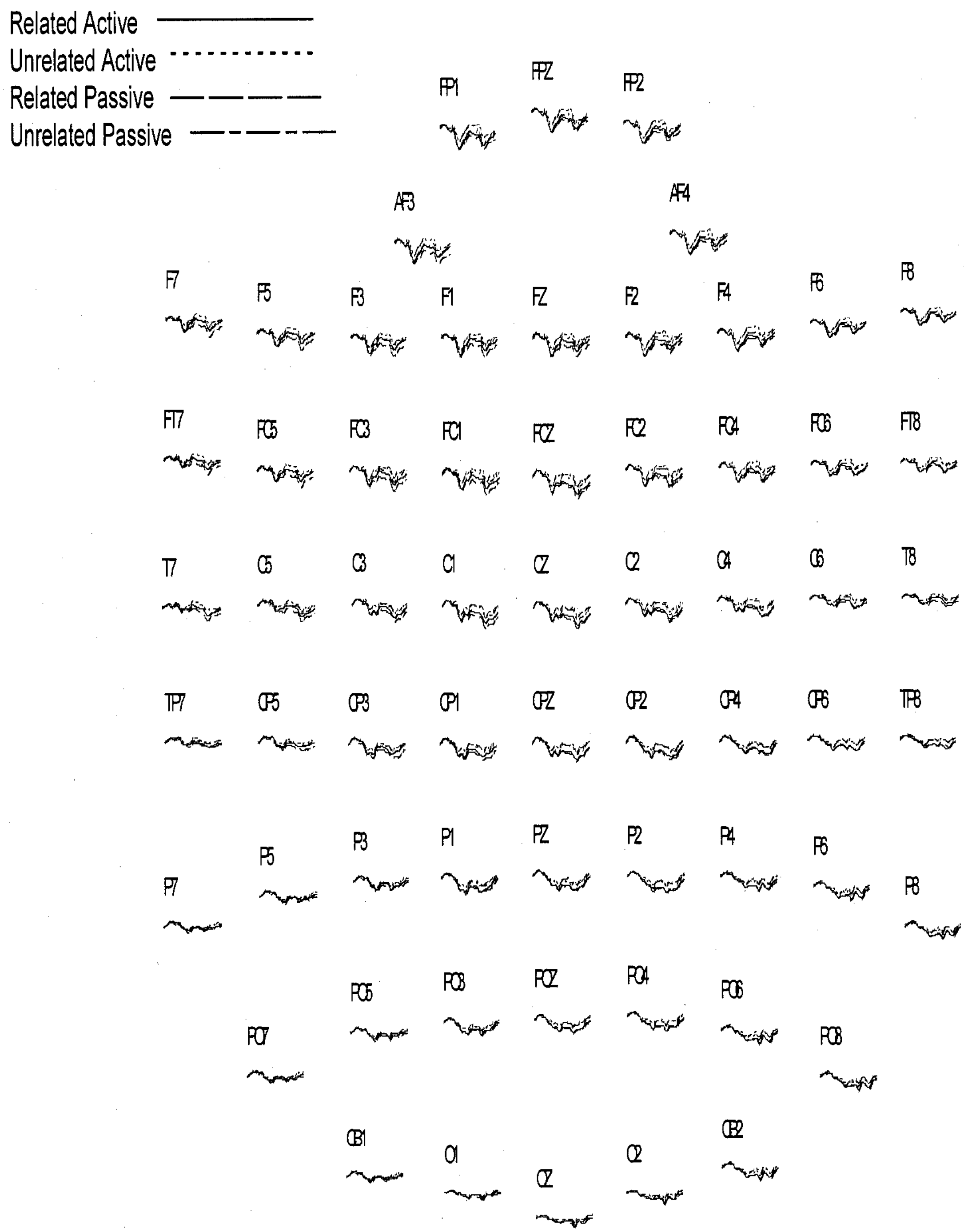

Related Active
Unrelated Active
Related Passive
Unrelated Passive
FP1
FPZ
FP2
AF3
AF4
F7
F5
F3
F1
FZ
F2
F4
F6
F8
FT7
FC5
FC3
FC1
FCZ
FC2
FC4
FC6
FT8
T7
C5
C3
C1
CZ
C2
C4
C6
T8
TP7
CP5
CP3
CP1
CPZ
CP2
CP4
CP6
TP8
P7
P5
P3
P1
PZ
P2
P4
P6
P8
PO7
PO5
PO3
POZ
PO4
PO6
PO8
CB1
O1
OZ
O2
CB2

Figure 6

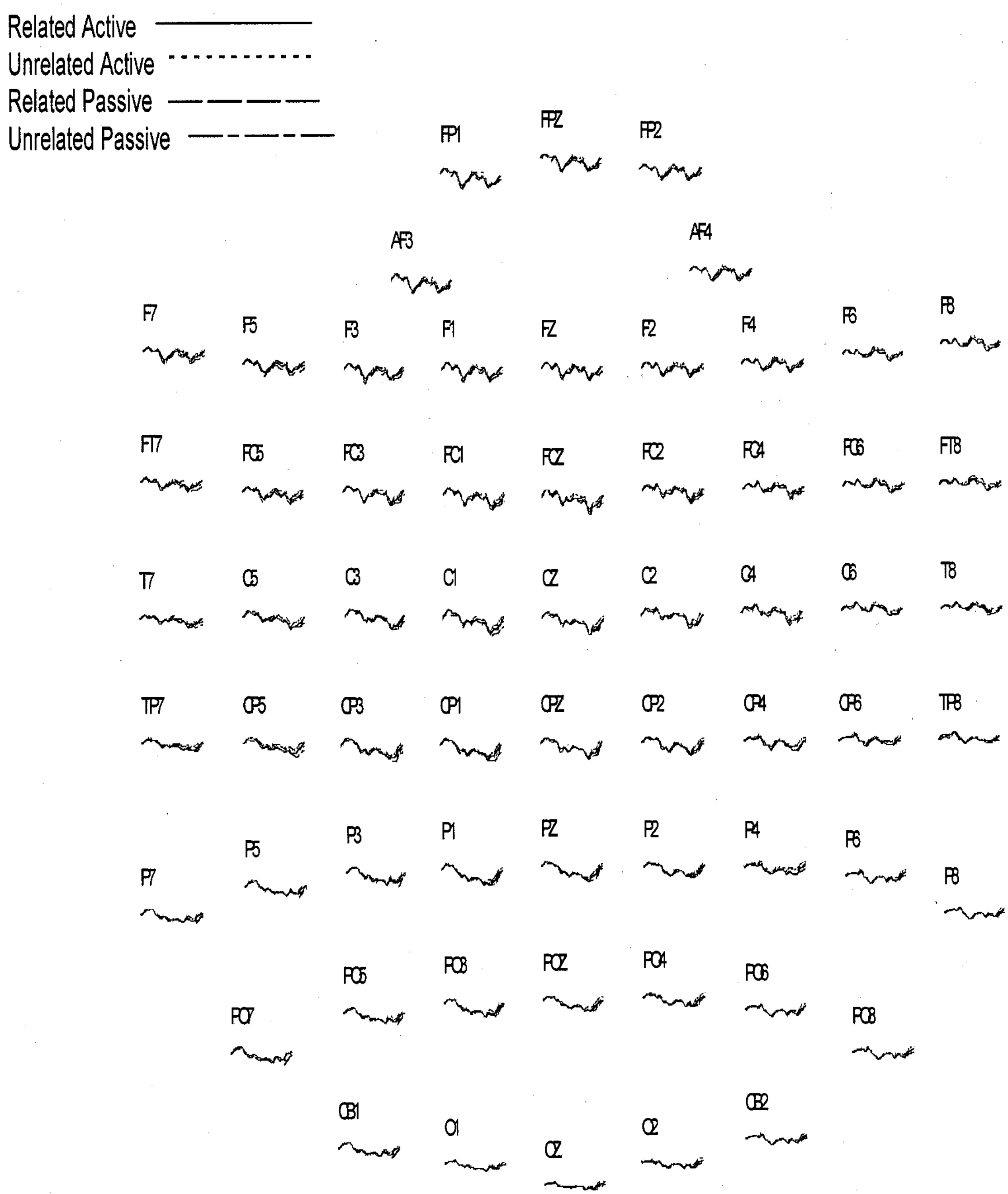

Related Active
Unrelated Active
Related Passive
Unrelated Passive
FP1
FPZ
FP2
AF3
AF4
F7
F5
F3
F1
FZ
F2
F4
F6
F8
FT7
FC5
FC3
FC1
FCZ
FC2
FC4
FC6
FT8
T7
C5
C3
C1
CZ
C2
C4
C6
T8
TP7
CP5
CP3
CP1
CPZ
CP2
CP4
CP6
TP8
P7
P5
P3
P1
PZ
P2
P4
P6
P8
PO7
PO5
PO3
POZ
PO4
PO6
PO8
CB1
O1
OZ
O2
CB2

Figure 7

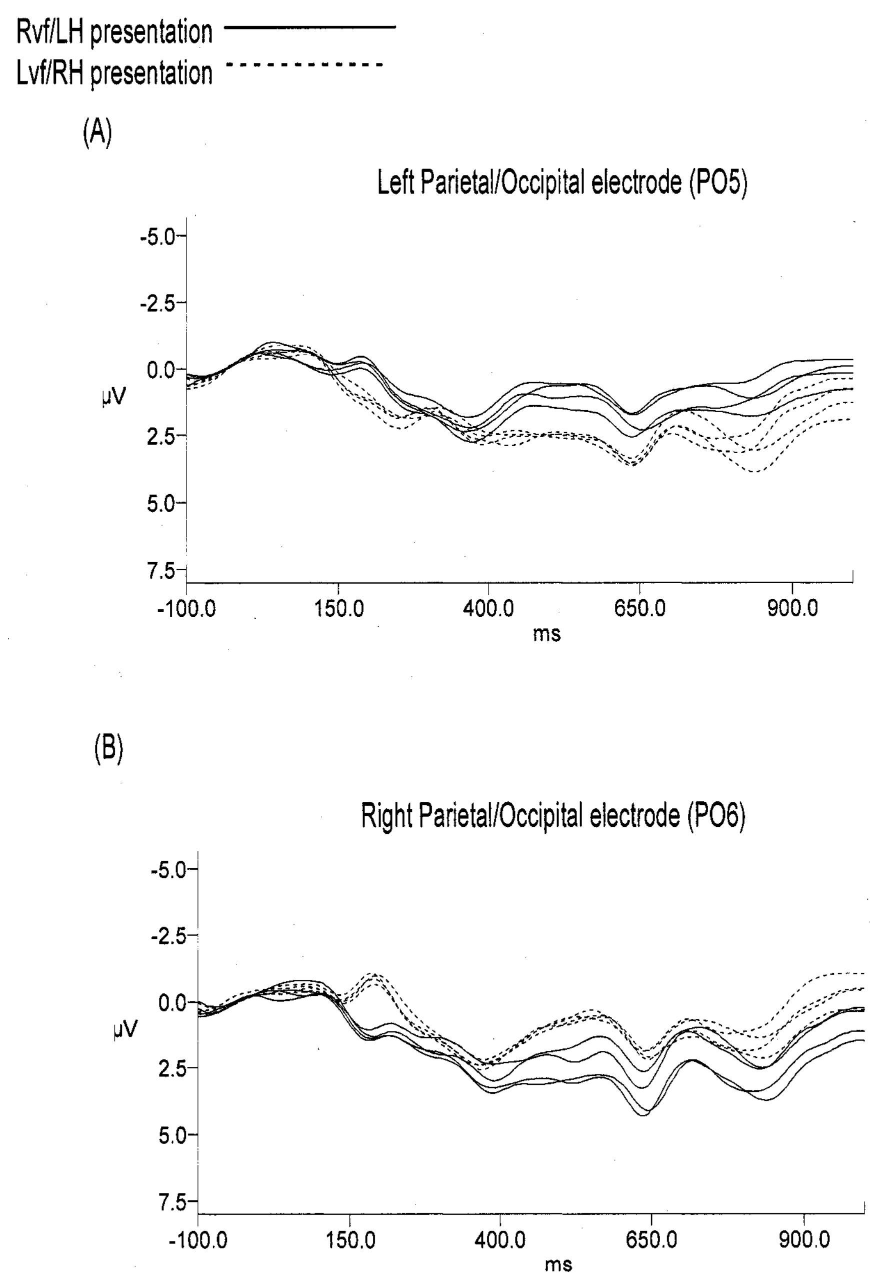

Rvf/LH presentation
Lvf/RH presentation
(A)
Left Parietal/Occipital electrode (PO5)
-5.0
-2.5
0.0
µV
2.5
5.0
7.5
-100.0
150.0
400.0
650.0
900.0
ms
(B)
Right Parietal/Occipital electrode (PO6)
-5.0
-2.5
0.0
µV
2.5
5.0
7.5
-100.0
150.0
400.0
650.0
900.0
ms

Figure 8

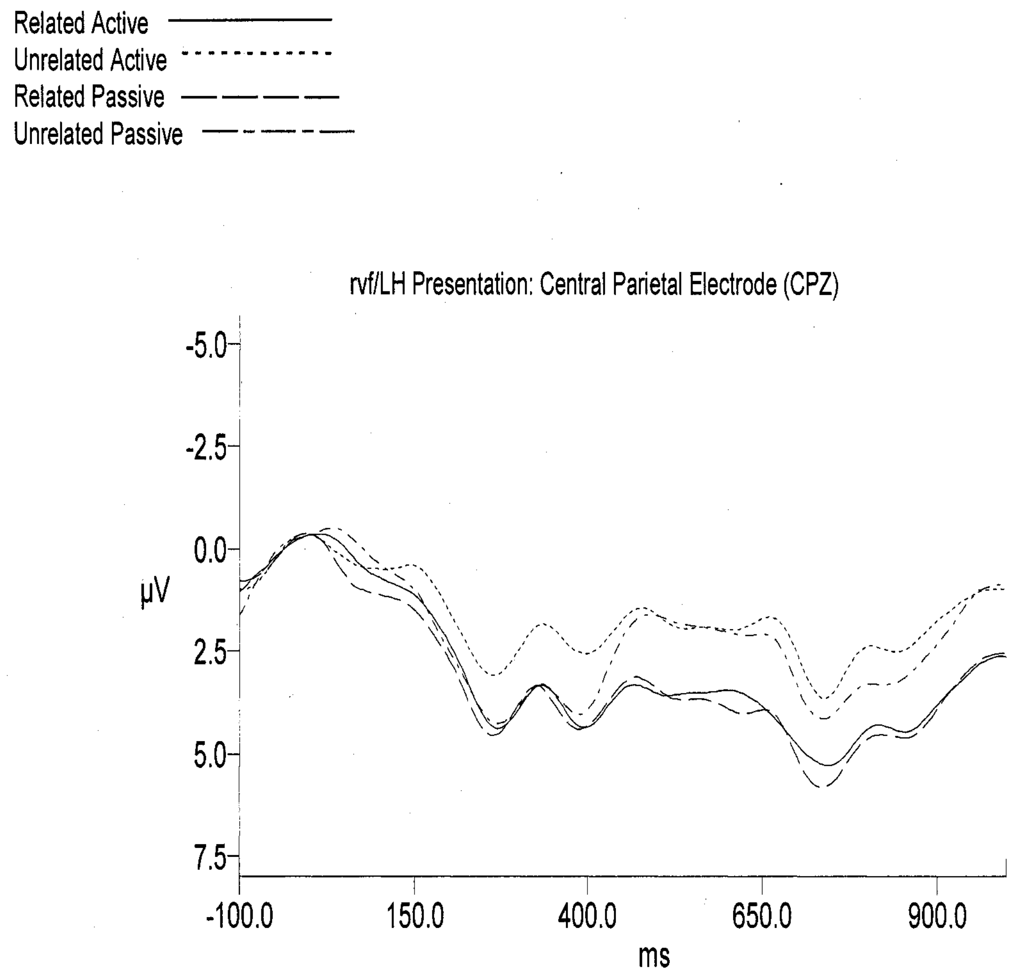

Related Active
Unrelated Active
Related Passive
Unrelated Passive
rvf/LH Presentation: Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
2.5
5.0
7.5
µV
-100.0
150.0
400.0
650.0
900.0
ms

Figure 9

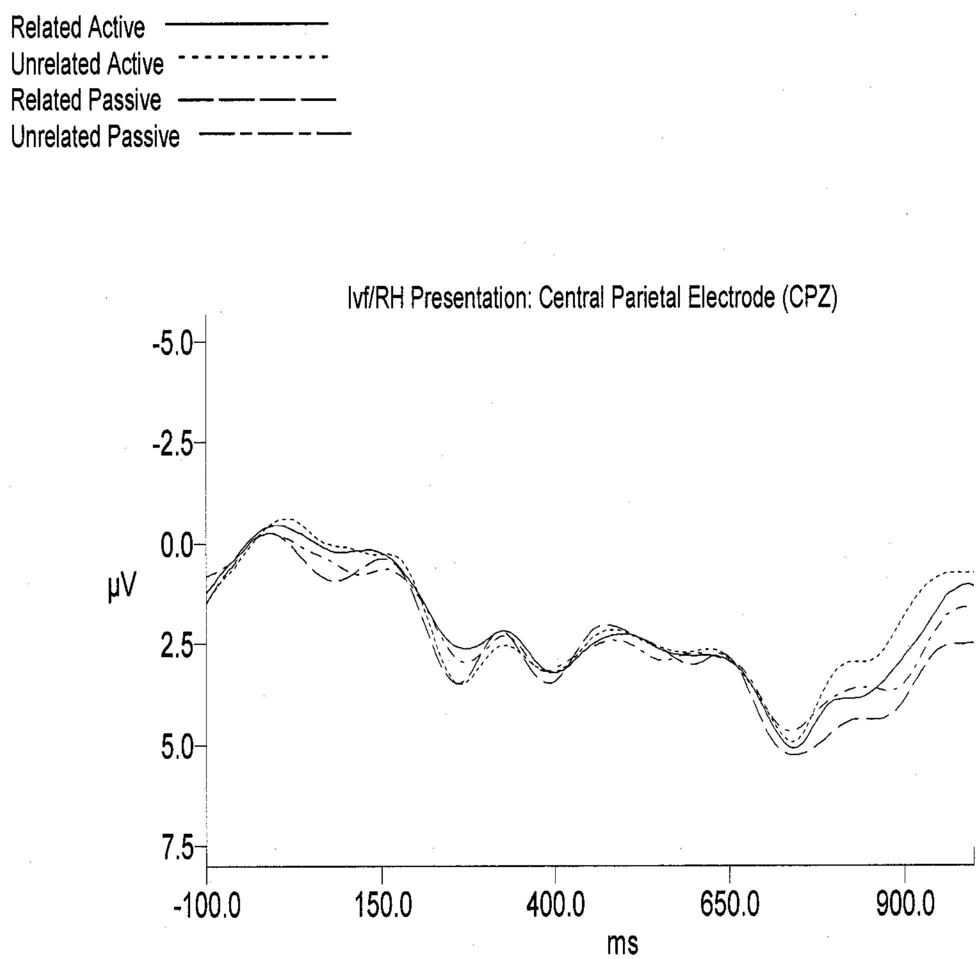
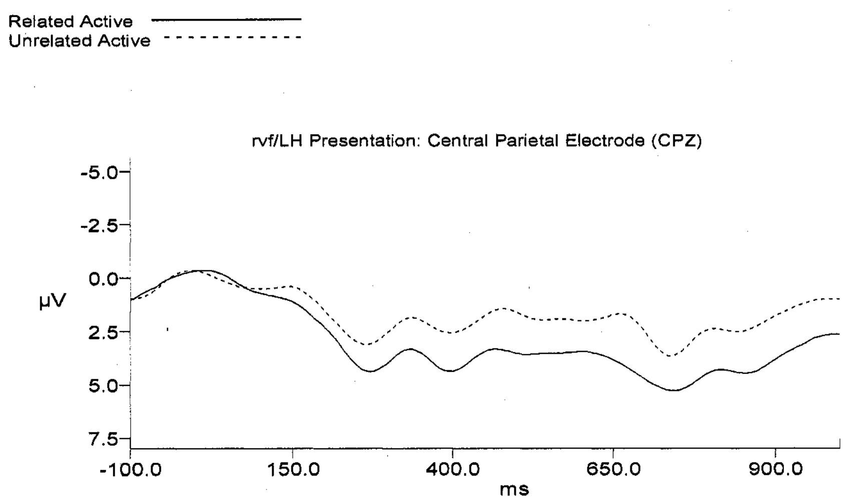

Related Active
Unrelated Active
Related Passive
Unrelated Passive
lvf/RH Presentation: Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
2.5
5.0
7.5
µV
-100.0
150.0
400.0
650.0
900.0
ms

Figure 10

(A)


Related Active
Unrelated Active
rvf/LH Presentation: Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
µV
2.5
5.0
7.5
-100.0
150.0
400.0
650.0
900.0
ms

(B)

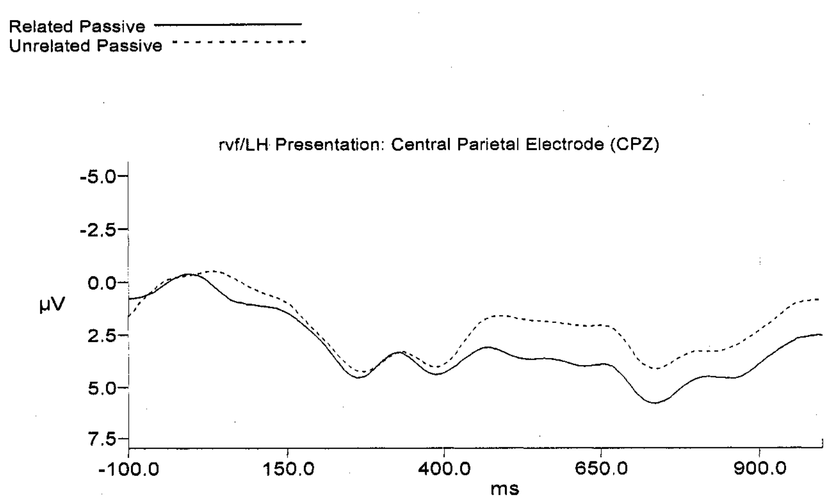
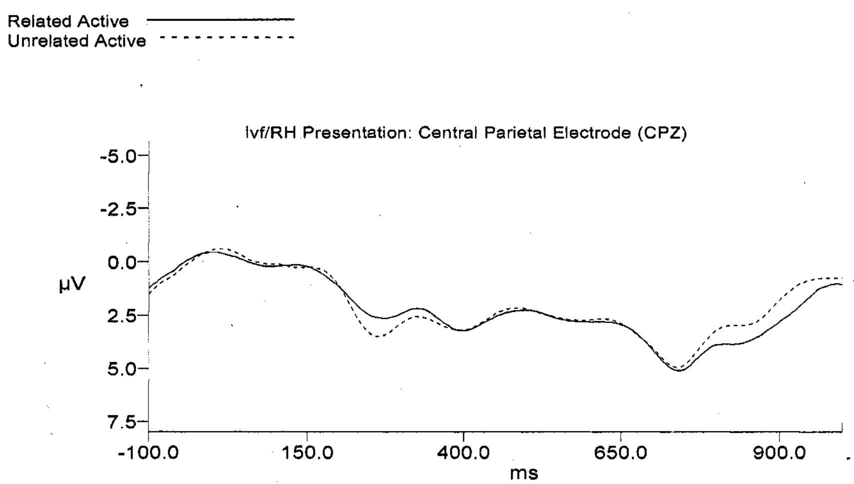
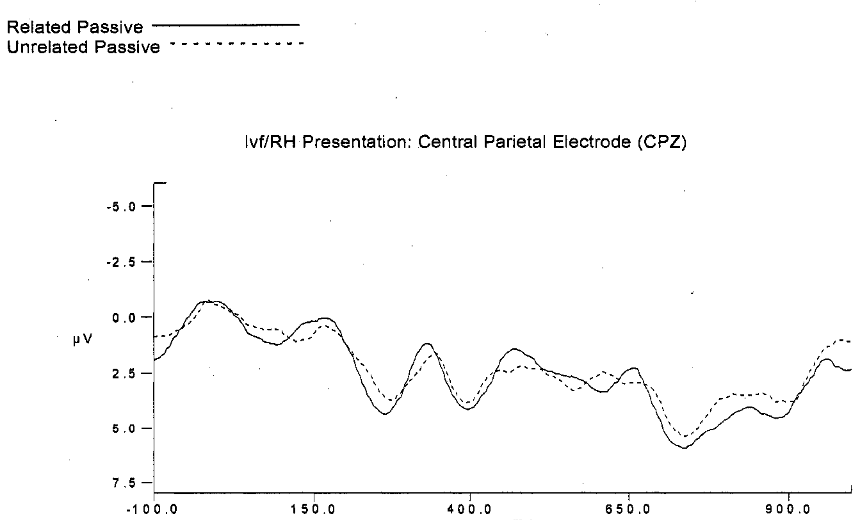

Related Passive
Unrelated Passive
rvf/LH Presentation: Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
µV
2.5
5.0
7.5
-100.0
150.0
400.0
650.0
900.0
ms

Figure 11

(A)


Related Active
Unrelated Active
lvf/RH Presentation: Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
µV
2.5
5.0
7.5
-100.0
150.0
400.0
650.0
900.0
ms

(B)


Related Passive
Unrelated Passive
lvf/RH Presentation: Central Parietal Electrode (CPZ)
-5.0
-2.5
0.0
µV
2.5
5.0
7.5
-100.0
150.0
400.0
650.0
900.0
ms

Appendix A

Each Sentence used in the Experimental Procedure

Item	Voice	Relatedness	Sentence
1.	active	related	The boss was hiring the man for little money.
	passive	related	The boss was hired by the man for little money.
	active	unrelated	The delinquent was hiring the man for little money.
	passive	unrelated	The delinquent was hired by the man for little money.
2.	active	related	The consultant was advising the executive about proper ethical conduct.
	passive	related	The consultant was advised by the executive about proper ethical conduct.
	active	unrelated	The audience was advising the executive about proper ethical conduct.
	passive	unrelated	The audience was advised by the executive about proper ethical conduct.
3.	active	related	The delinquent was antagonizing the child.
	passive	related	The delinquent was antagonized by the child.
	active	unrelated	The doctor was antagonizing the child.
	passive	unrelated	The doctor was antagonized by the child.
4.	active	related	The audience was watching the man have an epileptic seizure.
	passive	related	The audience was watched by the man for security purposes.
	active	unrelated	The consultant was watching the man have an epileptic seizure.
	passive	unrelated	The consultant was watched by the security firm.
5.	active	related	The fireman was helping the woman.
	passive	related	The fireman was helped by the woman.
	active	unrelated	The bull was helping the woman.
	passive	unrelated	The bull was helped by the woman.
6.	active	related	The teacher was lecturing the man for taking his parking spot.
	passive	related	The teacher was lectured by the man for taking his parking spot.
	active	unrelated	The fireman was lecturing the man for taking his parking spot.
	passive	unrelated	The fireman was lectured by the man for taking his parking spot.

7.	active	related	The bull was charging the man at the bull fight.
	passive	related	The bull was charged by the man at the bull fight.
	active	unrelated	The crab was charging the beach in order to avoid the big wave.
	passive	unrelated	The crab was charged by the hungry seagull.
8.	active	related	The crab was pinching the threatening boy.
	passive	related	The crab was pinched by the side of the boat.
	active	unrelated	The pirate was pinching the threatening boy.
	passive	unrelated	The pirate was pinched by the side of the boat.
9.	active	related	The pirate was terrorizing the poor man.
	passive	related	The pirate was terrorized by the angry man.
	active	unrelated	The spectator was terrorizing the poor man.
	passive	unrelated	The spectator was terrorized by the angry man.
10.	active	related	The policeman was capturing the delinquent teenager.
	passive	related	The policeman was captured by the terrorist.
	active	unrelated	The teacher was capturing the delinquent teenager.
	passive	unrelated	The teacher was captured by the terrorist.
11.	active	related	The spectator was cheering the young soccer players.
	passive	related	The spectator was cheered by the teenager.
	active	unrelated	The policeman was cheering the young soccer players.
	passive	unrelated	The policeman was cheered by the teenager.
12.	active	related	The doctor was curing the child
	passive	related	The doctor was cured by the man.
	active	unrelated	The poet was curing the child
	passive	unrelated	The poet was cured by the man.
13.	active	related	The poet was describing the scene.
	passive	related	The poet was described by the man.
	active	unrelated	The boss was describing the scene.
	passive	unrelated	The boss was described by the man.
14.	active	related	The parent was adopting the child.
	passive	related	The parent was adopted by the club.
	active	unrelated	The prosecutor was adopting the child.
	passive	unrelated	The prosecutor was adopted by the club.
15.	active	related	The prosecutor was accusing the woman.
	passive	related	The prosecutor was accused by the woman.
	active	unrelated	The instructor was accusing the woman.
	passive	unrelated	The instructor was accused by the woman.

16.	active	related	The assailant was attacking the woman.
	passive	related	The assailant was attacked by the man.
	active	unrelated	The pitcher was attacking the batter.
	passive	unrelated	The pitcher was attacked by the batter.
17.	active	related	The pitcher was throwing the ball as hard as he could.
	passive	related	The pitcher was thrown by the mechanical bull at the bar.
	active	unrelated	The assailant was throwing the gun into the river.
	passive	unrelated	The assailant was thrown by the authorities to the ground.
18.	active	related	The hangman was executing the prisoner.
	passive	related	The hangman was executed by the firing squad.
	active	unrelated	The mentor was executing the prisoner.
	passive	unrelated	The mentor was executed by the firing squad.
19.	active	related	The reporter was interviewing the woman.
	passive	related	The reporter was interviewed by the woman.
	active	unrelated	The prankster was interviewing the woman.
	passive	unrelated	The prankster was interviewed by the woman.
20.	active	related	The prankster was startling the woman.
	passive	related	The prankster was startled by the woman.
	active	unrelated	The salesman was startling the woman.
	passive	unrelated	The salesman was startled by the woman.
21.	active	related	The instructor was grading the woman.
	passive	related	The instructor was graded by the woman.
	active	unrelated	The parent was grading the woman.
	passive	unrelated	The parent was graded by the woman.
22.	active	related	The council was evaluating the woman.
	passive	related	The council was evaluated by the woman.
	active	unrelated	The miser was evaluating the woman.
	passive	unrelated	The miser was evaluated by the woman.
23.	active	related	The miser was safeguarding the cash.
	passive	related	The miser was safeguarded by the body guard.
	active	unrelated	The reporter was safeguarding the cash.
	passive	unrelated	The reporter was safeguarded by the body guard.
24.	active	related	The mentor was tutoring the woman.
	passive	related	The mentor was tutored by the woman.
	active	unrelated	The liar was tutoring the woman.
	passive	unrelated	The liar was tutored by the woman.

25.	active	related	The liar was deceiving the man.
	passive	related	The liar was deceived by the man.
	active	unrelated	The hangman was deceiving the man.
	passive	unrelated	The hangman was deceived by the man.
26.	active	related	The salesman was showing the man the new Audi.
	passive	related	The salesman was shown the figures on this month's sales and was impressed.
	active	unrelated	The council was showing the public the results of their inquiry.
	passive	unrelated	The council was shown by the law firm how many laws they were breaking.
27.	active	related	The chauffeur was driving the man to the nearest telephone.
	passive	related	The chauffeur was driven by the man to the nearest telephone.
	active	unrelated	The witness was driving the man to the nearest telephone.
	passive	unrelated	The witness was driven by the man to the nearest telephone.
28.	active	related	The heartbreaker was hurting the girl's feelings.
	passive	related	The heartbreaker was hurt by the girl's comments.
	active	unrelated	The chauffeur was hurting the girl's feelings.
	passive	unrelated	The chauffeur was hurt by the girl's comments.
29.	active	related	The stalker was following the woman.
	passive	related	The stalker was followed by the man.
	active	unrelated	The heartbreaker was following the woman.
	passive	unrelated	The heartbreaker was followed by the man.
30.	active	related	The warden was releasing the dogs when the intruder shot at them.
	passive	related	The warden was released by the intruder.
	active	unrelated	The butcher was releasing the dogs when the intruder shot at them.
	passive	unrelated	The butcher was released by the intruder.
31.	active	related	The butcher was slaughtering the pig.
	passive	related	The butcher was slaughtered by the man.
	active	unrelated	The mayor was slaughtering the pig.
	passive	unrelated	The mayor was slaughtered by the man.
32.	active	related	The maid was cleaning the child.
	passive	related	The maid was cleaned by the nurse.

	active	unrelated	The patrolman was cleaning the child.
	passive	unrelated	The patrolman was cleaned by the nurse.
33.	active	related	The predator was stalking the girl.
	passive	related	The predator was stalked by the grizzly bear
	active	unrelated	The bellhop was stalking the girl.
	passive	unrelated	The bellhop was stalked by the serial killer.
34.	active	related	The mayor was governing the municipality.
	passive	related	The mayor was governed by the provincial legislature.
	active	unrelated	The predator was governing the municipality.
	passive	unrelated	The predator was governed by the provincial legislature.
35.	active	related	The bellhop was greeting the man.
	passive	related	The bellhop was greeted by the man.
	active	unrelated	The stalker was greeting the man.
	passive	unrelated	The stalker was greeted by the man.
36.	active	related	The witness was recognizing the woman.
	passive	related	The witness was recognized by the woman.
	active	unrelated	The maid was recognizing the woman.
	passive	unrelated	The maid was recognized by the woman.
37.	active	related	The stripper was entertaining the men.
	passive	related	The stripper was entertained by the men.
	active	unrelated	The therapist was entertaining the men.
	passive	unrelated	The therapist was entertained by the men.
38.	active	related	The therapist was comforting the woman.
	passive	related	The therapist was comforted by the woman.
	active	unrelated	The warden was comforting the woman.
	passive	unrelated	The warden was comforted by the woman.
39.	active	related	The patrolman was searching the man.
	passive	related	The patrolman was searched by the man.
	active	unrelated	The stripper was searching the man.
	passive	unrelated	The stripper was searched by the man.
40.	active	related	The assassin was killing the man.
	passive	related	The assassin was killed by the man.
	active	unrelated	The coach was killing the man.
	passive	unrelated	The coach was killed by the man.
41.	active	related	The president was commanding the military to attack.
	passive	related	The president was commanded by the parliament to reveal the source of his accusations.

	active	unrelated	The tourist was commanding the thief to return his wallet.
	passive	unrelated	The tourist was commanded by the crossing guard to cross the street.
42.	active	related	The worker was lifting the woman.
	passive	related	The worker was lifted by the man.
	active	unrelated	The amnesiac was lifting the woman.
	passive	unrelated	The amnesiac was lifted by the man.
43.	active	related	The lawyer was questioning the woman.
	passive	related	The lawyer was questioned by the woman.
	active	unrelated	The worker was questioning the woman.
	passive	unrelated	The worker was questioned by the woman.
44.	active	related	The student was studying the man.
	passive	related	The student was studied by the man.
	active	unrelated	The hairdresser was studying the man.
	passive	unrelated	The hairdresser was studied by the man.
45.	active	related	The coach was instructing the boy about where to shoot the puck when in trouble.
	passive	related	The coach was instructed by the parent to play his child more often.
	active	unrelated	The cat was instructing the woman to refill the food bowl.
	passive	unrelated	The cat was instructed by the parent about where the kitty litter was located.
46.	active	related	The nanny was nurturing the child.
	passive	related	The nanny was nurtured by the family.
	active	unrelated	The alligator was nurturing the young offspring.
	passive	unrelated	The alligator was nurtured by the older alligator.
47.	active	related	The cat was scratching the girl.
	passive	related	The cat was scratched by the glass.
	active	unrelated	The nanny was scratching the girl.
	passive	unrelated	The nanny was scratched by the glass.
48.	active	related	The tourist was visiting the museum in Cuba.
	passive	related	The tourist was visited by his best friend while in Cuba.
	active	unrelated	The student was visiting the museum in Cuba.
	passive	unrelated	The student was visited by his best friend while in Cuba.
49.	active	related	The alligator was biting the fish and noticed how bony it was.

	passive	related	The alligator was bitten by the parasite.
	active	unrelated	The president was biting the fish and noticed how bony it was.
	passive	unrelated	The president was bitten by the parasite.
50.	active	related	The amnesiac was forgetting the family was going to arrive in an hour.
	passive	related	The amnesiac was forgotten by the family.
	active	unrelated	The assassin was forgetting the family was going to arrive in an hour.
	passive	unrelated	The assassin was forgotten by the family.
51.	active	related	The drifter was begging the woman for some spare coins.
	passive	related	The drifter was begged by the woman to stop loitering in front of her house.
	active	unrelated	The lawyer was begging the woman to drop her request for sole custody of her children.
	passive	unrelated	The lawyer was begged by the woman to speed up her divorce settlement.
52.	active	related	The hairdresser was cutting the hair.
	passive	related	The hairdresser was cut by the scissors.
	active	unrelated	The drifter was cutting the hair.
	passive	unrelated	The drifter was cut by the scissors.
53.	active	related	The pilot was flying the airplane for far to long to be considered safe.
	passive	related	The pilot was flown by the cargo plane into enemy lines.
	active	unrelated	The thief was flying the airplane to safety.
	passive	unrelated	The thief was flown by the police escort to the maximum security facility.
54.	active	related	The hero was saving the children from the fire.
	passive	related	The hero was saved by the alert citizen.
	active	unrelated	The bee was saving the nectar for the next trip out of the hive.
	passive	unrelated	The bee was saved by the mother and put back outside.
55.	active	related	The guard was disciplining the escapee.
	passive	related	The guard was disciplined by the panel for abusive behaviour.
	active	unrelated	The hero was disciplining the young apprentice for forgetful behaviour.
	passive	unrelated	The hero was disciplined by the panel for using excessive force to rescue the hostages.

56.	active	related	The thief was swindling the unsuspecting woman.
	passive	related	The thief was swindled by his colleague.
	active	unrelated	The inspector was swindling the unsuspecting woman.
	passive	unrelated	The inspector was swindled by the smooth talking restaurant owner.
57.	active	related	The bee was stinging the unsuspecting boy.
	passive	related	The bee was stung by the strong pesticide.
	active	unrelated	The psychoanalyst was stinging the client with electrical shocks.
	passive	unrelated	The psychoanalyst was stung by the allegations.
58.	active	related	The host was inviting the kids for a swim in the pool.
	passive	related	The host was invited by the family to stay at their cottage.
	active	unrelated	The pilot was inviting the kids for a swim in the pool.
	passive	unrelated	The pilot was invited by the family to stay at their cottage.
59.	active	related	The magician was fooling the children.
	passive	related	The magician was fooled by the children.
	active	unrelated	The host was fooling the children.
	passive	unrelated	The host was fooled by the children.
60.	active	related	The psychoanalyst was hypnotizing the crowd.
	passive	related	The psychoanalyst was hypnotized by the massive crowd.
	active	unrelated	The monster was hypnotizing the crowd with its enormous size.
	passive	unrelated	The monster was hypnotized by the truck's headlights.
61.	active	related	The monster was frightening the teenager.
	passive	related	The monster was frightened by the teenager.
	active	unrelated	The janitor was frightening the teenager.
	passive	unrelated	The janitor was frightened by the teenager.
62.	active	related	The janitor was scrubbing the walls
	passive	related	The janitor was scrubbed by the nurse.
	active	unrelated	The guard was scrubbing the walls.
	passive	unrelated	The guard was scrubbed by the nurse.
63.	active	related	The inspector was interrogating the suspicious adult.
	passive	related	The inspector was interrogated by the CIA.
	active	unrelated	The magician was interrogating the assistant about a theft.
	passive	unrelated	The magician was interrogated by the CIA.

64.	active	related	The priest was worshipping the Lord all day.
	passive	related	The priest was worshipped by his congregation
	active	unrelated	The hypnotist was worshipping the Lord all day.
	passive	unrelated	The hypnotist was worshipped by his followers.
65.	active	related	The hypnotist was mesmerizing the audience.
	passive	related	The hypnotist was mesmerized by the audience.
	active	unrelated	The priest was mesmerizing the audience.
	passive	unrelated	The priest was mesmerized by the beautiful landscape.
66.	active	related	The hunter was shooting the deer.
	passive	related	The hunter was shot by the careless boy.
	active	unrelated	The juror was shooting the targets for practice.
	passive	unrelated	The juror was shot by the careless boy.
67.	active	related	The guide was leading the group up the path.
	passive	related	The guide was led by the unwitting group members into rattle snake canyon.
	active	unrelated	The rabbit was leading the group of young bunnies to safety.
	passive	unrelated	The rabbit was led by the scent of the ripe huckleberries.
68.	active	related	The donkey was kicking the unsuspecting man.
	passive	related	The donkey was kicked by the angry man.
	active	unrelated	The fan was kicking the soccer ball.
	passive	unrelated	The fan was kicked by the angry man.
69.	active	related	The committee was approving the sale of the company.
	passive	related	The committee was approved by the university senate.
	active	unrelated	The hunter was approving the sale of his old rifles at the auction.
	passive	unrelated	The hunter was approved by the university to remove the poisonous snakes on campus.
70.	active	related	The cheater was betraying the woman.
	passive	related	The cheater was betrayed by the woman.
	active	unrelated	The committee was betraying the board about the actual cost of the project.
	passive	unrelated	The committee was betrayed by the woman.
71.	active	related	The critic was applauding the performance.
	passive	related	The critic was applauded by the media for her honest review.
	active	unrelated	The cheater was applauding the presentation of the trophy when he was disqualified for failing doping tests.

	passive	unrelated	The cheater was applauded by the school board for admitting his mistake.
72.	active	related	The juror was convicting the man for terrible crimes.
	passive	related	The juror was convicted by the court for taking bribes.
	active	unrelated	The professor was convicting the man during his court duty.
	passive	unrelated	The professor was convicted by the court for taking bribes.
73.	active	related	The rabbit was jumping the creek.
	passive	related	The rabbit was jumped by the wolf
	active	unrelated	The critic was jumping the puddle.
	passive	unrelated	The critic was jumped by the mugger.
74.	active	related	The customer was paying the woman for the groceries.
	passive	related	The customer was paid by the car wash business for the damage to his car.
	active	unrelated	The mountaineer was paying the woman for the groceries.
	passive	unrelated	The mountaineer was paid by the car wash business for the damage to his car.
75.	active	related	The bully was beating the boy for calling him a bad name.
	passive	related	The bully was beaten by the surprisingly tough boy.
	active	unrelated	The donkey was beating the gate with its hoof.
	passive	unrelated	The donkey was beaten by the mean master.
76.	active	related	The professor was teaching the course for the 5th year in a row.
	passive	related	The professor was taught algebra by some of the greatest mathematicians in the world.
	active	unrelated	The customer was teaching the other customer about how to build a sturdy deck.
	passive	unrelated	The customer was taught by the lady at the nursery about how to plant roses properly.
77.	active	related	The fan was admiring the game.
	passive	related	The fan was admired by the woman.
	active	unrelated	The guide was admiring the game.
	passive	unrelated	The guide was admired by the woman.
78.	active	related	The mountaineer was climbing the hill.
	passive	related	The mountaineer was climbed by the rambunctious kid.
	active	unrelated	The bully was climbing the hill.

	passive	unrelated	The bully was climbed by the rambunctious kid.
79.	active	related	The jockey was ridding the horse.
	passive	related	The jockey was ridden by the child.
	active	unrelated	The brat was ridding the horse.
	passive	unrelated	The brat was ridden by the child.
80.	active	related	The brat was disobeying the boy.
	passive	related	The brat was disobeyed by the boy.
	active	unrelated	The judge was disobeying the boy.
	passive	unrelated	The judge was disobeyed by the boy.
81.	active	related	The judge was sentencing the man.
	passive	related	The judge was sentenced by the court.
	active	unrelated	The jockey was sentencing the man.
	passive	unrelated	The jockey was sentenced by the court.
82.	active	related	The tormentor was teasing the man.
	passive	related	The tormentor was teased by the man.
	active	unrelated	The lifeguard was teasing the man.
	passive	unrelated	The lifeguard was teased by the man.
83.	active	related	The waitress was serving the woman.
	passive	related	The waitress was served by the woman.
	active	unrelated	The tormentor was serving the woman.
	passive	unrelated	The tormentor was served by the woman.
84.	active	related	The widow was mourning the man.
	passive	related	The widow was mourned by the man.
	active	unrelated	The carpenter was mourning the man.
	passive	unrelated	The carpenter was mourned by the man.
85.	active	related	The patron was ordering the shake.
	passive	related	The patron was ordered by the man.
	active	unrelated	The widow was ordering the shake.
	passive	unrelated	The widow was ordered by the man.
86.	active	related	The rapist was torturing the man.
	passive	related	The rapist was tortured by the man.
	active	unrelated	The scientist was torturing the man.
	passive	unrelated	The scientist was tortured by the man.
87.	active	related	The scientist was examining the child.
	passive	related	The scientist was examined by the man.
	active	unrelated	The ox was examining the child.
	passive	unrelated	The ox was examined by the man.

88.	active	related	The lifeguard was rescuing the man.
	passive	related	The lifeguard was rescued by the man.
	active	unrelated	The announcer was rescuing the man.
	passive	unrelated	The announcer was rescued by the man.
89.	active	related	The announcer was presenting the woman.
	passive	related	The announcer was presented by the woman.
	active	unrelated	The patron was presenting the woman.
	passive	unrelated	The patron was presented by the woman.
90.	active	related	The carpenter was hammering the board.
	passive	related	The carpenter was hammered by the apprentice by accident.
	active	unrelated	The waitress was hammering the board.
	passive	unrelated	The waitress was hammered by the truck when crossing the street.
91.	active	related	The ox was pulling the plough in deep mud.
	passive	related	The ox was pulled by the rope around its neck.
	active	unrelated	The rapist was pulling the plough in deep mud.
	passive	unrelated	The rapist was pulled by the rope around its neck.
92.	active	related	The headmaster was dismissing the child.
	passive	related	The headmaster was dismissed by the man.
	active	unrelated	The lion was dismissing the advances of the aggressive male.
	passive	unrelated	The lion was dismissed by the trainer.
93.	active	related	The detective was investigating the man.
	passive	related	The detective was investigated by the man.
	active	unrelated	The paramedic was investigating the man.
	passive	unrelated	The paramedic was investigated by the man.
94.	active	related	The paramedic was resuscitating the woman.
	passive	related	The paramedic was resuscitated by the woman.
	active	unrelated	The owner was resuscitating the woman.
	passive	unrelated	The owner was resuscitated by the woman.
95.	active	related	The cop was arresting the man.
	passive	related	The cop was arrested by the man.
	active	unrelated	The headmaster was arresting the man.
	passive	unrelated	The headmaster was arrested by the man.
96.	active	related	The mother was adopting the child.
	passive	related	The mother was adopted by the alcoholic anonymous

			club.
	active	unrelated	The detective was adopting the child.
	passive	unrelated	The detective was adopted by the alcoholic anonymous club.
97.	active	related	The owner was firing the woman.
	passive	related	The owner was fired by the woman.
	active	unrelated	The mother was firing the woman.
	passive	unrelated	The mother was fired by the woman.
98.	active	related	The lumberjack was chopping the tree.
	passive	related	The lumberjack was chopped by the angry man with the axe.
	active	unrelated	The postman was chopping the tree.
	passive	unrelated	The postman was chopped by the angry man with the axe.
99.	active	related	The smuggler was transporting the man.
	passive	related	The smuggler was transported by the man.
	active	unrelated	The accountant was transporting the man.
	passive	unrelated	The accountant was transported by the man.
100.	active	related	The artist was drawing the girl.
	passive	related	The artist was drawn by the girl.
	active	unrelated	The cop was drawing the girl.
	passive	unrelated	The cop was drawn by the girl.
101.	active	related	The lion was chasing the antelope.
	passive	related	The lion was chased by the hunter.
	active	unrelated	The lumberjack was chasing the dog away.
	passive	unrelated	The lumberjack was chased by the hunter.
102.	active	related	The accountant was auditing the firm.
	passive	related	The accountant was audited by the government.
	active	unrelated	The smuggler was auditing the firm.
	passive	unrelated	The smuggler was audited by the government.
103.	active	related	The postman was delivering the mail.
	passive	related	The postman was delivered by the shuttle to the beginning of his walking route.
	active	unrelated	The archaeologist was delivering the ancient scrolls to the museum.
	passive	unrelated	The archaeologist was delivered by the shuttle to the ancient ruins.
104.	active	related	The archaeologist was finding the ancient scrolls when

		he decided to call for extra help.
passive	related	The archaeologist was found at the bottom of the ravine.
active	unrelated	The artist was finding the correct address.
passive	unrelated	The artist was found at the bottom of the ravine.

Appendix B

Mean Agenthood and Patienthood Likert Ratings for each Item

Event	Related Agent	Agent rating	Patient rating	Unrelated Agent	Agent rating	Patient rating
hire	boss	6.50	1.50	delinquent	3.70	2.40
advise	consultant	6.90	3.70	audience	3.50	5.00
antagonize	delinquent	5.50	2.30	doctor	4.70	2.60
watch	audience	6.80	4.70	consultant	2.90	3.40
help	fireman	6.30	1.20	bull	4.00	2.10
lecture	teacher	6.10	2.60	fireman	3.70	3.00
charge	bull	5.90	2.10	crab	3.30	2.40
pinch	crab	6.20	3.40	pirate	3.70	1.80
terrorize	pirate	6.70	2.50	spectator	2.60	3.00
capture	policeman	6.20	2.40	teacher	3.10	1.90
cheer	spectator	6.20	2.20	policeman	2.40	3.50
cure	doctor	6.70	2.50	poet	4.30	3.20
describe	poet	6.30	4.50	boss	5.40	5.70
adopt	parent	5.70	2.60	prosecutor	1.70	2.40
accuse	prosecutor	7.00	2.90	instructor	4.50	3.70
attack	assailant	6.30	2.70	pitcher	4.60	2.40
throw	pitcher	7.00	3.90	assailant	2.30	2.30
execute	hangman	7.00	2.00	mentor	3.10	1.40
interview	reporter	7.00	1.60	prankster	4.00	2.90
startle	prankster	6.80	4.00	salesman	3.60	3.60
grade	instructor	6.70	3.90	parent	4.10	2.00
evaluate	council	6.60	3.00	miser	4.80	2.90
safeguard	miser	3.70	3.20	reporter	2.20	3.40
tutor	mentor	6.60	1.70	liar	2.10	2.50
deceive	liar	6.90	2.60	hangman	3.70	2.80
show	salesman	7.00	4.60	council	2.30	3.00
drive	chauffeur	6.50	3.00	witness	2.30	4.00
hurt	heartbreaker	7.00	2.20	chauffeur	3.90	3.20
follow	stalker	7.00	2.60	heartbreaker	3.10	3.30
release	warden	4.40	3.10	butcher	2.70	2.30
slaughter	butcher	6.70	1.40	mayor	1.90	2.30
clean	maid	6.90	3.10	patrolman	3.90	3.60
stalk	predator	6.90	2.20	bellhop	2.50	2.30
govern	mayor	6.90	2.30	predator	5.40	2.40
greet	bellhop	6.10	2.30	stalker	5.40	2.50
recognize	witness	5.60	4.10	maid	4.60	4.00
entertain	stripper	6.70	2.60	therapist	2.80	3.90
comfort	therapist	6.20	2.00	warden	3.20	2.30
search	patrolman	6.30	3.20	stripper	2.60	4.80
kill	assassin	6.70	1.70	coach	4.60	2.90

command	president	6.50	2.40	tourist	3.50	3.80
lift	worker	6.00	3.10	amnesiac	3.10	2.10
question	lawyer	6.50	4.00	worker	4.70	4.70
study	student	7.00	4.10	hairdresser	4.60	3.40
instruct	coach	6.90	1.40	cat	4.10	3.70
nurture	nanny	6.80	1.80	alligator	2.70	1.50
scratch	cat	6.70	1.80	nanny	4.50	3.70
visit	tourist	7.00	5.90	student	4.00	6.10
bite	alligator	6.40	2.60	president	3.70	1.90
forget	amnesiac	4.67	2.80	assassin	2.60	2.60
beg	drifter	5.30	2.50	lawyer	1.70	5.00
cut	hairdresser	6.90	2.50	drifter	4.30	2.60
fly	pilot	7.00	2.00	thief	4.20	2.10
save	hero	6.60	1.60	bee	2.40	1.90
discipline	guard	5.30	3.30	hero	3.30	1.80
swindle	thief	6.30	2.89	inspector	2.90	2.90
sting	bee	6.50	2.40	psychoanalyst	2.10	3.30
invite	host	7.00	3.50	pilot	4.20	3.70
fool	magician	6.90	2.20	host	3.11	3.10
hypnotize	psychoanalyst	3.60	1.70	monster	2.40	1.40
frighten	monster	6.70	2.50	janitor	2.00	3.10
scrub	janitor	6.10	2.10	guard	2.70	2.30
interrogate	inspector	6.60	1.80	magician	3.10	2.80
worship	priest	7.00	3.00	hypnotist	4.00	2.80
mesmerize	hypnotist	6.50	5.40	priest	2.40	3.20
shoot	hunter	6.40	1.70	juror	3.70	2.50
lead	guide	6.90	2.20	rabbit	3.40	2.80
kick	donkey	5.50	2.10	fan	3.20	3.00
approve	committee	5.90	2.70	hunter	4.50	3.40
betray	cheater	6.70	3.10	committee	3.60	3.20
applaud	critic	3.30	1.80	cheater	2.90	1.80
convict	juror	5.90	2.50	professor	2.60	3.40
jump	rabbit	6.00	1.80	critic	2.10	2.70
pay	customer	6.40	2.70	mountaineer	2.60	2.30
beat	bully	6.30	2.00	donkey	3.70	4.00
teach	professor	6.90	2.00	customer	4.50	2.80
admire	fan	5.60	3.60	guide	2.10	2.60
climb	mountaineer	6.90	3.70	bully	1.40	1.60
ride	jockey	5.70	2.60	brat	1.70	1.80
disobey	brat	6.70	1.90	judge	3.50	3.70
sentence	judge	6.90	1.40	jockey	2.10	2.20
tease	tormentor	6.90	1.70	lifeguard	3.20	2.40
serve	waitress	7.00	1.90	tormentor	3.00	2.20
mourn	widow	6.90	2.70	carpenter	3.50	3.60
order	customer	5.30	1.90	widow	3.30	2.50
torture	rapist	6.80	2.70	scientist	3.40	1.90

examine	scientist	6.90	1.40	ox	3.20	3.20
rescue	lifeguard	6.90	1.60	announcer	2.20	1.90
present	announcer	5.00	2.60	customer	3.90	2.80
hammer	carpenter	7.00	1.80	waitress	2.10	2.00
pull	ox	4.80	3.40	rapist	3.70	2.30
dismiss	headmaster	5.80	1.80	lion	2.20	1.50
investigate	detective	6.90	5.20	paramedic	3.50	3.40
resuscitate	paramedic	6.20	2.50	owner	2.70	2.40
arrest	cop	7.00	1.50	headmaster	2.40	2.30
adopt	parent	5.50	1.90	detective	1.80	2.40
fire	owner	5.30	2.40	parent	1.70	3.10
chop	lumberjack	6.80	2.00	postman	2.90	1.50
transport	smuggler	5.50	3.20	accountant	3.50	2.70
draw	artist	7.00	2.20	cop	3.50	3.00
chase	lion	6.00	1.50	lumberjack	2.60	2.00
audit	accountant	5.20	1.60	smuggler	3.80	3.30
deliver	postman	6.90	2.90	archeologist	2.30	2.30
find	archeologist	5.90	4.10	artist	2.70	2.90

Appendix C

Mean Frequency ratings for each verb form

Event	*'ing' frequency*	*'ed' frequency*	*was verbing log frequency*	*was verbed log frequency*
hire	6.00	25.00	5.26	6.16
advise	3.00	33.00	5.23	6.14
antagonize	1.00	1.00	2.81	5.22
watch	76.00	81.00	6.17	5.61
help	1.00	66.00	6.08	5.97
lecture	3.00	2.00	5.17	4.44
charge	8.00	57.00	5.61	6.48
pinch	2.00	7.00	4.64	4.90
terrorize	1.00	3.00	4.51	4.65
capture	2.00	17.00	4.92	6.11
cheer	1.00	2.00	5.39	5.34
cure	1.00	7.00	4.23	5.94
describe	17.00	120.00	5.89	6.05
adopt	11.00	45.00	5.10	6.05
accuse	8.00	25.00	5.13	6.14
attack	9.00	25.00	5.69	6.16
throw	17.00	40.00	5.97	6.18
execute	1.00	14.00	5.25	6.08
interview	7.00	12.00	5.63	6.14
startle	19.00	21.00	5.33	5.96
grade	1.00	2.00	4.57	5.97
evaluate	7.00	11.00	5.20	6.74
safeguard	1.00	1.00	2.94	4.46
tutor	2.00	1.00	4.59	4.87
deceive	1.00	5.00	4.89	5.48
show	61.00	166.00	6.08	7.01
drive	53.00	44.00	6.19	6.08
hurt	3.00	37.00	5.93	6.14
follow	221.00	172.00	6.05	6.11
release	2.00	26.00	5.35	6.65
slaughter	1.00	3.00	4.36	5.31
clean	37.00	16.00	5.94	6.01
stalk	2.00	7.00	5.24	5.38
govern	21.00	15.00	4.52	5.94
greet	5.00	20.00	4.76	6.10
recognize	10.00	80.00	4.90	6.00
entertain	12.00	11.00	5.93	5.58
comfort	8.00	1.00	5.42	5.28
search	23.00	9.00	6.09	5.96
kill	23.00	75.00	5.98	6.47

command	11.00	15.00	5.23	5.80
lift	8.00	43.00	5.42	6.09
question	21.00	29.00	5.53	6.06
study	40.00	79.00	6.07	6.00
instruct	2.00	16.00	4.95	5.06
nurture	1.00	1.00	4.41	5.31
scratch	12.00	7.00	5.18	5.53
visit	36.00	41.00	6.08	5.06
bite	6.00	3.00	5.28	5.85
forget	54.00	1.00	5.24	5.90
beg	10.00	13.00	5.58	4.42
cut	66.00	92.00	5.95	6.13
fly	43.00	4.00	6.07	6.02
save	21.00	43.00	5.77	6.09
discipline	1.00	11.00	3.98	5.39
swindle	1.00	1.00	3.40	4.41
sting	2.00	2.00	4.46	5.37
invite	8.00	26.00	5.32	6.15
fool	3.00	3.00	5.23	5.39
hypnotize	1.00	1.00	3.97	4.89
frighten	14.00	26.00	5.47	5.92
scrub	3.00	1.00	4.58	6.06
interrogate	1.00	1.00	4.42	5.53
worship	3.00	1.00	4.25	4.97
mesmerize	1.00	1.00	4.89	5.46
shoot	48.00	112.00	6.02	6.52
lead	68.00	129.00	6.05	5.91
kick	12.00	18.00	5.67	6.04
approve	1.00	40.00	4.70	6.54
betray	1.00	8.00	4.87	5.68
applaud	2.00	4.00	4.51	5.38
convict	1.00	14.00	2.93	6.38
jump	9.00	35.00	5.79	5.03
pay	26.00	145.00	6.07	6.09
beat	13.00	15.00	5.93	6.09
teach	67.00	50.00	6.05	6.09
admire	4.00	17.00	5.20	5.47
climb	11.00	44.00	5.69	4.57
ride	40.00	6.00	6.08	5.05
disobey	1.00	4.00	4.19	4.01
sentence	1.00	8.00	4.18	6.40
tease	3.00	2.00	5.32	5.26
serve	38.00	120.00	6.06	6.09
mourn	8.00	2.00	4.98	4.88
order	13.00	69.00	5.44	6.11
torture	1.00	9.00	4.84	6.00

examine	7.00	28.00	5.57	6.31
rescue	2.00	6.00	4.50	6.04
present	10.00	82.00	5.65	6.97
hammer	1.00	3.00	5.05	5.41
pull	25.00	73.00	6.01	6.11
dismiss	3.00	14.00	4.62	6.07
investigate	8.00	18.00	5.99	6.75
resuscitate	1.00	1.00	3.03	5.00
arrest	5.00	19.00	4.64	6.72
adopt	11.00	45.00	5.11	6.62
fire	1.00	44.00	5.51	6.12
chop	5.00	3.00	4.83	5.35
transport	3.00	5.00	5.29	6.05
draw	40.00	70.00	6.00	6.11
chase	3.00	1.00	5.75	5.63
audit	1.00	2.00	4.44	5.45
deliver	9.00	37.00	5.73	6.09
find	53.00	536.00	6.00	7.77

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