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Associative Priming from Lateralized Stimuli

by

Virginia A. Stanick

A dissertation submitted to the Graduate Faculty in Psychology in partial
fulfillment of the requirements for the degree of Doctor of Philosophy,
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ABSTRACT

Associate Priming from Lateralized Stimuli

by

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Semantic priming with prime-target pairs related exclusively by association was investigated, using N400 event-related potential (ERP) measures in a visual half-field paradigm. Gender was investigated as a variable potentially impacting hemispheric differences in priming patterns. Predictions included: significant priming with associated words, a left-hemisphere advantage for priming under these conditions, and gender-based differences in associate priming patterns. There were 3 studies: a study that explored factors of priming, visual field of stimulus presentation, scalp electrode recording site, and gender with this paradigm, as well as studies of males and females separately, to investigate gender-specific effects.

Word pairs, associatively (but not categorically) related, and unrelated, were presented to either right (RVF) or left visual field (LVF). Each followed by a "?" cue to response readiness on each trial, followed by a "probe" word, in the same visual field, about which subjects made judgments (related/ unrelated to either prime or target word(s)). Equal numbers of each type of trial were presented, with order of stimulus interrelationships and visual field of presentation randomized across the protocol. Stimuli were of 185 msec. duration, with stimulus onset asynchrony of 250 msec. The above design features were used to maximize processing of stimuli for meaning while minimizing potential for a large P3 component to influence N400, and to control for the possibility of post-lexical processing effects.

Results indicated significant associate priming; left hemisphere-lateralized priming in males, while females showed bilateral priming effects; with differences between gender groups in recording sites reflecting maximum priming. Implications of these results are discussed, in terms of: 1) contrast between these results and those of Chiarello, et al. (1990); and 2) their support of a model of semantic memory proposed by Deacon (2000) suggesting that language is locally represented in left hemisphere and in a distributed manner in right hemisphere. Findings are discussed in the context of that model and various constructs related to semantic memory. Gender differences are discussed with regard to possible mechanisms by which they arose with this paradigm, as well as their implications.

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I. INTRODUCTION

MODELS OF ENCODING, REPRESENTATION, AND ACCESS:

Semantic priming is generally agreed to occur when two or more words are presented sequentially and antecedent words proactively facilitate responses to subsequent words. In the study of semantic priming, this effect is measured by comparing responses to sequences of words *having* some relationship of interest with others *lacking* that relationship but equivalent on all other parameters. Priming is inferred from occurrence of classes of behavior consensually accepted as signs of cognitive facilitation: faster performance on behavioral measures of word recognition (e.g., lexical decisions, reaction time (RT) measures, naming tasks, etc.) and/or systematic changes in brain activity indicative of accelerated processing (Meyer and Schvanenveldt, 1971; Posner and Snyder, 1975, Neely, 1976; Kok, 1997; Rosler, Heil, and Roder, 1997). An apt summary of this process was provided by Balota (1994), who stated, "It appears that letter- or word-level representations do not passively accumulate information . . . but letters and words appear to be recognized in the context of similar representations that either reinforce or diminish the activation at a given representation."

The concept of *activation* is basic to any discussion of language processing. Indeed it can be considered part of the foundation of an even broader range of general principles in cognitive psychology, memory theories, semantic network/feature models, and theories of reading comprehension (Haberlandt, 1994). Many theorists use the concept of activation in the sense that it is the mechanism that drives access to information encoded and represented in the brain in a nodal fashion. Lexical conceptual units are related according to organizing principles that—metaphorically, if not anatomically—form nodes. Coding, interrelationships, and activation of such linguistic representations are topics that have provided much material for theoretical debate.

Another dimension of language-related cognition involves issues of the manner(s) in which lexical representations are effectively (and efficiently) encoded, stored, and accessed by the brain. Much has been written to address these problems. However, there is proportionately very little material in the literature that could be said to take a definitive position in support of any of the various theories of linguistic representation.

There is yet an even more general—and perhaps more accurate—statement that could be made about the condition of the literature in this area to date. It is often difficult if not impossible to discern whether authors are taking theoretical positions on modes of representation *physically* in the brain, or if what is being addressed is more a matter of *conceptual ideas* regarding the manifestation of language representation. The former implies a commitment to specify neuroanatomical architecture of lexical information in the brain, concentrated most on physical mechanisms of storage, interconnection, neural activity, etc., related to lexical material in the brain. The latter is a more metaphorical, taxonomic approach emphasizing the lexical information system and how it is structured. The fact that the preponderance of work in this area states no strong commitment to either often leaves the reader in a state of uncertainty about which of those analytical vantage points is being taken by any author (What, specifically, is being addressed? Is it more about the brain as a mass of protoplasm and how it stores knowledge, or about the structure of a database that happens to be housed in brain tissue?). That is at present an inherent limitation on the system of thought in the study of brain-behavior relationships regarding language, and as such, represents a point upon which any review of the subject matter is concomitantly inconclusive.

Bearing those thoughts in mind, there are two major areas of theory that are germane to the research under discussion here, which to a certain extent (again not precisely defined) represent opposing views. The primary debate related to theoretical viewpoints is essentially that of "local" versus "distributed" encoding and/or processing of lexical representations.

The criticism regarding nonspecificity of theories applies very centrally to the debate about local and distributed processing. Part of this enigma may stem from the absolute proliferation in the last several years of applications of neural network schemes to artificial intelligence (AI) systems. There appears to be a great deal of shuttling back and forth between AI and central nervous system (CNS), during which concepts and assumptions are freely borrowed and traded. While some of the principles of both may be interchangeable, just as ideas generated by basic animal neuroscience work have been applied to reasoning about human brain function, the limits and extents of interactions among these various areas must be tested before yielding to the tempting impulse to assume their validity. We are making strong efforts to avoid the problems inherent in that kind of quantum leap in logic, appealing though it might be to make it. Thus we will establish a general rule in addressing this topic such that references to representational theories or processes will refer to the "meta-" level, *the organization and structure of information* (as opposed to brain tissue), unless explicitly stated contrarily.

Local Representation/Processing:

Local models of semantic representation, almost by nature, have a basis in the assumption that neurons (or assemblies thereof) in circumscribed, definable brain areas, are units of linguistic representation. Thorpe (1995) expressed an eloquent encapsulation of the general idea of local representation in the following:

> What happens in the brain when one recognizes a familiar stimulus such as the face of one's grandmother? Most researchers accept that the act of perception involves the activation of some form of internal representation, but there is little agreement about how such representations are implemented in neural hardware. While it is clear that many millions of neurons in the visual system are activated during the processing of each retinal image, many of them are involved in generic visual processing. Nevertheless, it seems likely that at some level of the visual system there exists a population of neurons whose activity in some way represents the concept *grandmother* . . . Specifically, could it be that the final representation involves neurons that respond selectively to grandmothers—so called *grandmother cells*? . . . Could neurons behave like nodes in a semantic network, with a direct mapping between neurons and concepts? (p. 12)

Thorpe goes on to state, in support, incidentally, of the foregoing critique, "Connectionists generally avoid this question by insisting that the nodes in a connectionist network are not to be thought of as real neurons." A key feature of "pure" local representational theories is that they assume singular, unique coding of words such that access to any given word involves activation of a single irreducible unit assigned exclusively to that word.

According to most theories of semantic representation, when a given concept (/idea/term/word) is activated by a stimulus condition, that activation spreads to other nodes via (inter)relationships between nodes, i.e., "automatic spreading activation" (Posner and Snyder, 1975; Neely, 1977). Quillian (1962, 1967) proposed a spreading activation theory of human semantic processing for application to computer simulations of verbal memory and language comprehension (Quillian, 1966, 1969). The model founded on Quillian's theory has since been extended and elaborated to apply to human linguistic systems instead of its original purpose, ". . .to show how to build human semantic structure and processing into a computer" (Collins and Loftus, 1975). The assumptions of Quillian have been outlined and expanded by Collins and Loftus (1975), summarized below:

Concepts are represented as nodes in networks; the capacity for information storage in a given node is indeterminate. Nodes are linked with others which share properties, the links between them specifying what relationship they have to one another. Links between nodes are usually bidirectional (i.e., between two given concepts the link usually points to each as related to the other). Links between nodes have different "criterialities," or weighting factors, specifying how critical each link is to the meaning of the concept to which it is connected. Between two nodes, the link can depict different criterialities on either side (e.g., for the concept "spoon," the fact that it is a "utensil" is criterial, but the fact that "spoon" is one of a number of "utensils" is not equally criterial to the concept "utensil.") There are different types of links serving different purposes, and the variety of links is flexible enough to adequately depict any type of relationship between concepts. A memory search between concepts entails activation along the path of links to each concept node specified by the input word(s), beginning with those that define the breadth of related concepts, and progressively activating in turn, nodes linked to *those* concepts (/nodes), then to those one more level removed, etc. According to the Collins and Loftus (1975) version of this model, in such memory searches, there is a mechanism (unspecified as to what or how) that tracks the path this process takes, such that all relevant links can be retraced through all nodes reached in the above back to their origins. When common sources of activation are detected in this process, in which there is an intersection found between nodes that is traced back to the starting concept, the path is evaluated as to how well it fits syntactic and contextual constraints. Ill-fitting paths are rejected, those better fitting are retained, until the system finds that which fits best with the limits specified.

Priming, according to Collins and Loftus (1975) engages the same sort of tracing/elimination process described above, in which the objective is to eliminate all but the most closely fitting paths between nodes. In addition to concept nodes priming one another, links, themselves, may prime. Quillian "treated links themselves as concepts. . . provid[ing] a very powerful context mechanism" (Collins and Loftus (1975).

In addition to the above, Collins and Loftus (1975) extended the original framework provided by Quillian and added modifications stipulating that activation spreads when a concept is processed/stimulated, along paths of a network ". . . in a gradient the strength of which varies proportional with "accessibility or strength of the links in the path." In addition, they stated that activation of nodes/links/paths in a given network progressively decreases/decays with the passage of time and/or as a result of "intervening activity" (presumably not related to processing the stimulus in question, thus competing with previously activated nodes).

Smith, Shoben and Rips (1974) have presented a model which is in some ways "local" in nature, the essence of which is that there are lexical loci (this writer's term) consisting of superordinate categories, within which are nested the various subordinate elements of each. They (Rips, Shoben, and Smith, 1973) refer to their model as a "set-theoretic" model, and distinguish their model from "network" models according to how relations between lexical units are expressed or coded. Their claim is that what they term "network" models ". . . assume that words or their conceptual counterparts exist as independent units in semantic memory, connected in a network by labeled relations" (Smith, et al., 1974). Their "set-theoretic" model has been described as representing concepts "as bundles of semantic features," of two types: "defining features and characteristic features" (Collins and Loftus, 1975). *Defining* features are those essential for inclusion in a concept, while *characteristic* features are those which may be frequently found as subset properties of a concept but which are not necessary for inclusion.

The import of the above is that their model seems founded on principles of category membership based on defining features. In fact, they explicitly state that their model "represents semantic information by only one means—semantic features," and continue, "we consider a broader range of features than those which strictly define a category. . . we propose a two-stage comparison process in which the relationship between the two stages is probabilistic, in contrast to [a] strictly additive stage model. . ." (Smith, et al., 1974).

Another aspect of their "featural" model is that it further subdivides superordinate/subordinate relationships so that "typicality" ratings are determined between subordinate and superordinate elements, analogous to the concentric circular arrangement of an archery target. The superordinate concept in a given semantic unit is (metaphorically) located in the middle ("bullseye") area. Subordinate terms are arranged around the superordinate in ringlike fashion, their distance from the superordinate defined by their "typicality" (Rips, et al., 1973; Smith, et al., 1974) or relative degree to which each is a typical case of the superordinate.

Collins and Loftus (1975) critiqued the set-theoretic model on various salient points. They highlighted a great difficulty in distinguishing defining and characteristic features, in that no feature is *essential* to any category, and added that ". . . people seldom know the defining properties of concepts." They further pointed out a potential flaw in the assumption of the set-theoretic model that every categorization decision was made by comparison between features of instance and category, without the use of superordinate links between terms. They argued that people would "use whatever evidence they find" in making those judgments, not exclusive of superordinate links. Finally, they strongly stated that the major logical flaw of the set-theoretic model is that if people had access to superordinate information they would not fail to utilize it, if it would facilitate or enhance processing. Their interpretation of Smith, et al.'s (1974) position has been that the model in question specifically disallows or excludes contributions to processing by such superordinate information, and the position of Collins and Loftus (1975) is that this is simply not a pragmatic notion. There is no reason or evidence in support of the idea that in the course of accomplishing a processing task people would selectively exclude or ignore information that might facilitate that objective.

The model of Smith, et al. (1974) is essentially a local (again at least in the metaphoric, organizational sense) model of encoding and access to lexical material, in that it postulates semantic areas defined by superordinates and containing (at various semantic distances based on "typicality") all subordinate terms within the bounds set by those superordinates. It seems almost as if this model is a schema describing the structure of representation of categorical information in which superordinate terms could be considered local nodes. Within those local nodes are subordinate terms, coded in a distributed manner by features. Thus, the model of Smith, et al. (1974) can be viewed as a form of micro-analysis of categorical representation.

While there is explanatory merit in that approach insofar as the subject of categorical semantic relationships, the model does not explicitly address or explain what happens with stimulus material that is other than categorically related. If lexical elements are related according to some axis other than category or super- sub-ordinate juxtaposition, there is little to predict by that model how such stimulus material would be processed. There are cases in which *associative* relationships are strong (e.g., CAGE-BIRD, COW-MILK, etc.) but the lexical items are in no way members of the same formal *category*. If we take the Smith, et al. model literally, instances such as these should not show facilitation of one term by its antecedent term. We will discuss later that facilitation *is, indeed,* obtained from such pairings.

Distributed Representation/Processing:

Masson (1995) presented a "distributed memory" model of semantic priming based on principles derived from Hopfield network rules. According to Hopfield's (1986) conception of model neural circuits and their networked interconnections, in the most simplified form of this idea, processing units are composed of collections of interconnected neurons. These sets of neurons compile specific patterns of activation across the entire network that correspond to (probably equally specific) stimulus characteristics. Hopfield network principles can be applied to understanding and modeling of a number of neurobiological systems, among which language may be included.

Masson's model (1995) and its subsequent (slight) revision (Masson and Borowsky, 1998) involve a Hopfield network with weighted connections between encoded linguistic features. Masson (1995) has implied that a major distinction between his "distributed memory model" and a classic Hopfield net model is that in the latter, there is no possibility for differentiating among different types of processing units; the state of each neuron (i.e. electronically simulated or actual) is compared in pairwise fashion to that of every other neuron in the network. Each individual unit is capable of taking on only one of two (binary) values of activation: "on" or "off." When criterion activation patterns are reached in response to a given stimulus (i.e., a threshold volume of units collectively has "on" and "off" states in correspondence with a specific pattern representing that stimulus), the neurally-encoded representation of the stimulus is activated. This suggests that, according to Masson's (1995) conceptualization of a classic Hopfield net, there is one large collection of binary processing units, all of which work conjointly, to cover widely distributed functions of orthographics, phonics, and semantics, with a given word activated/identified when a criterion threshold number of on/off values are reached, across the system. Thus any word, e.g., DOG, would evoke a characteristic pattern within graphic, phonetic, semantic, and perhaps other (depending on one's theoretial preferences) units; if enough "dog" pattern units are appropriately on/off simultaneously, the word DOG is identified.

Masson (1995; Masson and Borowsky, 1998) has developed a version of a Hopfield net which has included "modules" of processing in his distributed model. Those modules include separate but integrated processing units for orthography, phonology, and semantics. Masson's various modules are not identical to one another in their functioning, according to his model; especially with regard to systematic attempts to replicate human experimental results with simulations (Masson, 1995; Masson and Borowsky, 1998). In order to optimize performance of those modules, there are differences among them in the sampling process by which system updates are accomplished and frequency of "updating cycles" in each discrete module (Masson and Borowsky, 1998).

In Masson's distributed memory model, words are defined as patterns of activation of all units in the system, each of which has potential binary values, +1 or -1. Thus, for every unique word in any lexicon under consideration, there should be a corresponding (unique) pattern of activation across all units representing various features in their respective modules (orthographic, phonological or semantic). Acquisition of new lexical items according to this model takes place through alteration of weights of connections between pairs of units (as in a typical Hopfield net), according to a Hebbian learning rule (Masson and Borowsky, 1998). Connection weights increase (according to the rule) if a given pair of units is in at an identical (binary) value, either "+ +" or "- -" during an update cycle while the pattern for the word being learned is established within the system. They decrease if the pair of units is in opposite states ("+ -" or "- +") during the update.

According to Masson (1991; 1995; Masson and Borowsky, 1998) the "learning" of a word is completed when further updates of the system produce no further changes in status of correlations between units, i.e. all connection weights have been established. (In reality, that being the simulations conducted by Masson, a task-related criterion regarding what constituted sufficient updating and/or system stabilization was established as a termination point for word learning.) Thereafter, according to this model, when the system is presented with a pattern that evokes activation across units identical to that previously established for a particular word stimulus, the representation of that word will be accessed.

Masson depicts relationships between words as being represented by degree of similarity of the collective patterns of unit activation between stimuli. Thus the "degree of match" (Masson and Borowsky, 1998) present between any two words corresponds to the strength of their relationship(s). Representations with high degrees of connectedness, according to that model, have greater similarity of activation across units than do those with less connectedness. (Depending on task definition in any given situation, the specific *type* of connection between stimuli may emphasize one processing module more heavily than others.)

Semantic priming, according to distributed models such as that outlined above, would logically be a phenomenon tied to a continuum of similarity-dissimilarity between activation patterns of words in the lexicon. Presented/read sequentially, words that evoke very closely aligned, similar (or identical, in the case of simple repetition) activation patterns would: a) take fewer unit-for-unit changes between first- and second-presented words, in order for the second-presented to reach a point of stabilization, and as a result, b) probably consume less time and energy to transition from activation of one to the next.

There is negligible evidence of any clearly delineated theoretical work to date presenting models of distributed language representation explicating how their proponents postulate distributed representation to be enacted on a neural level. Of distributed systems, Thorpe (1995) points out that the preponderance of strong arguments for distributed coding come from work on sensory and motor systems, both of which require coding of continuous variables. Instead of neurons being oriented to circumscribed sets of specific values (e.g., degrees of deflection of orientation, spherical direction, etc.) the brain employs groups of neurons coded with overlapping variable features. The outcome (in behavior) stems from the total activity of a given set of neurons, weighted by the strength of each neuron's response. This concept has also been referred to as population vector coding.

Thorpe (1995) goes on to question how "high-level concepts like *apple*, *chair*, and *grandmother*, which cannot be represented as continuous variables" could be coded, and implies that local coding is probably not a viable possibility as an answer to that. He cites several criticisms of local coding that in essence rule it out as a semantic coding mechanism then refutes each of those criticisms in turn with arguments in support of the continued plausibility of local representation. Those criticisms (a) and corresponding refutations (b) include the following.

1) a) An unrealistic amount of neural tissue that would be needed to implement a totally localized 1:1 neuron-to-stimulus scheme; (b) The number of neurons needed does not equal the number of discrete stimuli, but the number of "perceptual categories" (estimated at ~100,000).

2) (a) The relatively high cell-death survival risk of completely nonredundant local coding; (b) A small amount of redundancy would answer this; the chances of 2 given cells failing simultaneously are very small.

3) (a) The argument Thorpe terms, "*No One Has Ever Found a Grandmother Cell,*" (b) There is evidence of very selective "tuning" properties of sensory/perceptual neurons.

4) (a) The relative unreliability of individual neurons; (b) There is evidence (again in sensory/perceptual neurons) of single cells that contain as much stimulus information as animals' behavioral responses; and

5) The claim of some that local representations do not generalize; (b) local coding schemes generate generalizations rather easily "if unit responses are graded rather than binary."

It is striking that after providing refuting arguments for the above criticisms, Thorpe (1995) adds to the answer for the last stated above by proposing that the solution to it may come in the form of "systems based on a combination of local and distributed representations." Congruous with that possibility, an alternative to the above perspective of "local versus distributed" (which implies a general commitment to one or the other view of encoding/processing) can be found in the model under investigation in our laboratory. This model essentially posits that semantic memory is arranged such that lexical items are locally represented in left hemisphere (LH), while the same items are encoded/represented in right hemisphere (RH) via distributed mechanisms. Deacon (2000) points out that this view contrasts with those put forth by Beeman (1998), not just simply in the idea that the size of semantic fields differ between hemispheres. In addition, according to our model, the mechanism(s) by which semantic representation is accomplished are different between LH and RH. According to Deacon,Yang, et al.

(2001), no associative links among RH-based feature nodes are extant, although features with associative qualities can come to represent an item, e.g., *"eaten with butter"* is a possible encodable feature of the word *"bread"* and the two terms (bread and butter) also happen to be closely associated. With this RH absence of associative links, there would be no mechanism by which activation would spread from one item to another, under conditions in which the items contain little or no featural overlap.

What we would expect to result from the above is a situation in which items high in association but sharing few features might show a priming effect when presented to LH, but not when presented to RH. In a complementary fashion, assuming the validity of this model, RH might prime more strongly when presented with items that have high rates of shared features, where association is not a property of their relatedness. That idea has been supported by a study in our laboratory. A set of stimulus material was constructed such that prime-target pairs were related by physical or functional features exclusively (i.e., they were neither categorically nor associatively related, but only related by *shared features*). Thus, the words TREE-BROCCOLI or BASEBALL-GRAPEFRUIT shared features of physical characteristics; RAKE-COMB and SHOVEL-SPOON would be considered to share both physical and functional features. These types of word pairs in a visual half-field priming paradigm (in which all words in a given trial were presented either to LVF/RH or RVF/LH) produced N400 priming *exclusive to RH in the absence of LH priming.* No significant priming was found in LH, and between-subjects differences due to gender were not found (Deacon, Yang, Nagata, and Grose-Fifer, 2001).

THE N400 AS AN INDEX OF SEMANTIC PRIMING:

A tremendous volume of work has used reaction time (RT) and other behavioral measures as data from which to infer processing under various conditions, semantic priming paradigms being no exception. In relatively recent years, ERP techniques have been applied to many of the same sorts of problems. ERP techniques have been cited as potentially advantageous over reaction time (RT) and other behavioral measures for mapping "the course of central events in real time;" ERPs are "unequivocally tied to their defining behavioural indices," (Milner, 1986) and provide ". . . evidence concerning the temporal structure of the events which intervene between experimental probes and subjects' overt responses" (Neville, 1980).

The N400 component of the ERP is generally agreed to reflect cognitive processing of linguistic stimuli at the level of words, and can be manipulated to reflect semantic priming (Kutas and Van Petten, 1988; Kutas and Hillyard, 1989). It has been suggested that N400 is a covariate of "lexical search" activities and that, in effect, its amplitude corresponds with the magnitude of activation processes designed to integrate "linguistic information that is inconsistent with a given semantic context" (Rosler and Hahne, 1992).

Given the ongoing debate regarding whether N400 reflects automatic spreading activation or a post-access processing phenomenon, (Deacon, Hewitt, et al., 2000; Holcomb, 1994; McCann, Remington, and van Selst, 2000; Perea and Gotor, 1997; Shelton and Martin, 1992; Silva-Pereyra, Harmony, et al., 1999) we should clarify our position on the above. While the words "search" and "integrate" may imply some actively directed, consciously selected, strategic process, those terms could refer to the specific path of the spread of activation for a given word or words, and settling of the system on overlapping or shared representational nodes. The expression regarding the amplitude of N400 is generally valid in the sense that the more semantically distant, incongruous, novel, or unexpected a word is (in whatever context is defined), the greater the negative amplitude deflection is found in N400. Initial studies of the N400 ERP component utilized variations of the Cloze probability of words in sentence endings, in which "contexts" for those words were set by the preceding words in their respective sentences (Kutas and Hillyard, 1980, 1984).

More recent studies have used priming paradigms in which word pairs are stimulus material and a single antecedent word sets the context of a consequent word. This word-level processing may be seen as not necessarily implying *directed awareness* of word *meaning*, as the N400 has been elicited under a number of conditions in which meanings were not consciously accessible due to masked priming, etc. (Deacon, Hewitt, Yang, and Nagata, 2000; Schnyer, Allen, and Forster, 1994). Additional evidence of N400 priming effects in the absence of opportunities for post-lexical processing have come from studies that have used stimulus onset asynchronies (SOAs) that were too brief to allow for that type of processing (Anderson and Holcomb, 1995; Boddy, 1986; Deacon, Hewitt, and Tamny, 1998).

The N400 component is sensitive enough to priming effects that associative priming has been found even in studies which manipulated task demands so subjects did not expect that word meaning would be a relevant stimulus parameter. Kutas and Hillyard (1989) required subjects to make judgments regarding whether or not a letter, presented after a pair of related or unrelated words, was present in either of the words. N400 priming was obtained for related word pairs, despite task demands which made word meaning superfluous. Katayama and Yagi (1990) obtained similar results in a study in which orthographic cues for occasional targets were used and stimuli were presented in different modes created by combining three different Japanese writing systems. Semantically deviant words produced larger N400 components than did frequent category words; however the amplitude differences found were smaller than those produced when the task required semantic processing.

While priming certainly could be obtained under conditions that do not emphasize word meaning as salient, previous work indicates manipulation of the degree to which processing demands are *semantic* in nature can affect the magnitude of N400 priming (Chwilla, et al., 1995; Deacon, Bretton, Ritter, and Vaughn, 1991; Katayama and Yagi, 1990). Thus these results seem to indicate that there may be a phenomenon not unlike a "dose-response curve" that can operate with semantic processing, such that overtly semantic task demands actually induce larger amplitude differences than those brought on by situations in which semantic stimulus parameters are "incidental." That general principle seems to apply across sensory modalities of stimulus presentation (Rugg, Furda, and Lorist, 1988; Bentin, Kutas, and Hillyard, 1993).

McCallum, Farmer, and Pocock (1984) found that *semantic incongruity* in spoken sentence endings reliably evoked N400 responses, while *incongruity in voice* (last word spoken in a female voice) has been found to evoke only a roughly equivalent *positive* component (Chwilla, Brown, and Hagoort, 1995). A task requiring purely *physical* judgments (i.e., capital versus lowercase letters) did not produce priming on N400 or reaction time measures, while a lexical decision task (Chwilla, et al., 1995) and category judgments (Deacon, Bretton, Ritter, and Vaughan, 1990) have elicited N400 priming. It could be surmised that priming is specifically a function of lexical decision tasks that make *semantic* attributes of stimuli relevant at some level. These studies indicate that N400 effects should be fairly specific to lexical characteristics of stimuli, as opposed to those defined in more "physical" (acoustic, graphic) ways. However, it is also possible that lexical decision tasks, in comparison with purely physical judgments, require relatively more complete processing of stimulus material in order to generate appropriate responses. In keeping with the semantic "dose-response" principle established above, even if lexical decision tasks do not seem to inherently direct subjects toward processing words for semantic attributes, they may be higher than physical stimulus characteristics on a hierarchy of meaning-based processing.

Brown and Hagoort (1993) differentiated between lexical *access* and post-lexical *integration*, in a study combining reaction time (RT) and N400 ERP measures with masked and unmasked prime words. Their findings were that RT demonstrated semantic priming regardless of masking condition; however, N400 priming effects were only present when primes were *unmasked*, taken by the authors of that study as evidence that N400 reflected post-lexical processing. The authors concluded that the N400 component reflects integration, post-lexically, into higher-order contextual frameworks. As pointed out by Deacon, et *al.* (1995), Brown and Hagoort's (1993) interpretation accounts for the lack of evidence of N400 priming in that study, but fails to explain the *elicitation* of an N400 response, if masking prevented processing from occurring. Subsequent studies have yielded additional information that contrasts with results of Brown and Hagoort (1993), demonstrating that N400 priming can be obtained with repetition (Schnyer, Allen, and

Forster, 1994) and manipulation of semantic relatedness (Deacon, Hewitt et al., 2000), even with masked stimuli.

Brown and Hagoort's (1993) methodology may have had a profound influence on the results upon which their conclusions (above) are based. It may be quite possible that some subjects assigned to their masked priming condition would not have shown priming under *either* of the protocols employed in the study (masked *or* unmasked). Given the fact that conditions assigned to each subject group were mutually-exclusive (i.e., if a given subject was in the masked condition, he/she was never exposed to the parallel, unmasked one, and vice-versa), the investigators could not have determined (if at all) to whom this applied. Thus an interaction of their protocol and individual differences among subjects may have affected their results (Deacon, Hewitt, et al., 2000; Deacon and Shelley-Tremblay, 2001).

Rugg, Doyle, and Holdstock (1994) reported results of four studies that employed variants of repetition priming; these studies were designed to progressively investigate the effects on priming of local versus global context. Their theory was that N400 is influenced by ease of integration of stimuli with their respective contexts. Apparently much to the authors' surprise, this series of studies did not support their hypotheses. Instead, what was found was that single word repetitions that were delivered out of initially-set context (i.e. paired with different words than those with which they were initially presented) did not differ from those presented as exact repeated pairs with regard to an N400 priming effect. That principle held even when repeated items were separated by a number of intervening trials. The only type of repetition condition that did not show

N400 priming was that in which only one previously-presented word was repeated as part of a pair (i.e., a single-word repeat paired with a "new" word).

In the above series, however, *behavioral* (RT) facilitation was shown with *all* repeated stimulus conditions. The authors speculated that the lack of ERP priming effects found under the condition in which only one item of a pair is a repeat while the other is "new" may be due to the effect of attentional mechanisms; the single repeat may not have been attended due to a bias in favor of attending more strongly to novel material. The consistent facilitation of RT responses obtained, in contrast, may reflect a differential obtained in post-lexical processing, such that repeats—in any form—attenuate slowing of responses due to word-by-word checking.

Condor and Campbell (1991) combined RT and N400 measures in a protocol where subjects were differentially instructed either to concentrate on response speed or accuracy. RT was faster under conditions where speed was emphasized, compared to those concentrated on accuracy; however, N400 latency reflected no differences based on the type of instructions given. This is further evidence that N400 is not *necessarily* linked to the type of post-lexical processing discussed by Brown and Hagoort (1993), as, if it were, it should have reflected a similar type of differential based on instructional set.

EXAMINATION OF PRIMING USING LATERALIZED STIMULI:

Studies of priming using different types of semantic relationships and observing effects of both centralized (i.e., foveal) and lateralized stimulus presentation have yielded very mixed results. In some cases, lateralized presentation yielded equal priming in both hemispheres (Marcel and Patterson, 1978; Burgess and Simpson, 1988). In others there was greater semantic priming for right hemisphere (RH)/left visual field (LVF) presentation (Chiarello, 1985). Under "controlled processing" conditions such that subjects could develop expectations regarding the occurrence of semantically-related stimuli, priming was greater for LH/RVF conditions. When priming for categorical relationships (cat-elephant, plate-bowl, etc.) was compared to that of category-unrelated associates (cow-barn, polish-shoe, etc.), priming was found for both types of relationship via a lexical decision task. With naming as a behavioral measure, priming has been reliably present only with word pairs that were associated; categorical relationships showed weak, unreliable priming in an early study (Lupker, 1984) while others have found significant (pronunciation based) priming with both types of relationship (see Neely, 1991, pp. 268-270 for a summary).

Beeman (1998) has suggested a framework with which finely-coded, strongly-activated semantic field that is narrowly defined, is an ideal candidate for such patterns of activity. According to Beeman (1998), those characteristics are in many ways prototypical of LH functioning, and RH, in contrast, activates relatively larger semantic fields, providing rough or approximate renderings of meaning(s). If that is the case, with any given word, in RH there is a higher probability of overlap with possible consequent words that share features. This putative arrangement is potentially germane to all of those interpretive functions noted above (plus, probably, numerous others). Let us assume that the above is an accurate portrayal of this aspect of LH and RH functioning and distinctions between the two hemispheres. According to that model, the logical expectation regarding results in a lateralized associate priming paradigm would be that RH would most likely show priming, with LH responses being less predictable.

An alternative possibility exists, if we consider RH encoding to be based on features or properties in a distributed manner, and LH encoding based on associations, with local coding of whole semantic unit nodes. The feature-only priming study from our laboratory (described above) provides insight into this LH/RH dichotomy, especially regarding support of our contention that coding is performed based on features in RH but not in LH (Deacon, Yang, et al., 2001).

The above type of schema better explicates the present data and the experimental literature than does the Beeman (1998, as above) LH fine/strong/narrow vs. RH coarse/weak/broad model of hemispheric language coding. In fact, while Beeman's system does not satisfactorily explain much of the data we have obtained to date in the investigation of our model, our model may shed light on how Beeman's (1998) system was conceptualized.

Chiarello, et *al.* (1990) published results of two behavioral studies of semantic priming with a variety of types of semantic relationships. Central presentation of prime words with RVF- or LVF-lateralized target presentation yielded equivalent priming in both hemispheres for all semantic relationships tested. In a second group of subjects to whom the same stimulus sets were presented laterally (i.e., prime and target pairs for each trial presented to either RVF or LVF), priming was equivalent only for words that were related by *both* category *and* association. Under those completely lateralized stimulus conditions, *no priming effect was seen for words the authors defined as purely associated, and categorical priming was greater for LVF/RH trials than for RVF/LH.* This pattern held across two behavioral studies, one using RT and the other naming accuracy; indicating that the specific behavioral task used probably did not spuriously induce the effects that were found.

In contrast, Abernethy and Coney (1996) summarized the available literature by stating that several authors have made a case for the concept of categorical relationships being strictly within the functional purview of the LH. In fact they paraphrased a suggestion from Drews (1987, cited in Abernethy and Coney, 1996) that "the left hemisphere is organized according to an hierarchy of logical relationships described as 'intraconceptual' (e.g. BUS-TRAIN). The right hemisphere . . . is organized in accordance with 'interconceptual' relationships (e.g. COFFIN-EARTH)." They further argued for "a powerful consensus that it is the [LH] which is the natural site of semantic category relationships." This implies differential capacities within RH and LH, such that the former would have a relative strength in processing pure associative relationships, while the latter would demonstrate superiority with categorical relationships.

Chiarello *et al.*. (1985, 1990, 1992) were criticized by Abernethy and Coney (1996) on various methodological grounds, including the following: 1) Lack of certainty that stimulus pairs deemed "categorically related" were truly *just* related in that way and not "mixed" category and associate relationships (e.g., INCH-YARD, given by Chiarello (1985) as an example of a pure categorical relationship); 2) Abernethy and Coney (1996) further called into question the stimulus onset asynchrony (SOA) between prime and target words in the work(s) of Chiarello *et al.* They pointed out a potentially significant influence of the relatively long SOAs (575 and 600 msec.) in the studies, stating that while "timing differences" may not have totally accounted for discrepancies between their previous studies (Abernethy and Coney, 1990, 1993) and Chiarello's findings, SOA differences may have been at least partially responsible.

In an attempt to clarify some of the issues they raised (above), Abernethy and Coney (1996) undertook behavioral studies of priming that used carefully formulated prime-target pairs, such that related pairs were *only categorically-related;* pairs that had both categorical and associative relationships were strictly eliminated. A second (comparison) condition that was considered "neutral" by the authors was also comprised of the word "BLANK" as a prime, followed by each target word from the related set. Two SOA intervals were employed, one relatively short (250 msec.), and one considerably longer (450 msec.) Primes and targets were randomly presented to RVF or LVF; equivalent numbers of each possible combination of prime-target/visual field were accumulated for each subject (i.e., RVF-RVF, RVF-LVF, LVF-LVF, LVF-RVF).

Results of the above studies supported a conclusion that "pure" categorical priming is exclusively the domain of LH, and that while LH can transmit information from categorical priming words to RH, a reciprocal process does not apply (i.e., RH does not prime LH for categorical relationships). The latter conclusion was reached based on the fact that RVF/LH-presented primes yielded RTs indicative of facilitation *regardless of visual field of target presentation* (albeit overall, RVF-LVF prime-target pairs showed considerably slower RTs than exclusively RVF-RVF presentations). LVF/RH primes, in contrast, yielded no significant evidence of behavioral (RT) facilitation in response to related prime-target pairs. Results were essentially consistent at both SOAs studied. Thus, conclusions of Chiarello et al. that indicated RH representation and processing of categorical relationships were called into question by these results; indeed, those results were contradicted by this series of studies.

In addition to the aforementioned potential problems with methods as described in the various Chiarello studies referenced, we have noted another feature (or lack thereof) in work of Chiarello previously cited. While there are fairly thorough descriptions of apparatus and protocols, the authors do not mention any method used to inhibit and/or control for subjects' eye movements during stimulus presentation. Eye movement control is not described or acknowledged. This may simply have been an oversight; however it seems a rather glaring one. If, indeed, eye movements were not controlled for, there would have been no way to account for any number of trials for any given subject in which lateral saccades provided hemispheric exposure to stimuli that was unintended. Thus, were that the case, trials intended for right- or left-lateralized presentation could well have been the opposite, a mixture, or bilateral.

It appears that LH at this point in time is the leading candidate as the likely location for representation of categorical relationships. Given mixed results across previous studies, possible methodological shortcomings found in the Chiarello studies with absence of any priming in either hemisphere for associatively related items when both prime and target were lateralized, the issue of associative versus categorical representation and hemispheric functioning remains open. Considering that the obvious "other" facet of this topic—purely associative (*sans* category) relationships—remains even more open to question, the need for further exploration is clear.

GENDER, LANGUAGE, AND LATERALITY:

The vast majority of semantic priming studies (as well as most others in similar areas), have commingled male and female subjects within the same group(s), without regard to possible gender effects. The overarching principle that has been derived throughout volumes of research has been that, in general, males are more completely lateralized than females. A generalization has been drawn, that the LH and RH subserve more discrete, separable functions in males, while females show more globalized, equivalent functions between RH and LH. Some of the relevant literature is reviewed below, tracing the means by which that generalization has been derived.

There is much empirical evidence that gender-related hemispheric differences in language processing exist, and follow the same general pattern found with many other cognitive functions. Lake and Bryden (1976) found females with familial sinistrality were more likely to test on dichotic listening tasks as having an atypical left-ear advantage (LEA), while in males exactly the opposite pattern was exhibited. A significant gender difference was found overall, indicating males to be more completely lateralized than females. Bradshaw, Gates, and Nettleton, (1977) studied gender effects on lateralized lexical decision tasks with words, illegal consonant strings, and legal nonwords. Females showed significantly reduced hemispheric differences and faster responses than males on all tasks; males demonstrated "typical" LH advantages. Of note also is that sinistrals of both sexes showed considerable equivalence between hemispheres. On a lateralized Stroop (color-word incongruity) paradigm, comparisons among male and female dextrals and sinistrals demonstrated differences in RT between right and left visual half-fields for dextral subjects. Both dextral and sinistral males had significantly greater errors in LH presentations, but no lateralized differences were found in females, again lending support to more equality between hemispheres in the female group (Franzon and Hugdahl, 1986).

Findings of gender differences on unilaterally-presented auditory word reception tasks are also common. Taylor and Heilman (1982) used a monaural, lateralized listening task to test dependence of language laterality on memory tasks and to determine whether gender and familial sinistrality would have similar effects on the monaural task as on dichotic and lateralized visual tasks. The authors discovered that a right ear advantage (REA) was present *only in males without familial sinistrality,* on recall of recency but not primacy items. They concluded that "echoic" memory mechanisms are particularly well lateralized, that the monaural REA may be similar to those found with other paradigms, and that processing demands inherent in the monaural technique may have resulted in the finding indicating the lack of a significant REA in females. A dichotic listening task using consonant-vowel combinations yielded results that indicated clear-cut gender differences. Despite overall dextral results indicating REA and sinistral results indicating LEA, only *dextral male* group results were homogeneous enough to conclude the REA found was reflective of LH specialization for speech perception (Hugdahl and Franzon, 1987).

It is not surprising to find that males with LH pathology including aphasic symptoms present more severe and refractory language problems than females with similar conditions. There is substantial evidence that LH pathology in males is correlated with more profound verbal memory (Davies, Bell, Bush, and Wyler, 1998) and language deficits than in roughly equivalent female clinical groups (DeRenzi, Faglioni, and Ferrari, 1980; Hochstenbach, Mulder, van Limbeek, et al., 1998; Schechter, Schechter, Abarbanel, et al., 1985; Trenerry, Jack, Cascino, et al., 1995). Likewise, data longitudinally tracking language functions and prognoses in aphasia cases have indicated generally better improvement rates in females than in males (Basso, Captiani, and Moraschini, 1982; Pizzamiglio, Mammucari, and Razzano, 1985).

Despite copious findings indicating that males and females demonstrate differentiable patterns of information processing, ERP studies—and semantic priming studies in more general terms—have not systematically explored this variable (King, Ganis, and Kutas, 1998). Given strong evidence that females appear to be less completely lateralized than males, and females tend to show greater EEG power and interhemispheric coherence than males (Flor-Henry and Coles, 1982), it would make sense to investigate--or at minimum *account for*--gender as a variable. This is especially valid in instances where previous studies have used mixed-gender groups (which most have, seemingly in an effort to "control" for gender by balanced inclusion), have yielded equivocal, counterintuitive, or contradictory results. However, even in some of the most recent work in this area, gender seems still to be an ignored or neglected variable. The study currently under discussion seeks to remedy that trend by making gender a primary factor for investigation.

THEORY:

The major area of exploration underlying the studies discussed hereafter has historically been a point of theoretical debate among investigators of semantic processing, and involves attempts to model mechanisms by which the brain encodes, stores, and accesses semantic information. Two of the most prevalent theoretical stances in this ongoing debate are those of distributed versus local processing.

Models of *distributed processing* generally posit that a variety of semantic concepts, features, or characteristics are encoded and represented as nodal units. To access the meaning of a word, stimulus-relevant nodes are concurrently activated and the particular cumulative combination of nodes "turned on" under a given set of conditions determines an end-state sense of word meaning. Thus, according to the distributed model, there is a certain set of coding parameters that, in simplest terms, (*differentially*) covary with each word in the lexicon.

In contrast, *local* processing models view meaning units (words) as discrete, self-contained nodes; activation of a single node will, according to localized models, afford access to the meaning of that stimulus. Activation of a node carries with it the co-occurrence of activation, within its defined network, of other nodes related to the "primary" one *through that network. How representations are coded in these "nodes"* (e.g., how discretely, with how much specificity, in what form, etc.), *how extensive their interrelationships are,* ***and*** *how, specifically, they are activated* (e.g., an "on-off" mechanism, "gated" threshold activity, etc) constitute crucial basic distinctions among theories in this area.

McClelland (1985) made an eloquent argument for considering distributed models as a context against which to analyze and integrate findings from neuropsychology, neurophysiology, and neurochemistry, especially in the area of learning and memory. Of particular salience to him was the fact that the distributed model seemed to better explain disorders such as amnesia, deep dyslexia, Wernicke's aphasia, and other deficits associated with neuropathology, than did some other models exigent at that time. Farah and McClelland (1991) presented intriguing possibilities of a parallel distributed processing (PDP) model in explaining dissociation between aphasic deficits connected with representations of living versus nonliving things (e.g., animals, plants, vs. minerals, objects, etc.)

Both distributed and local models have conventionally dealt with the brain and its functions as a unitary entity (i.e., a homogeneous processing mechanism that, according to the above models, "should" exhibit *one or the other*—but *not both*, forms of processing). Models such as those described above, which attempt to apply generalized principles to the brain as a single processing unit, cannot completely adequately explain incongruous results of past studies. Many of those studies have been basically well-designed and empirically sound. However, when the model upon which hypothesis testing rests runs counter to data that those designs generate, it seems to be the case quite often that presuppositions regarding "how the brain works" take precedence over explaining the data themselves. Even if "distributed" or "local" are not terms that at any point are under discussion by a given set of authors, assumptions that underlie those perspectives seem to dictate data that do not fit whatever implicit model is at work be called "counterintuitive," or given other similar labels.

The model proposed here is one that acknowledges the possibility that two (or more) different types of processes might coexist within a single brain; given plentiful results indicating that the RH and LH frequently do not function in the same manner, this proposition is consonant with that same line of observations. Specifically, based on conclusions derived from previous work on laterality and semantic processing, it may be that as in a number of other cases, the RH may be much more prone toward a "distributed" manner of processing, while LH functions in keeping with a "local" set of processes. This fits with existing clinical and empirical results, and, in many ways may actually explain those results more parsimoniously than previous models have.

The research under consideration here attempts to clarify some of the major issues raised above. Those include: differences between RH and LH processing, the impact on processing of semantic association (absent the influence of additional "layers" of relatedness like shared category membership), and possible effects of gender,

HYPOTHESES:

The major hypotheses of this project encompassed some salient point discussed above. They included: 1) the concept of semantic priming with stimuli exclusively related by association (as opposed to category or mixed relationships); 2) hemispheric differences in magnitude of priming effects with such stimuli; and 3) potential gender differences in degree of laterality of processing under the stimulus conditions stipulated. Specific hypotheses tested were:

1. Semantic priming will be demonstrated in response to prime/target pairs that are associatively related; significant differences in N400 area will be found between target stimuli in related vs. unrelated trials.
2. Overall magnitude of priming effects on N400 will be significantly different between LVF/RH- and RVF/LH-presented trials, such that RVF/LH trials show larger priming effects than those found in LVF/RH trials.
3. There will be significant differences between males and females, such that: a) in males, magnitude of RVF/LH N400 priming effects will be significantly greater than that for LVF/RH effects; and b) in females, N400 priming effects will not be significantly different in RVF/LH-vs.-LVF/RH comparisons.

II. METHODS

SUBJECTS:

Table 1 (below) summarizes relevant demographic information on subjects included in the sample. Subjects were adult males (N = 10) and females (N = 10), ranging in age from 22 to 49 years (mean age = 37.7; male mean = 36.2, female mean = 39.2). All subjects were native English speakers, and none had attained a significant degree of fluency in a second language during childhood. All were volunteers from the academic community and related professional areas. Due to our assumption that processing of some types of stimulus items might be correlated with vocabulary level, priority was given to recruiting subjects whose educational levels presupposed average or better lexical competence (i.e., at or above college). The range of educational attainment across the group ranged from current enrollment in BA programs to Ph.D. degree; mode level of education (i.e., from a simple frequency count) was at the Master's level. Mean years of educational attainment was 17.45 (males = 16.7, females = 18.2).

Subjects were right-handed; only those indicating strong right-hand preference were included in the study. The Edinburgh Handedness Questionnaire (Bryden, 1982) was administered prior to subjects' participation in the study protocol, to determine strength of hand preference. (See Appendix A for this questionnaire.) This instrument yields a laterality quotient (LQ) score indicative of relative strength of right-hand dominance. Scores on this instrument may range from -100 (strongly left-handed) to +100 (strongly right-handed). Mean LQ across the entire sample was +87.97 (male mean = +81.57; female mean = +94.02). According to self-reports, subjects were free of histories of general medical, neurological or psychiatric disorders and use of medications that might have impacted on results. Subjects were paid a small fee upon completion of the study protocol.

	DEMOGRAPHIC VARIABLE MEANS		
GROUP	**Age**	**Education (yrs.)**	**LQ Score**
Male	36.2	16.7	81.566
Female	39.2	18.2	94.021

Table 1: Subject Demographics.
Mean age, education (yrs.) and LQ score by group.

PROCEDURES:

Stimuli:

Stimuli were common English concrete nouns, 3-10 characters in length. Complete lists of stimuli and the sequences in which they occurred are found in Appendix B. Stimulus words were equated according to standard frequency indices (SFI; per Carroll, Davies, and Richman, 1971) across related (i.e. primed) and unrelated (i.e. unprimed) conditions. Mean SFI for words used in primed and unprimed trials were 42.8 (primed) and 42.55 (unprimed). Words chosen for inclusion were associatively related, according to norms of Palermo and Jenkins (1964), but not categorically related (as determined by category norms of Battig and Montague, 1969). The mean forward association frequency (as determined by production) was 4.86 for RVF/LH prime-target pairs (standard deviation = 5.03, range = 1-18); and 4.71 for LVF/RH (standard deviation = 4.71, range = 1-30).

Stimuli were presented on a computer monitor in uppercase, 8 mm. x 4 mm. black characters on a light gray background, according to standard stimulus delivery options available on the Neuroscan^{TM} ERP system. Each stimulus trial consisted of four discrete (albeit very brief) parts: a "prime" word (S1), a "target" word (S2), a question mark (?) designed to signal subjects that a "probe" word (S3) that required a response was upcoming. All of the above subcomponents of a trial (i.e., S1, S2, ?, S3) were presented on the monitor for a duration of 185 ms., with stimulus onset asynchronies (SOAs) of 250 ms. The brief stimulus duration and short SOA were used to minimize the possibility of post-lexical processing effects. An intertrial interval (ITI) of 2.5 sec. occurred between S3 of a given trial and S1 of the following trial. (See the schematic diagram discussed below for illustration.)

Presentation of each stimulus word was lateralized, centered at 4° to the right or left of a central gaze fixation point (marked continuously on the screen with a +, sized 8 x 8 mm.). Letters comprising stimulus words were always spatially separated from the fixation mark (+) such that they did not contact any part of the mark. The "?" cue to response readiness preceding S3 was centrally presented, just above the (+) fixation mark. 50% of trials were presented to the right hemifield and 50% to the left, relative to the fixation point. All stimuli of any given trial were presented to the same visual field. Order of right and left hemifield stimulus presentation was randomized throughout each block of trials, so subjects were not able to develop expectations regarding the probable location of S1 and its consequent stimuli from one trial to the next. A lateralized (right/left) mode of presentation was utilized along with the gaze fixation point, to assure that stimuli were presented exclusively to the designated visual hemifield during any given trial. This, in turn, assured receipt of stimuli exclusively by the hemisphere contralateral to the side of stimulus presentation (due to complete decussation of fibers in the visual system exclusively to the contralateral hemisphere). This allowed for testing of each hemisphere's responses to stimuli relatively independently of the other.

Below *(Figure 1)* is a schematic diagram that illustrates the relationship between stimulus trial events, the time frame(s) in which these events occurred, and an example of stimulus words used in one trial of the protocol. Also included is a notation of lateral deflection from the fixation mark, indicating which VF/hemisphere to which those particular stimuli were presented and the type of trial illustrated (i.e., relationships among words in the trial).

Screen Appearance (STIMULUS MATERIAL) — Approximation							
EVENT +	+ SEED	+	+ BIRD	+	? +	+	+ FLOWER
Part of Trial:	Prime		Target		(Prompt)		Probe
VF & Stimulus Type:	RVF/RELATED		RVF/RELATED				RVF/RELATED
ITI	S1	SOA	S2	SOA	?	SOA	S3
2.5 sec.	185 msec.	250 msec.	185 msec.	250 msec.	185 msec.	250 msec.	185 msec.
TIME (msec.) →							

Figure 1. Schematic Diagram of Stimulus Presentation Protocol/Example.

Semantic relatedness between S1 and S2 words was experimentally manipulated such that 50% of S1-S2 pairs were associatively but not categorically related (e.g., pony—saddle, dentist—teeth, bee—honey) and 50% were unrelated (e.g., corn—diamond, plate—door, dog—keys). Thus 50% of trials were "primed" (S1 related to S2, presumed to facilitate processing). The remaining 50% of trials were "unprimed" (S1 unrelated to S2; should not facilitate processing). Further, relatedness between S3 and S1/S2 was controlled, such that S3 was *related* to S1 and/or S2 on 50% of trials and *unrelated* on 50% (randomly ordered). To assure that no bias occurred with regard to the sequencing of lateralized presentation of primed and unprimed trials to right and left visual fields, sequencing of visual field for each trial was randomized. After trial sequences were determined in that way, they were checked for frequency of trials occurring in each visual field. Minor post-randomization adjustments were made to completely equalize the number of trials presented to each visual field (i.e. 50% to RVF, 50% to LVF).

Subjects were instructed to respond to S3 (by pressing the right or left key of a computer mouse) to register a judgment regarding whether S3 was *related in meaning to one or both of the preceding words* (a left-key-press) *or unrelated to both* (a right-key-press). The purpose of this task was to assure sustained attention and processing of all stimuli presented. The critical stimulus on each trial (for the purpose of ERP comparisons) was S2. Requiring a response to S3 allowed (S1-S2) priming to be measured without eliciting a large P300 ERP component; P300 has been shown to be a correlate of stimulus classification activities, and its presence often overrides or obscures N400 (Deacon, et *al.*, 1995). The task focus (at least in terms of subjects making linguistic relationship decisions) was on a point considerably later in time than that of the occurrence of the critical stimulus. This protocol afforded us a substantial safeguard against contamination of N400 by a P300; that positive component would not be elicited (if at all) until the entire critical measurement period had passed.

The various possible combinations of relationships among stimuli in each trial (i.e., related/unrelated S1-S2 + related/unrelated S3) were pseudorandomly ordered such that subjects could not anticipate from one trial to the next which type of trial was upcoming. Triads of highly interrelated words were not ordered adjacently. (For example: "meat - doll - ? - butcher," and "barbecue - coals - ? - marshmallow" would not have been placed in sequential order.) The latter action was taken to prevent possible contamination (i.e. by extension of priming) of one trial by its antecedent trial.

Each subject participated in a protocol consisting of 4 blocks of equal length, separated by brief rest periods. Thus one entire experimental protocol consisted of 4 subunits, each lasting about $5^1/_2$ min. and containing 168 complete stimulus trials. Order of stimulus presentation blocks was counterbalanced between subjects to control for order effects.

Practice trials were administered prior to recording ERP data. Practice trial stimulus sets consisted of material developed for use in experimental trial blocks in excess of that needed for sufficient data collection and, as such, were essentially equivalent to subsequent experimental trials. Practice trial blocks were abbreviated in length compared to actual experimental runs. In addition to allowing subjects the opportunity to become acclimated to the mode of stimulus presentation and required behavioral responses, practice blocks also afforded an opportunity to monitor and provide subjects feedback regarding facial muscle activity and eye movements. Verbal feedback and instructions regarding these elements were provided as discussed below.

EEG Recording

EEG was recorded from 18 scalp electrodes mounted in an Electrocap^{TM} and referenced to the nose. Scalp recording sites included: FP1, FP2, FZ, F3, F4, T3, C3, CZ, C4, T4, P3, PZ, P4, T5, T6, O1, OZ, and O2. Horizontal (HEOG) and vertical (VEOG) occulomotor activity was recorded from 4 facial electrodes (2 HEOG, 2 VEOG). Interelectrode impedance levels were tested multiple times during scalp preparation and held well below 5 KOhms (in most cases impedance levels were < 3 KOhms). HEOG/VEOG recordings were used to monitor eye movements throughout the experimental protocol. Subjects were instructed to avoid blinking during each trial, but were allowed to do so during the 2.5 sec. ITI while/after making their keypress responses. They were given feedback regarding eyeblink artifact, as well as on adequacy of central gaze fixation (avoidance of left-right saccades) during practice trials (and, if needed, between blocks of experimental trials). Feedback from VEOG and HEOG recordings was given to subjects verbally, regarding the adequacy of their timing of eyeblinks and inhibition of HEOG activity; additional verbal feedback and instructions were issued as needed during the protocol.

EEG and EOG recording were time-locked to stimulus presentation, both of which were performed on (separate) desktop computers equipped with Neuroscan^{TM} system software. Reaction time (RT) data for keypress responses was coded numerically (by response type) on-line and time-locked to EEG recording on a separate channel, for examination regarding the proportion of correct vs. incorrect responses. In addition to EEG data, horizontal and vertical electrooculogram (EOG) data were simultaneously recorded to control for excessive eyeblink artifact, inadequate gaze fixation, etc.

Continuous EEG/EOG recordings were epoched and processed off-line to derive averaged ERP waveforms for measurement. Each sweep consisted of 750 data points, sampled from 200 msec. prior to S1 onset in each trial to 750 msec. after S3 onset (a total of 1700 msec. per trial, encompassing S1 - S3). EEG and HEOG recordings were filtered using a bandpass of .1 - 35 Hz. Baseline correction was performed with reference to averaged EEG activity in the 200 msec. prior to onset of S1(-200 to 0 msec.of each sweep). An artifact rejection criterion was set that excluded from averaging any trial in which EEG or EOG surpassed the range of -50 to +50 μV. This criterion was strictly adhered to, and if a given subject generated too few acceptable trials (after artifact rejection) to yield meaningful averaged waveforms, consideration was given to excluding that subject from the sample.

Data Analysis:

Continuous EEG data were filtered, artifact-corrected, and averaged according to standard ERP conversion processes available in the Neuroscan™ system. Averaged waveforms were derived for each subject, separated by electrode site, stimulus type (S1, S2, etc.) and condition (primed/unprimed, LVF/RVF presentation).

Subsequent ERP analyses were based on individual subjects' averaged waveform data, as well as group (grand-) averaged data; particularly calculation of area measures for the N400 time period of interest (determined upon examination of measurement periods across the entire group (N = 20) to encompass the period from 200-450 msec.

following S2 (580-880 msec. after S1 onset). Data of interest in this study were N400 mean area values obtained from S2—the "target" stimuli—under primed (P) and unprimed (U) conditions. For clarity, it should be noted that the term "primed" refers to data derived from trials within the protocol in which S1 and S2 were *related*, while "unprimed" refers to trials in which S1 and S2 were *unrelated.*

Data used in analyses were N400 mean area measurements individually made for each subject. A table of N400 data is found in Appendix C.

All data were processed and formatted for SPSS file specifications, in spreadsheets using Microsoft Excel^{TM} (for Windows 95). Data were analyzed with SPSS-PC^{TM} (Version 6.1) statistical software, with standard applications available in that program. Medial electrode sites (FP1, FP2, FZ, CZ, PZ, and OZ) were eliminated prior to initiating statistical analyses, so that those remaining were assumed to maximally reflect lateralized EEG activity. Sites included in initial analyses were: F3, F4, C3, C4, P3, P4, T3, T4, T5, T6, O1, and O2. Subsequent exploratory examination of ERP scalp topography further reduced electrodes that were retained in final analyses to those discussed below.

Analyses utilized repeated-measures Analysis of Variance (ANOVA), with factors defined as follows. In order to test for experimental effects at electrode sites that recorded values over mutually exclusive (but parallel) RH/LH areas, the electrode site (ELECT) factor was constructed with a total of 4 ELECT levels designated. Each level of ELECT represented an homologous, "mirror-image" pair. LH electrodes (odd-numbered in the standard 10-20 system) and RH (even-numbered) respectively represented the hemisphere over which each site was located. Thus the ELECT factor could be said to represent coronally-divided sectors of ERP activity, beginning with that which was most anterior (T3/T4) progressing in a posterior direction (through P3/P4 and T5/T6) to most posterior (O1/O2). Mean amplitude values for each electrode, thus, were used to represent measures of activity exclusive to one or the other hemisphere, distributed in an anterior→posterior vector. Electrode site (ELECT) for analysis consisted of electrode locations that were maximally lateralized, with 4 levels designated as "anterior temporal" (T3, T4), "parietal" (P3, P4), posterior temporal (T5, T6) and "occipital" (O1, 02). Following preliminary analyses (reported below in "Results") the ELECT factor further eliminated anterior temporal electrodes (T3/T4), rationale for which is specified in reports on those analyses.

Visual field of stimulus presentation (VISFLD) was designated as a factor with 2 levels (RVF=right visual field; LVF=left visual field). At times during descriptions and discussions of data analyses these terms are used in an alternating manner, primarily determined by whether a given point refers primarily to lateralized *stimulus conditions* (RVF/LVF) or *brain activity* (RH/LH).

Semantic priming (PRIME) was defined as a factor with 2 levels: primed (referring to the stimulus condition in which S1 and S2 were *associatively related*) vs. unprimed (in which S1 and S2 were *unrelated*). As noted, stimulus pairs for related S1 and S2 were chosen on the basis of our desire to isolate N400 priming to words related by association from those related in some other way (e.g., categorically, mixed categorical/associative relationship simple repetition, etc.). Stimulus trials designated as "primed" were those in which there was a high degree of strictly associative relationship;

those designated “unprimed” were exclusively those in which S1 and S2 had no documented (or inferred) relationship of any kind.

All of the above-defined factors were so-called within-subjects factors. Finally, at the appropriate point in this series of studies, subject gender (GENDER, 2 levels, male or female) was added as a between- subjects factor. The GENDER factor only became germane to analyses in which male and female groups were combined in overall ANOVAs which sought to separately partition and test the effect(s) of subject gender (i.e., Study #3, below).

III. RESULTS

Study 1: Males

It must be noted that in the course of this study, data were collected on accuracy rates for all subjects, in regard to their judgments of the relationship of S3 to S1 and/or S2. These data are taken as indicators that subjects were attending to stimuli, and that stimuli were, overall, processed adequately for meaning. The mean accuracy rate generated by male subjects was 71.8%; The male accuracy mean may have been somewhat lower than that of females due to the 50% of trials delivered to LVF/RH, and the fact that males (see details below) demonstrated lateralized effects. A lack of priming, as was found (below) in males in one hemisphere, might well have precluded accurate responses on those trials.

Initially, pilot data were collected on a small sample of males (n=4). ERP waveforms (individual subject and group averages) and N400 mean area measurements were made, at the largest negative peak in the 200-450 msec. epoch following presentation of S2. Measurements were expressed as the largest negative deflection (measured by mean amplitude) present during the designated measurement period, determined individually for each subject. That determination (of beginning and endpoint of the measurement period for each subject) was made by visual inspection of ERP waveforms of each subject, to ascertain the onset and return to baseline of N400 components. Pilot data were examined for patterns of N400 ERP responses, N400 priming, etc. Based on that preliminary examination of pilot data, additional data were collected to constitute a sufficient sample for meaningful analysis (n=10). Data on the additional subjects collected to increase sample size were derived by the same procedures described above. N400 averaged waveforms generated by this group can be seen in Figure 2.

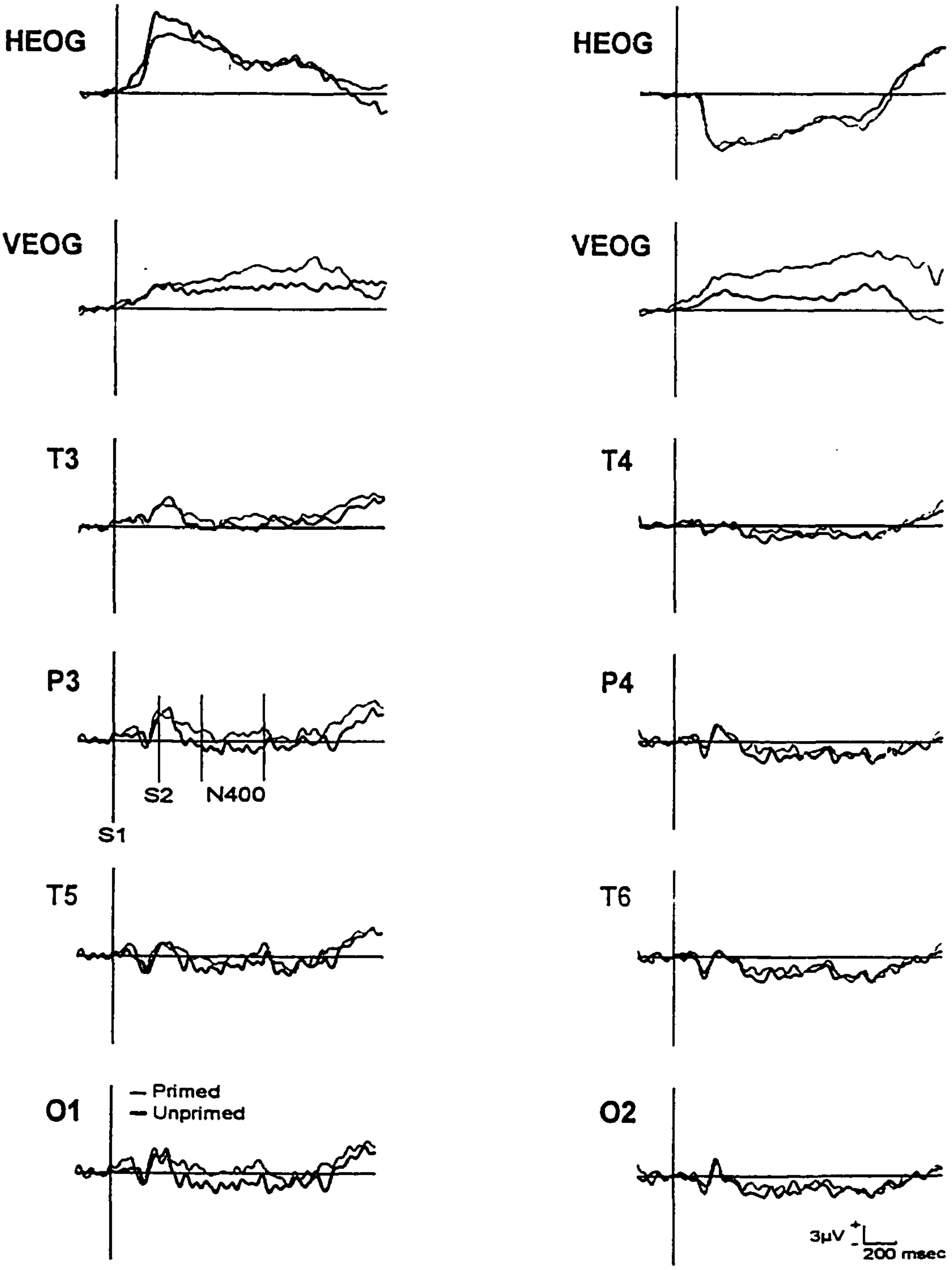

Figure 2: Male N400 Priming. Note that electrodes shown in right-hand column represent ERP priming at designated (RH) electrodes on trials in which stimuli were lateralized to LVF/RH. The left column represents ERP priming at designated (LH) electrodes on trials lateralized to RVF/LH.

Data Analysis:

Mean N400 amplitude values for this sample of males (n=10), by ELECT (listed by corresponding designated levels) by stimulated hemisphere, are listed in *Table 2.*

MALE MEANS, N400 MEAN AREA MEASURES (in microvolts) n = 10

LEFT HEMISPHERE PRIMED			LEFT HEMISPHERE UNPRIMED		
Electrode/Factor		Mean (Std. Error)	Electrode/Factor		Mean (Std. Error)
T3	Anterior Temporal	1.52 (0.61)	T3	Anterior Temporal	.32 (0.60)
P3	Parietal	1.62 (0.94)	P3	Parietal	-0.91 (1.16)
T5	Posterior Temporal	1.24 (1.06)	T5	Posterior Temporal	-0.75 (1.23)
O1	Occipital	1.09 (1.15)	O1	Occipital	-1.22 (1.45)

RIGHT HEMISPHERE PRIMED			RIGHT HEMISPHERE UNPRIMED		
Electrode/Factor		Mean (Std. Error)	Electrode/Factor		Mean (Std. Error)
T4	Anterior Temporal	-0.65 (0.82)	T4	Anterior Temporal	-1.78 (0.73)
P4	Parietal	-1.07 (0.94)	P4	Parietal	-1.74 (1.25)
T6	Posterior Temporal	-0.99 (0.82)	T6	Posterior Temporal	-2.28 (1.04)
O2	Occipital	-0.60 (0.85)	O2	Occipital	-1.60 (1.21)

Table 2. Male Means, N400 Measures. Key: O1, O2, etc. = electrodes.

Data were subjected to a repeated measures Analysis of Variance (ANOVA). ELECT (4 levels), (VISFLD, 2 levels), AND PRIME (2 levels) were used as within-subjects factors. Results of that analysis are found in *Table 3.*

Main/Interaction Effect(s)	Sum(s) of Squares W + R	Sum(s) of Squares Effect	F Value	Degrees of Freedom	Significance Level
VISFLD	108.89	115.89	9.58	9,1	0.013*
PRIME	54.45	91.69	15.16	9,1	0.004*
ELECT	171.42	6.49	0.36	27,3	0.785
VISFLD x PRIME	59.70	9.69	1.46	9,1	0.258
VISFLD x ELECT	29.59	6.64	2.02	27,3	0.135
PRIME x ELECT	25.93	1.63	0.57	27,3	0.642
VISFLD x PRIME x ELECT	7.49	4.42	5.31	27,3	0.005*

__Table 3. Male Data (8 Electrode) ANOVA Results__. Electrode (ELECT, 4 levels), Visual Field (VISFLD, 2 levels), and Priming (PRIME, 2 levels) as within-subjects factors.

As shown, highly significant main effects were found for VISFLD and PRIME, as well as a fairly robustly significant interaction of VISFLD x PRIME x ELECT. Other main effects and interactions were not significant.

The highly significant VISFLD x ELECT x PRIME interaction prompted post-hoc examination of means for individual electrode sites, in order to determine how isolated electrodes may have influenced results. Results of those post-hoc analyses, which consisted of t-tests for correlated samples, (differences between primed and unprimed values at each electrode site) are listed in *Table 4*.

Comparison	Mean Diff.	Std. Dev.	S.E. of Mean	t-value	d.f.	Significance Level
RPT3-RUT3	1.20	2.15	0.68	1.77	9	0.110
RPP3-RUP3	2.53	1.20	0.38	6.65	9	0.000*
RPT5-RUT5	1.98	1.31	0.415	4.77	9	0.000*
RPO1-RUO1	2.31	1.67	0.53	4.36	9	0.000*
LPT4-LUT4	1.12	1.94	0.614	1.83	9	0.100
LPP4-LUP4	0.671	2.39	0.756	0.89	9	0.398
LPT6-LUT6	1.29	2.47	0.78	1.65	9	0.133
LPO2-LUO2	0.999	2.566	0.811	1.23	9	0.249

Table 4. Results of Post-Hoc Comparisons for Male Data. **VARIABLE KEY: R=RVF stimulus presentation, L=LVF stimulus presentation; P=Primed, U=Unprimed; O1, O2, P3, P4,T3, T4, T5, T6=electrodes.** T-test results are on paired comparisons between primed and unprimed values under stimulus conditions in which the visual field designated (L or R) was stimulated. [Example: RPT3(RVF/LH primed stimulus condition) was compared to RUT3(RVF/LH unprimed condition)].

The anterior temporal electrode site was found to be the single LH electrode site (T3) that did not significantly reflect N400 priming. Examination of individual subjects values for primed RVF/LH T3 and its unprimed counterpart revealed that a number of subjects showed anomalous *reversals* of the typical effect compared to their own (and others') responses at all remaining electrode sites. (In many of those cases, T3 N400 waveforms that were *more negative for primed vs. unprimed conditions.*)

As a result of the above discovery, data from homologous anterior temporal electrodes (T3, T4) were eliminated, and an additional analysis, identical to the first except for reduction of ELECT levels from 4 to 3 (P3/P4, T5/T6, O1/O2) was performed. Results of that analysis are summarized in *Table 5.*

Main/Interaction Effect(s)	Sum(s) of Squares W + R	Sum(s) of Squares Effect	F Value	Degrees of Freedom	Significance Level
VISFLD	88.28	72.88	7.43	9,1	0.023*
PRIME	64.07	79.71	11.20	9,1	0.009*
ELECT	26.37	0.59	0.20	18,2	0.821
VISFLD x PRIME	40.16	12.39	02.78	9,1	0.130
VISFLD x ELECT	10.70	4.17	3.51	18,2	0.052
PRIME x ELECT	3.14	0.02	0.04	18,2	0.956
VISFLD x PRIME x ELECT	2.38	1.70	6.44	18,2	0.008*

Table 5. Male (6 Electrode) ANOVA Results. Electrode (ELECT, 3 levels), Visual Field (VISFLD, 2 levels), and Priming (PRIME, 2 levels) as within-subjects factors.

Significant main effects were found for VISFLD and PRIME. There were significant interaction effects for VISFLD x ELECT and PRIME x ELECT.

Study 2: Females

A parallel female-only study was performed, with data collected and transformed by methods identical to the above. The female mean response accuracy rate was 75.4%. Female ERP N400 waveforms can be found in Figure 3. Means for parameters in females identical to those of the initial male study are found in *Table 6*.

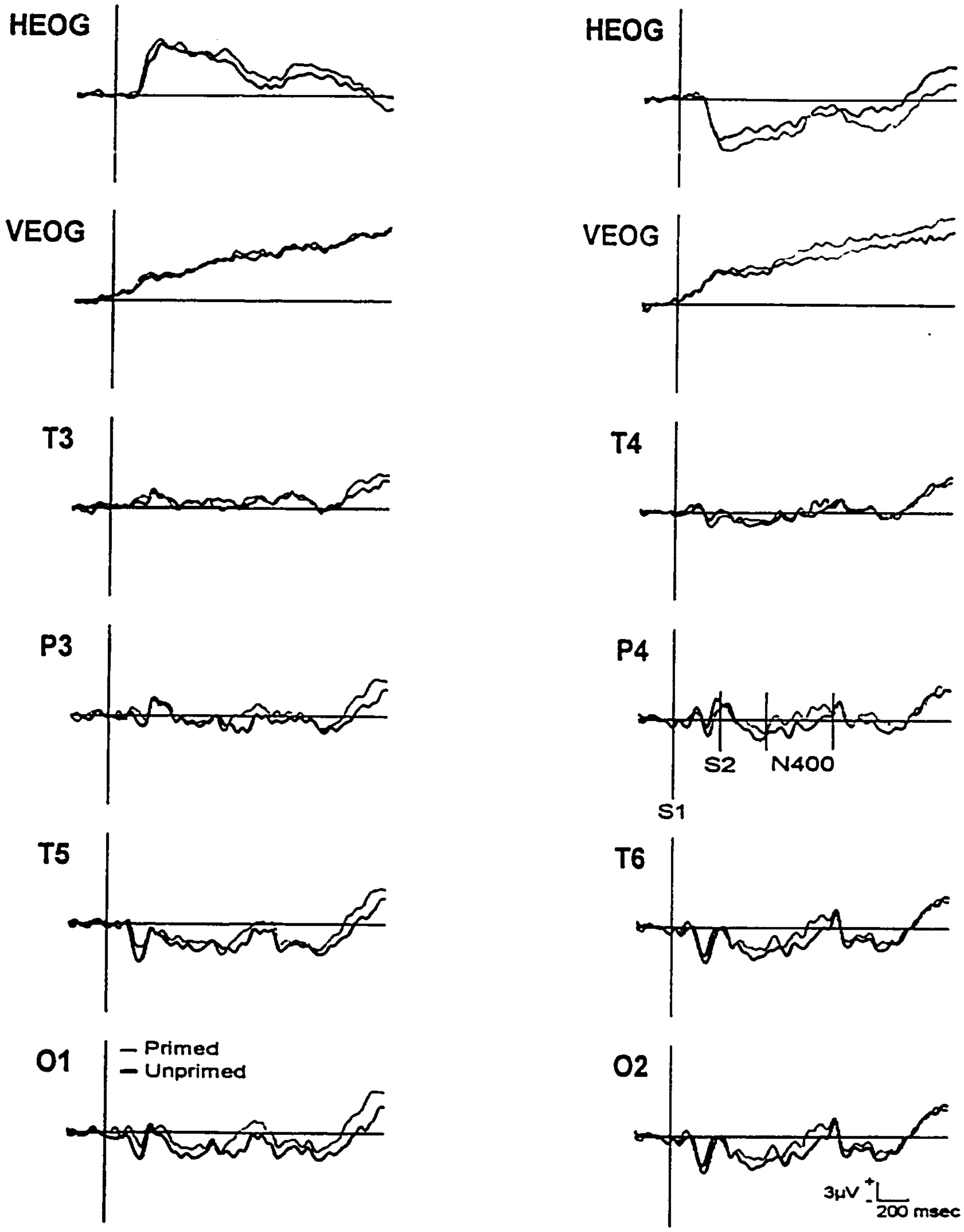

Figure 3: Female N400 Priming. Note that electrodes shown in right-hand column represent ERP priming at designated (RH) electrodes on trials in which stimuli were lateralized to LVF/RH. The left column represents ERP priming at designated (LH) electrodes on trials lateralized to RVF/LH.

FEMALE MEANS, N400 MEAN AREA MEASURES (in microvolts)

n = 10

LEFT HEMISPHERE PRIMED			LEFT HEMISPHERE UNPRIMED		
Electrode/Factor		Mean (Std. Error)	Electrode/Factor		Mean (Std. Error)
T3	Anterior Temporal	0.08 (1.34)	T3	Anterior Temporal	0.58 (1.00)
P3	Parietal	-0.40 (1.21)	P3	Parietal	- 1.48 (0.86)
T5	Posterior Temporal	-2.01 (1.03)	T5	Posterior Temporal	- 2.36 (1.10)
O1	Occipital	-0.31 (1.10)	O1	Occipital	- 1.82 (1.13)

RIGHT HEMISPHERE PRIMED			RIGHT HEMISPHERE UNPRIMED		
Electrode/Factor		Mean (Std. Error)	Electrode/Factor		Mean (Std. Error)
T4	Anterior Temporal	1.12 (1.21)	T4	Anterior Temporal	- 0.03 (0.90)
P4	Parietal	1.78 (0.87)	P4	Parietal	- 1.02 (1.33)
T6	Posterior Temporal	0.36 (1.21)	T6	Posterior Temporal	- 2.15 (1.11)
O2	Occipital	2.31 (1.43)	O2	Occipital	- 0.24 (1.26)

Table 6. Female Means, N400 Area Measures. *Key: O1, O2, etc. = electrodes.*

Data Analysis:

Initial data analysis was performed on raw N400 area measures for the subjects (n=10) included in the study. Data were subjected to a repeated measures ANOVA. ELECT (4 levels: Anterior Temporal [T3/T4]; Parietal [P3/P4]; Posterior Temporal [T5/T6]; and Occipital [O1/O2]), visual field of stimulus presentation (VISFLD, 2 levels, LVF and RVF), and priming condition (PRIME, 2 levels, primed or unprimed) were used as within-subjects factors. Results of that analysis are found in *Table 7*. In that analysis, main effects of PRIME and ELECT were found to be significant. The interaction of PRIME x ELECT was significant.

Main/Interaction Effect(s)	**Sum(s) of Squares**		**F Value**	**d.f.**	**Significance Level**
	W + R	Effect			
VISFLD	316.84	60.43	1.72	9,1	0.223
PRIME	107.23	81.94	6.88	9,1	0.028*
ELECT	228.81	86.14	3.39	27,3	0.032*
VISFLD x PRIME	131.31	27.02	1.85	9,1	0.207
VISFLD x ELECT	118.01	18.11	1.38	27,3	0.270
PRIME x ELECT	25.61	18.38	6.46	27,3	0.020*
VISFLD x PRIME x ELECT	8.55	1.56	1.64	27,3	0.204

Table 7. Female (8 Electrode) ANOVA Results. *Electrode (*ELECT, *4 levels), Visual Field (*VISFLD, *2 levels), and Priming (PRIME, 2 levels) as within-subjects factors.*

In order to obtain parity between female and male analyses, anterior temporal electrode sites were eliminated in a second analysis and an ANOVA performed with the ELECT factor at 3 levels (P3/P4, T5/T6, O1/O2). Results of that analysis are found in *Table 8*. PRIME was again highly significant, as was ELECT, and VISFLD x PRIME x ELECT.

Main/Interaction Effect(s)	**Sum(s) of Squares**		**F Value**	**d.f.**	**Significance Level**
	W + R	Effect			
VISFLD	277.077	73.92	2.401	9,1	0.156
PRIME	73.185	97.184	11.951	9,1	0.007*
ELECT	62.756	53.116	7.62	18,2	0.004*
VISFLD x PRIME	96.288	20.219	1890	9,1	0.234
VISFLD x ELECT	40.657	4.193	0.928	18,2	0.413
PRIME x ELECT	17.067	2.077	1.095	18,2	0.356
VISFLD x PRIME x ELECT	3.565	1.557	3.931	18,2	0.038*

Table 8. Female (6 Electrode) ANOVA Results. *Electrode (*ELECT, 3 levels), *Visual Field (*VISFLD, 2 levels*), and Priming (PRIME, 2 levels) as within-subjects factors.*

The above results indicated an "across-the-board" bilateral priming response in females, irrespective of VF of stimulus presentation. In the absence of any other effects involving VISFLD, the significant VISFLD x PRIME x ELECT interaction can be seen as the result of some electrodes being more highly reflective of priming than others.

Study 3. Combined Male/Female Analysis

Results of the above gender-segregated studies indicated that there were potential gender-based differences in responses to the paradigm applied in the study. Therefore a strong rationale existed to perform an overall analysis combining the two groups using gender as a between-subjects variable. A summary of means/standard errors of raw data for each group (males, females, and the combined male/female means) is found in Table *9*.

COMBINED GROUP MEANS, N400 MEAN AREA MEASURES (in microvolts)

GRAND MEANS (n=20)			MALE MEANS (n=10)			FEMALE MEANS (n=10)		
LEFT HEMISPHERE STIMULUS PRESENTATION			LEFT HEMISPHERE STIMULUS PRESENTATION			LEFT HEMISPHERE STIMULUS PRESENTATION		
Mean (Std. Error)			Mean (Std. Error)			Mean (Std. Error)		
	Pr.	Unpr.		Pr.	Unpr.		Pr.	Unpr.
T3	0.80(0.74)	0.45(0.57)	T3	1.52 (0.61)	0.32 (0.60)	T3	0.08 (1.34)	0.58 (1.00)
P3	0.61(0.78)	-1.20 (0.70)	P3	1.62 (0.94)	-.91 (1.16)	P3	-0.40 (1.21)	- 1.48 (0.86)
T5	-0.39 (0.81)	-1.55 (0.82)	T5	1.24 (1.06)	-.75 (1.23)	T5	-2.01 (1.03)	- 2.36 (1.10)
O1	0.39 (0.79)	-1.52 (0.90)	O1	1.09 (1.15)	-1.22 (1.45)	O1	-0.31 (1.10)	- 1.82 (1.13)
RIGHT HEMISPHERE STIMULUS PRESENTATION			RIGHT HEMISPHERE STIMULUS PRESENTATION			RIGHT HEMISPHERE STIMULUS PRESENTATION		
Mean (Std. Error)			Mean (Std. Error)			Mean (Std. Error)		
	Pr.	Unpr.		Pr.	Unpr.		Pr.	Unpr.
T4	0.23 (0.60)	-0.90 (0.60)	T4	-.65 (0.82)	-1.78 (0.73)	T4	1.12 (1.21)	- 0.03 (0.90)
P4	0.35 (0.81)	-1.38 (0.89)	P4	-1.07 (0.94)	-1.74 (1.25)	P4	1.78 (0.87)	- 1.02 (1.33)
T6	-0.32 (0.73)	-2.22 (0.74)	T6	-.99 (0.82)	-2.28 (1.04)	T6	0.36 (1.21)	- 2.15 (1.11)
O2	0.85 (0.87)	-0.92 (0.86)	O2	-.60 (0.85)	-1.60 (1.21)	O2	2. 31 (1.43)	- 0.24 (1.26)

Table 9. Summary of Group/Grand Means. Grand Means (Male and female combined), male means, female means by hemisphere of stimulus presentation (left or right) by electrode (homologous electrodes were used to represent uniform anterior→posterior axes). Only electrodes on the hemisphere stimulated in a given type of trial (e.g., t3 in RVF/LH trials, t4 in LVF/RH trials) were included.

Data Analysis:

Again, repeated measures ANOVA was utilized for this analysis, with ELECT, VISFLD, and PRIME as within-subjects factors; GENDER was added as a between-subjects factor. Since the anterior temporal ELECT level had been found to yield results for both groups that were not significantly reflective of priming as found in other electrode levels, it continued to be omitted in this analysis. Results of the overall ANOVA performed on raw data are found in *Table 10*, and can be summarized as follows. Highly significant F values were obtained in main effects of PRIME and

ELECT. Significant interactions were found in: GENDER x VISFLD, GENDER x ELECT, GENDER x VISFLD x PRIME, and VISFLD x PRIME x ELECT.

Main/Interaction Effect(s)	Sum(s) of Squares		F Value	d.f.	Significance Level
	W + R	Effect			
GENDER	1,998.97	0.01	0.00	18,1	0.994
VISFLD	365.36	0.00	0.00	18,1	0.993
GENDER x VISFLD	365.36	146.80	7.23	18,1	0.015*
PRIME	137.26	176.46	23.14	18,1	0.000*
GENDER x PRIME	137.26	0.43	0.06	18,1	0.814
ELECT	89.13	31.79	6.42	36,2	0.004*
GENDER x ELECT	89.13	21.91	4.42	36,2	0.019*
VISFLD x PRIME	136.44	0.48	0.06	18,1	0.805
GENDER x VISFLD x PRIME	136.44	32.13	4.24	18,1,1	0.054*
VISFLD x ELECT	51.36	8.35	2.93	36,2	0.066
GENDER x VISFLD x ELECT	51.36	0.02	0.01	36,2,2	0.994
PRIME x ELECT	20.21	1.03	0.92	36,2	0.409
GENDER x PRIME x ELECT	20.21	1.06	0.95	36,2,2	0.397
VISFLD x PRIME x ELECT	5.94	2.32	7.04	36,2	0.003*
GENDER x VISFLD x PRIME x ELECT	5.94	0.93	0.47	36,2,2	0.072

Table 10. Overall ANOVA Results. *Electrode (*ELECT*) and Visual Field (*VISFLD*) as within subjects factors. Gender(*GENDER*) is a between-subjects factor.*

IV. DISCUSSION

Summary:

Major findings of this study were as follows: In the study of male subjects, N400 priming was found such that there were significant differences based on a main effect of visual field of stimulus presentation (and by extension which hemisphere received the stimuli). There was also a significant interaction effect of visual field with electrode site: post-hoc tests indicated that this was probably attributable to the fact that some electrodes reflected significantly more N400 priming than others. So, in males, N400 priming was found to be exclusively lateralized to LH, with electrodes at the parietal level being vastly superior at reflecting that effect. Occipital electrodes, showing LH-lateralization of priming effects that was only moderate (just failing to reach statistical significance), may have made some contribution to the major findings above. Anterior and posterior temporal electrodes showed negligible evidence of consistent N400 priming effects.

In females, results did not indicate an interaction between visual field and priming, independent of the electrode factor. This indicated that females as a group were essentially equal across hemispheres in N400 priming under the stimulus conditions employed, but that there was some differential based on scalp recording site. Since the electrode factor was constructed with homologous electrodes (one on LH, one on RH in each electrode factor), this is simply a case of a differential in one or more of the electrode pairs in how much priming each reflected, while significant priming was obtained at some electrodes in both hemispheres.

Results of the combined male + female analysis produced a highly significant interaction between gender, visual field, and electrode, this being primarily attributable to differences between males and females in the degree of magnitude to which priming was found in LH in males (unilaterally) and bilaterally (in both RH and LH) in females. Of note in this regard is the following. Not only were there differences in priming patterns such that males showed unilateral (LH) priming while female priming was bilateral, but in addition, female group means indicated RH priming magnitudes that were somewhat larger than those of LH (i.e., female RH differences between primed and unprimed conditions were larger than homologous LH differences).

While the above-noted RH/LH differences in priming index for females did not reach statistical significance (there was no visual field x priming interaction for females), the tendency in the female group toward larger RH priming effects is still of some anecdotal interest in this regard: Females could still have shown statistically equivalent priming across hemispheres, if RH and LH priming measures were: a) essentially equal, or b) apportioned so that LH priming was the larger-magnitude of the two but not "larger enough" to make a statistically significant difference. Instead, what actually happened was the opposite: *RH priming was larger than LH*, albeit not enough to constitute statistical significance.

Thus, considering the results above, males demonstrated what might be considered a roughly stereotypical pattern of associative language processing. This was much in keeping with the now-popularized notion of the "left brain-right brain" verbal-nonverbal schematic. Females evidenced bilateral priming.

Of note is the fact that comparisons of means for male and female groups indicated two somewhat distinct manners in which those groups differed. In instances where LH variables were those in question (e.g. LH parietal and posterior occipital sites), males simply showed difference scores of significantly greater magnitude than those of females (between primed and unprimed conditions). Both groups had already displayed significant priming effects in LH on earlier gender-separated analyses, but males had the larger absolute magnitude of LH priming of the two.

In reference to RH priming effects, however, we propose that mechanisms by which differences between groups were reached were somewhat distinctive (and not quite as straightforward). In the case of RH effects: 1) males had (from earlier, preliminary study #1) no significant RH priming, while females did. 2) In addition to the latter fact, females as a group *actually had greater mean priming indices in RH than LH.* Stated simply, then, according to mean priming values for each group per condition, *females not only had significant priming that was bilateral, but actually tended toward more pronounced priming in RH; males had the largest magnitude priming effect of the two groups, but exclusively lateralized to LH.*

Therefore, not only were these gender x visual field interaction effects in regard to priming significant in the overall analysis, but they also were contributed to by apparent gender-based hemispheric priming patterns that indicated differentiable patterns such that males demonstrated expected (LH-lateralized) priming and females evidenced bilateral effects (that actually tended toward stronger RH priming).

Hypotheses and Outcomes:

Major hypotheses of this study and results relevant to each are reviewed below.

H1. ***Semantic priming will be demonstrated in response to associative relationship of prime/target pairs; significant differences in N400 area will be found between target stimuli in related vs. unrelated trials.*** This was supported by results of all statistical tests in which PRIME was included as a factor. Highly significant priming was demonstrated in ANOVAs for both exclusively male and female studies and in the overall ANOVA result, in which there was a highly significant main effect of PRIME. (It is a gross understatement to say that these results were critical to the outcome of this study, as all other hypotheses and design elements presupposed the presence of N400 priming under the conditions described. It is also probably an understatement to assert that priming was, indeed, demonstrated in this case.)

H2. ***Overall magnitude of priming effects on N400 will be significantly different between LVF/RH- and RVF/LH-presented trials, such that RVF/LH trials show larger priming effects than those found in LVF/RH trials.*** This was partially supported, in the case of analysis of male data, in which males evidenced a significant effect of VISFLD x PRIME x ELECT. However, in the other analyses that included females, this prediction was not continually borne out. In fact, the parallel analysis using gender-segregated female data yielded a finding that most likely stemmed from *bilateral* priming in the female group. (This finding is related in a striking way to the final hypothesis, below.)

H3. ***There will be significant differences between males and females, such that: a) in males, magnitude of RVF/LH N400 priming effects will be significantly greater than that for LVF/RH effects; and b) in females, N400 priming effects will differ less than males in RVF/LH-vs.-LVF/RH comparisons.*** Premise (a) of H3 was supported by the significant interactions in the overall analysis of GENDER x VISFLD, and GENDER x VISFLD x PRIME. Premise (b) was statistically supported by lack of significant interaction in the female analysis between priming and visual field.

Implications of Findings:

1. Semantic Associate Priming Effects:

This study's results stand as almost directly converse to Chiarello, et al. (1990), who reported that prime-target pairs related purely by association, laterally presented, evidenced no priming (behaviorally-measured). Maxfield and Chiarello (1996) attempted to determine whether priming might be obtained with associate pairs in which primes are presented centrally and targets laterally. They proposed that this effect stems primarily from the impact of the location of the prime word; that centrally-presented primes cannot be ignored by subjects (i.e., via an attentional mechanism). If we extend that logic into the realm of explaining why Chiarello et al. (1990) did not find priming with both stimuli lateralized, it could be assumed that their thinking would dictate this was because subjects *were* able to ignore lateralized primes. Our data did not bear out that logical extension of their idea.

In fact, our results stand in contrast to the above. Were selective attention to stimulus words a core factor in this type of priming paradigm, there is no reason to think that our results would have been any different from those obtained by Chiarello et al. (1990). Had the principles underlying Chiarello and Maxfield's (1996) assumptions, above, been applicable here, we would have obtained no priming effect *at all* in our study. As all of our stimuli were lateralized, by the above logic, subjects should have shown inattention to our primes, evidenced by *no priming*. Thus, the attentional mechanism proposed by Chiarello and Maxfield (1996) was apparently of no significant influence in our study.

Results obtained in these studies may be taken as useful commentary on the nature of associative language processing and how it may be impacted by methodologies used to evoke it. There are a number of differences between our study and those of Chiarello et al. (1990), including subject variables, contrasts between stimulus sets, and task demands of the protocol employed. *Table 11*, below, is offered as a summary of those differences between studies, which were detailed in the Introduction (Chapter 1).

Methodological Issue	Treatment of and/or Control for Methodological Issue		Comments
	Chiarello, et al., 1990	Present Study	
Subject Hand Preference	Relatively low mean hand preference score	Relatively high mean hand preference scores	Possible differences in cerebral lateralization between studies.
Bilingual Subjects	Liberal criterion for inclusion of subjects with significant 2nd language experience	Strict exclusion of all subjects who reported significant 2nd language.	Differing degrees of bilingualism may have impacted on subjects' cerebral organization between studies..
Eye Movement Control Imposed	No method described, except description of general instruction to subject, no way to reject trials with inordinate eye movements	ERP artifact-rejection criteria allowed more control over entry of movement-affected trials into data.	Chiarello, et al. had no way of assuring that stimuli reached the intended VF/ hemisphere. Present study used standard control measures.
Number of Trials with Critical Stimuli	Small	Large	
SOA Length	"long" (575 and 600 msec.)	"short," 250 msec.	"Short" SOA better assures that results were not due to post-lexical processing effect.
Stimulus repetitions within the same protocol, to same subjects.	Yes	No	Repetitions open the possibility of a confound due to repeated receipt of stimuli by each subject and unknown effect of repetition on findings.
Task Demands	Lexical Decision/ Naming	Meaning-related judgment	Our task may have induced more complete semantic processing.

Table 11. Outline of Differences in Methodologies. Methodological elements of Chiarello, et al. (1990) and present study are listed, with comments on possible impacts on data/findings.

Interpretation of associatively related words often depends heavily on surrounding factors such as context, and probably the state of the processing "mechanism" (person). It would follow that pure semantic associates are probably more multiply—or at least divergently—represented in semantic stores than are other forms. Certainly, categorically related words have been found to produce more consistent facilitation effects (i.e., priming) than words which are only associatively related (Neely, 1991).

It makes fairly good intuitive sense that the "qualitative" distinction of associative language addressed here may be reasonable. After all, the nature of associative relationships is that they are learned by pairing stimuli (or *clustering* groups of words larger then two) under various definable environmental conditions. The same, of course, is true of categorical relationships, but *not in the same way.*

In the case of categorical relationships, within any cultural/geographic environment in which people learn language, there are fairly invariant and static categorical elements acquired throughout the course of development. Although some categorical relationships may vary to some degree depending upon "culture of origin," there is at least some general consensus regarding what is "related" versus "unrelated" that does not change appreciably across cultures or individual experiences.

For example, within the general category "animals" can be found an exemplar, "dog." That is a categorical relationship, linguistically speaking (as well as in other venues). It is quite stable in its status as a categorically connected lexical pair. (The lexical status of a "dog" as an "animal" is not likely to make an abrupt change anytime in the near future.) However, depending on cultural/educational/individual-environmental conditions that serve as context for their acquisition, lexical *associates* to "dog" may be widely diverse: a) between unique individuals and/or b) in a given individual at different points in his/her history (all the while maintaining consistent relational integrity between subordinate "dog" and superordinate "animal"). The word "dog" can develop ("pure") associates to other nouns as broadly cast about in semantic space (to name a few) as "sled," "bone," "guard," "leash," "kennel," "fangs," "statue," and "meat." Whether or not each of those—or innumerable other—associates develops within a given individual's representational system(s) for the word "dog" depends on individual/cultural experiential context. Within a given culture, consensual agreement is developed (probably based on frequency of conventional usage), regarding standard associate relationships between words. (However, across cultures and experiences, the category relationship "dog-animal" is still fairly well maintained.)

The above can be illustrated rather pointedly by citing a query posed by one of our subjects while participating in the experimental protocol. This question was directed, actually, at the decision task operative in our design, which was to differentially respond to S3, as to its relationship in meaning or lack thereof, to either or both S1 or S2. At the conclusion of one of the experimental blocks, the subject asked, "When you say, 'related,' do you mean related to me personally, or as it applies to people *in general*?" He further explained that in one trial within the preceding block, S1 or S2 had been "cat," and S3 was "window." Although he knew that most people would not view those words as related, those terms *were* related for him personally, as he had a friend whose cat was almost iconically "known" for *sitting in a particular window*. Although the content of that question (at the time unbeknownst to the subject) was quite tangential to the essence of the experimental conditions—which had already passed by the time S3 occurred—the fact that it was asked, and the manner in which it was asked, made it illustrative. That subject (and probably most others) had the capacity to actively and accurately parse relationships between stimulus words into "personal" and "universal" associates.

The advantage of our ERP-based priming measurement over the behavioral measures of Chiarello, et al. (1990) is in the fact that in our protocol, the task assigned to subjects is relevant to priming outcome (or lack of it) only in the degree to which it induces a focus on a specific type of processing (i.e., for meaning). By the time subjects are called upon to "respond" in a behavioral ("conscious," directed, intentional) manner, *priming itself has, in effect, already been registered.* In studies using behavioral priming measures (such as Chiarello, et al., 1990), *the behavioral task is the priming phenomenon that is registered for measurement.* One could view the above as related to principles of signal to noise ratio, where one form of "noise" is the quantity over some time course of response-related, conscious, non-automatic processing. Our ERP paradigm, thus, if viewed from this perspective, has intrinsically less "noise" (and by extension a clearer field for measurement of response purely to the lexical/semantic "signal") than do the behavioral paradigms under discussion.

The net impact of summing the dichotomous gender group means in grand means per electrode is that it appears to yield *different priming effects* (as in our gender-combined LVF/RH condition) than are present in groups separated by gender. This mathematical possibility points out a potential methodological risk in collapsing data together into conglomerated large group means, which may lead to conclusions that are unwarranted once data are "dissected" into component elements (e.g., in this case, gender subgroups). There is no mention in Chiarello, et al. (1990) of investigators having examined gender as a possible factor that impacted their results. That is despite the fact that "individual differences in priming" (Chiarello, et al., 1990) were explored, in the form of subdivision of the sample by processing (RT) speed. It would be instructive to explore whether or not a gender effect existed in their data. This is an issue that clearly needs attention in future work.

Associatively-related words are decidedly more meta-linguistic than is the case with those that are categorically related. Associative links contain qualitative elements that often do not as immediately connect tangible objects represented in lexical stores of the individual responsible for processing them. This may derive from representation and activation of pure associative relationships via local mechanisms wherein, given a single word (i.e. S1), what is activated is a relatively large set of semantic links to stored associates. Priming occurs, simply put, when the consequent term that follows a given antecedent *is congruent* with one (or more) of those activated links.

2. *Left Hemisphere vs. Right Hemisphere Effects:*

According to Beeman (1998), fine coding, strong activation, and constrained definition of semantic fields prototypical of LH functioning, while RH coarsely codes and weakly activates larger, more broadly-defined fields. If that were the case, RH is likely to have a higher probability of overlap between words that are broadly related but do not necessarily share features. By that model, the we would have expected results from our paradigm to indicate that RH would most likely show priming, with LH responses being less predictable. (As demonstrated, our outcome was quite to the contrary.)

If we consider our model, in which RH representation is based on features or properties in a distributed system, and LH encoding based on associations, with local coding, it better explains our results as a whole than does Beeman's (1998, as above) description of possible hemispheric distinctions in language representation. In fact, while

Beeman's system does not explain our data, our model and results to date may shed light on how that system was conceived, based on the findings Beeman examined to derive it.

3. Gender Effects:

With regard to the portion(s) of our findings that were gender-related, it appears that females demonstrated more homogeneous responses, regardless of hemisphere of stimulus presentation. This may represent a coding/processing surround in females in which the two hemispheres are comparatively equipotent in processing capacities, such that associative stimulus material is more easily processed by RH in females than in males. This is especially pertinent in the case of the significantly smaller differential in females, compared to males, between RH- and LH-presented material. (Or, put in a different way, the relative lack of apparent RH priming shown by males subjected to our protocol.)

Associative priming draws on links between encoded words with few if any shared features; this should be, in a very generalized sense, primarily a LH function. Male priming patterns were in keeping with that principle, by which priming was strong in LH and absent in RH-lateralized trials. This is some evidence in support of a coding/processing mechanism within LH that is local in nature, and inculcated to a particularly great degree in (stereotypically) strongly/completely lateralized, LH-language-dominant male subjects (those who are right-handed as in our sample, at least). This is bolstered by the fact that there was a statistical absence of priming in LVF/RH trials in males, in contrast with their female counterparts.

The difference in our male and female groups probably was not attributable simply to differences in the degree of "LH dominance," if we can consider the hand preference measure used as any indication of degree of lateralization. In fact, based on mean scores on that measure, our *female* group actually had the (slightly) higher of the two right-hand preference means, indicating that the male group was slightly *less* inclined than females toward strong right-hand (LH) preference. However, according to normative neuropsychological standards, either group would have been considered substantially and strongly "right-handed/left-hemisphere dominant."

One obvious inference that can be drawn from results reported here is that a conventional stereotype regarding differences in functional brain lateralization between males and females has been supported, at least insofar as the processing of associative language. The pattern of results indicated that associative priming in males is a function subserved largely if not exclusively by LH. Females demonstrated a much more even distribution between hemispheres of semantic associate priming than did males. This is consistent with findings from other areas of study that have supported the idea that there is more functional asymmetry in males than in females; or put from the alternate point of view, females show more functional *symmetry*.

There is much material for speculation regarding possible mechanisms behind the differential RH effects in males and females. Of interest is the fact that in the feature-only priming study from our laboratory (described above), males and females had equivalent priming effects *and exclusively in RH.* That fact, coupled with data reported here, creates a context for interpretation that leads us to postulate that perhaps associate pairs of the type utilized in this study are a "special case" of semantic relationship. Males in our "feature priming" study (Deacon, Yang, et al., 2001, above) exhibited RH priming, *and primed equally with females* under that stimulus condition, which was conceptually a type of stimulus relationship defined by shared properties. We must assume, then, that something else was different (other than the particular male brains processing our various stimuli).

There are two major possibilities that could explain the differential between male and female results in this study. The first involves the encoding/processing mechanisms that may be operative with stimulus material of this type. Females may have, overall, more equivalence between hemispheres in the manner of coding, such that female RH codes in a more local manner than that of males. Female RH in our priming paradigm performed very much like male LH, creating the appearance of similar priming patterns, possibly having arisen from similar coding mechanisms. By extension, given our result of statistically equivalent LH and RH priming in females, the coding mechanisms within the female gender may be more similar between hemispheres than those of males, thus yielding similar priming patterns in this case.

The second potential explanation of our male-female differential involves the linguistic structure of the stimulus material in question. Associative relationships are analogous to a situation in which common properties exist between words. This is not meant in the sense of sharing *features* between words, but instead as *an arrangement by which one term*—or in many instances *each* word—*is a property of the other.* This differentiates association from other types of relationships, in that associates do not share features in the conventional sense of that term. In the classic example, BEE and HONEY share few, if any, features (at least of which we are aware). However, "makes HONEY" can be seen as a *property* of BEE. In this respect, words constituting associative relationships *do not share features*, but often are *comprised of nested semantic properties.*

The above could explain our female results in the sense that female RH may have the capacity to code and activate property-based relationships (in which one term is a "nested" feature of the other), whereas male RH may only code/activate *shared features*, i.e., properties in common between two words. This would explain and integrate the results of this study and our "feature" study (Deacon, Yang, et al., 2001), in the sense that females may have been able to prime in RH in both cases via the above-described property coding mechanism, while males may evidence RH priming only based on shared features between items.

The 250 msec. SOA we used in the present study may have been too brief to elicit RH priming in males. Females may have a different mechanism for activation of associates in RH such that they activate a greater portion of the relevant network more quickly than males. Both groups exhibited LH priming; perhaps at that SOA both groups may already have achieved activation in LH of all relevant parts of the network. This is congruent with principles of LH language activation discussed above, in terms of LH beginning with almost immediate activation of the maximum quantity of representations. This possibility is also not incompatible with the property-coding idea discussed above, in regard to the RH differential between females and males. Females may have quicker activation of this property- based portion of the RH network that is effective at relatively short SOAs; males may either simply not code in RH in that manner, or, alternatively, activation of this form of properties in male RH may take place at a rate slower than allowed by our 250 msec. SOA. We can safely assume that both genders activate features (as in Deacon, Yang, et al., 2001) in RH rapidly enough to achieve priming based on that element; unfortunately we cannot extend conclusions regarding this matter as our design did not intend to yield the information necessary to do so.

Implications of this research bear on retrospective examination of results from previous studies—not just from ERP literature but in a broader sense—as it appears that this is an addition to a growing body of evidence that one person's (/gender's) brain is not just like another's. Results of this study imply that data from many sources, and the working assumptions to which they have given rise, should be re-examined with the express purpose of exploring the impact of subjects' gender on findings, whether they were findings of differences or support for null hypotheses.

Using our data as an example, the exclusion or inclusion of gender as a factor influenced: a) the appearance of ERP waveforms, especially related to RH recordings, and b) statistical results especially related to hemisphere- and electrode-related effects. We did not perform (above) analyses including both males and females, in which gender was *absent* as a factor, due to the obvious scientifically sound reasoning that performance of superfluous, excessive tests was contraindicated. Formally, given the apparent contrasts that emerged in gender-segregated analyses which *were* reported above, and the impact of that fact on our subsequent decision to do a combined analysis to explore the effect of gender, inclusion of a "gender-ignorant" ANOVA would, indeed, have seemed excessive.

However, for purposes of demonstration, in an ANOVA disregarding gender (i.e., collapsing males and females into a large group, as many studies have done), it would have been parsimonious to conclude that (by examination of mean values by hemisphere) LH associate priming was simply larger than RH priming. By extension, the corresponding generalization to be drawn would be that associate priming is a function served largely by LH. However, in the gender-factor ANOVA, reflective of our reported results, the one change yielding a significant interaction of GENDER x VISFLD, made a critical difference in the way that priming was portrayed. This allowed us to better interpret gender-based priming patterns. The gender-ignorant results would lead to a conclusion that all subjects pretty much primed in the same way, that there were no appreciable distinctions based on which hemisphere received stimuli, and that various electrode sites differentially reflected priming. (Not to belabor these points: gender-based ANOVA results are already under discussion here, thus yet another iteration of them is probably unwarranted.) Suffice it to say that consideration of gender can make a world of difference in the differences portrayed by data.

As stated earlier, most studies to date have used conglomerate samples that make the basic presupposition that gender is not a significant factor; conclusions of such studies (which are prolific) and the directions in which they have taken subsequent work, are based on those assumptions. Now we can confidently state that there is a distinct possibility that generalizations drawn from such work may prove misdirected, in the light of what appears to be a fairly profound influence of gender in our data.

Some of the work that has compared hemispheric priming responses under conditions of varying strengths of relationship between stimulus words may provide helpful insights in interpreting our divergent male/female results. *RH priming patterns in such studies play out such that at short SOAs there are priming effects only for dominant* *meanings of target words; both dominant and subordinate meanings of targets are primed only with long SOAs (*Burgess and Simpson, 1988). Unfortunately, since our study did not focus on the effects of varying SOAs, we do not know precisely how our study may have fallen in line with the above. However, given our results, it seems that the dominant/subordinate meaning principle may be useful as a potential analogue.

It may be that in the venue of associative semantic relationships at our relatively short SOA, males were restricted to efficient, effective processing (reflected by priming) only in LH. Females, in contrast, may have greater RH capacity for the type of processing demanded by our protocol. The scope of the study does not give us empirically-derived material through which we might infer possible mechanisms underlying the apparent gender-based hemispheric differences in associative language representation/processing evidenced by our data. The same, apparently, could be said of the state of research in the area of language laterality in general, as subject characteristics as factors in such work have been some of the least frequently studied elements.

With evidence that our subject sample, regardless of gender, was very capable of associative priming, as indicated by results in the RVF/LH stimulus condition, we must assume that the nature of responses to associative stimuli employed in the study truly was differentiable by gender group. We would like to avoid the implication that males with intact brains somehow have right hemispheres that are relatively "incapacitated" in their language processing compared to equivalent females. For, after all, males in that category are usually perfectly capable of functioning "in the real world" even if our results are absolutely valid.

Given the rarefied and very well-controlled conditions that occur within a laboratory, it appears that one potentially parsimonious conclusion might be that females have a uniquely enhanced capacity for direct access to RH representations compared to males. Or to state the converse in a positive manner, males may have greater capacity for hemispheric selectivity and/or for selective inhibition of hemispheric activity than females. Yet another possibility is that males may have less access to RH represented language in a form that is directly usable, except under very circumscribed conditions. However, in our particular design, combined use of an N400 priming paradigm and brief SOAs should have evoked activation of it, had it been there to be tapped in the male group.

Females also may be more able than males to access and utilize distributively represented information encoded in RH. Females may encode in RH more abstract, qualitative features (that would semantically link many words otherwise unrelated), in addition to coding of concrete physical or functional attributes.

The above is offered in the context of considerable evidence from studies of populations with lateralized CNS pathology, that indicates generalized RH functional capacities that are impacted by such damage. RH functions have been particularly strongly implicated in processing in stimulus situations requiring inference, interpretation of non-literal language (irony/sarcasm, metaphor, etc.), humor, and affective language (Brownell and Martino, 1998; Beeman, 1998). As stated by Brownell and Martino (1998), ". . . many studies have used predominantly male patients and control participants or have not analyzed results separately for male and female participants. Gender differences may affect how brain damage affects patients' use of forms of discourse such as sarcasm or humor that are governed by cultural and social conventions."

Even given that implied limitation on general inferences about data from clinical populations, it appears that (according to the above, *especially in males*) RH makes a primary contribution to processing of material of the types enumerated; all of which have in common the fact that they somehow deviate from conventional rules that govern language comprehension. RH has been proposed to "coarsely" code and "weakly activate" a relatively large collection of meanings and features of a given word, "including features that are only distantly related to the input word . . ." (Beeman, 1998) There is a functional advantage to the ability to do this, if a task requires that a wide variety of possible word meanings be held open for a relatively long time period (e.g., interpretation of the punch line of a joke) and concepts or ideas are relatively discontinuous.

As noted earlier, RH semantic activation has been shown to be stronger than in LH, when remotely related features have particular import in a set of stimuli, and they would usually be dormant or decay quickly in LH. (Beeman, 1998; Deacon, Yang, et al., 2001). The above seems particularly applicable to our group of female subjects, who showed significant priming bilaterally, *and* particularly strong RH priming. Males, in contrast to females, evidenced priming exclusively lateralized to LH (and particularly *weak* priming in RH). Perhaps what we see as more equivalent coding and activation mechanisms bilaterally in females gave them a relative "advantage" over males in our paradigm, in terms of effective access/processing of purely associated words in RH.

By our alternative schema, common or mutually-defining properties may be central to this proposition, in the fact that coding/processing by common properties are essential activities in effective comprehension of metaphoric, figurative, analogic, and other non-literal language forms. It must be noted again that this concept better answers our data than do those of Beeman (as proposed earlier). This particularly applies to the portion of our findings related to gender. Whereas Beeman's (1998) notions of the fine/coarse, strong/weak, LH/RH distinction do not provide a satisfactory framework for understanding how our priming patterns (and the related gender differential) arose, the idea of LH whole-word/associate, RH property/feature coding does. This is especially true in regard to answering how in our protocol, males exhibited significant priming only in LH, while females could prime bilaterally.

Obviously if RH damage evokes deficits in functioning (that as noted above have been primarily documented in males), it has been widely assumed that *intact* functioning relies on the ability to draw on requisite capacities of RH. It may be that under normal (i.e. nonlaboratory, binaural/binoccular) nonlateralized stimulus conditions, males by and large manifest greater left-hemispheric "metacontrol" (Hellige, 1995) over language processing than do females. This would give rise to a situation in which, although lexical information may be *represented* in RH similarly regardless of gender, *activation* of that information is relatively constrained in males to those times when it is "called for" by LH. The companion corollary to that in the case of females would be that under the same set(s) of conditions, females may evidence a lesser degree of LH influence in directing processing. If so, females might have substantially less RH "subordination" (to LH) at least insofar as activation of and/or direct access to associative semantic representations coded in RH.

Our protocol, especially in regard to the manner in which associate-pair stimuli were constructed, may have had an impact on the results obtained in the following manner. In considering stimulus word pairs for inclusion in the protocol, one of the criteria for inclusion of a given word (or pair) was the standard frequency index (SFI) of each. We chose words that were of reasonably high frequency (see Appendix B for specifics), and in the case of selection of S1/S2 pairs for primed conditions, the pairs that were included had high associative probability (i.e., by word association normative standards, related S1-S2 pairs were *documentedly* related, not just "related if you think about it.")

Males and females may diverge as groups in the degrees to which RH-stored lexical information is activated under various conditions. It may be that while information is equivalently represented in RH in both genders, *activation* of RH lexical units by stimuli manifests itself differently within the two groups. Females may have a relatively low threshold of activation in RH, such that presentation of stimuli to RH evokes a classic automatic spreading activation phenomenon, regardless of other potentially mitigating conditions. Males, in contrast, may have higher activation thresholds that hold RH-stored lexicon in abeyance until they are reached. They may have inhibitory mechanisms not present in females that suppress or dampen RH contributions to language processing on an ongoing, routine basis, unless/until whatever conditions defined as necessary or sufficient for activation are reached. In keeping with the "metacontrol" idea noted earlier, males may have a greater degree of LH dominance in the sense that LH may retain a greater portion of the "executive" functions such that it determines to a greater degree (than in females) under what conditions and within what parameters RH functions. If that is assumed to be valid, then females, in contrast, might be subject to more equanimity between hemispheres, with RH taking a more autonomous role (and functioning more actively in isolation from LH) in "putting in its two-cents-worth" without constraint from LH to the degree it is exerted in males.

Such differences between genders in interhemispheric functioning and activity are not completely speculative; much of the gender-related literature reviewed earlier in this document addresses various differences in activation patterns, basal EEG hemispheric concordance, and cognitive/neuropsychological/behavioral performance. The preponderance of evidence points toward general conclusions with which the ideas under immediate consideration fit.

Findings described here have implications for the interpretation of empirical and diagnostic data in clinical populations. Especially with regard to findings related to focal and/or unilateral cortical pathology, gender differences may bear on the way those types of pathology affect language-related cognitive and behavioral functioning. It appears that LH-damaged females may have an overall potential for better-preserved associative language processing than their male equivalents. This is by virtue of the fact that (on average, at least) females, at least with our concrete, associatively-related words, have demonstrated greater potential for direct RH-mediated facilitation of lexical activation and/or access than do males.

With the relatively recent advent of the use of scanning techniques to perform brain area mapping during task performance, findings from this research should provide material for further thought among researchers interested in functional mapping. The process by which data in this series of studies unfolded into a rather clear-cut gender difference principle suggests that separate study—or inclusion as factors—of these basic subgroups is practically imperative. When "averaged brain functions" are examined in isolation from the brains in which they originated (i.e., grand averages for experimental conditions, without accounting for gender), this potentially creates a problem due to homogenization of functions that may be quite disparate into a single "typical"—but totally inaccurate—composite portrait of functioning.

Further work based on the results reported here is suggested on several fronts. Variations on our paradigm that attempt to elucidate male RH activation/priming mechanisms would be one area of obvious interest. Manipulating task demands to emphasize relatedness (and processing for it) among all stimulus elements, modifying stimulus material to move it up or down the "hierarchy" of associative relationships, and creation of a similar protocol using abstract words as stimuli (to increase the "load" on associative processing of distantly-related material) might prove productive in this regard. Application of the same protocol at a wide range of SOAs might assist in clarifying issues of hemispheric differences related to the idea of a temporal continuum of activation.

Retrospectively, given the tremendous contrast between results of our study and that of Chiarello et al. (1990) as well as the fact that subject gender proved to be a salient factor, development of a protocol that included both associative and categorical priming (either mixed or in separate blocks) might be worth the effort. (This is stated with some (retrospective) caution, for the addition of another variable would serve to inordinately increase the time consumption and complexity of administering each experimental protocol which, as it stood, subjects found somewhat daunting, primarily due to the completely lateralized stimulus presentation mode, which taxed the fortitude of almost all subjects in the study.) The opportunity to measure responses *in the same individuals* to the various types of stimulus sets in question would allow for comparison between stimulus relationship types with less concern about the impact of "individual differences" on data obtained. Another potentially interesting variant would be a combination of lexical and pictorial stimuli, with the objective of testing (especially in males) the impact of non-lexical representational material on hemispheric functioning and priming. Our presumption would be that males might evidence greater priming in RH than in LH with non-language-based representations, while with words as stimuli, still manifesting strong LH priming as was found in the present study. This type of paradigm might prove useful in clarifying the nature and extent of dichotomous, dissociable RH/LH functions often presumed to operate in males.

A further recommendation stemming from our findings involves re-examination of data generated by many previous studies in order to determine whether subject gender may have had as much of an impact on results as it apparently did in our case. A plethora of gender-difference studies have been done to date, with more being conceived and implemented on an ongoing basis. However, despite that fact, it becomes apparent that the concept of gender as an influence on experimental results in neuroscience (we are addressing that, but the same is probably true in a number of areas) is still not taken as a factor that needs to be routinely and systematically considered. The (biological) fact that has been apparent to many of us since time immemorial—that males and females are *different* from one another—has been operative throughout the enactment of any experimental examination of brain-behavior relationships. Unfortunately many sets of results have been accepted and incorporated into the fabric of our thinking without the attention to diversity of results that may have been brought to bear by the existence of that "hidden" (perhaps more aptly put, "ignored") element of gender differences.

Appendix A: Copy of Edinburgh Handedness Questionnaire

Name____________________________ Date_____________________

Age_________ Sex___________

DIRECTIONS

Please indicate your preferences in the use of hands in the following activities by putting + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++. If in any case you are really indifferent put a + in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

	LEFT	RIGHT
1. Writing	_____	_____
2. Drawing	_____	_____
3. Throwing	_____	_____
4. Scissors	_____	_____
5. Toothbrush	_____	_____
6. Knife (without fork)	_____	_____
7. Spoon	_____	_____
8. Broom (upper hand)	_____	_____
9. Striking Match (match)	_____	_____
10. Opening box (lid)	_____	_____
Total	_____	_____
i. Which foot do you prefer to kick with?	_____	_____
ii. Which eye do you use when using only one?	_____	_____

Many people, even adults, have some degree of confusion in telling (or remembering) left from right, while others have no difficulty with this whatever and consider it an automatic function. Please indicate whether you ever had problems with left and right, whether you have consciously to think about it, or whether it comes to you naturally.

_____ Frequently get confused
_____ Sometimes get confused
_____ Have to think about it consciously
_____ Comes naturally

$$\text{L.Q.} = \frac{(\text{right} - \text{left})}{(\text{right} + \text{left})} \times 100 = \underline{\hspace{2cm}} \qquad \text{Decile=}\underline{\hspace{2cm}}$$

Appendix B : Concrete Associate Word Pairs
Standard Frequency Index Values, Letter Counts

(NOTE: Overall Means, Standard Deviations appear at end of chart.)

WORD 1	Freq.	Length	WORD 2	Freq.	Length
BIRD	61.6	4	FEATHER	52.4	7
SCHOOL	66.9	6	TEACHER	61.5	7
JUICE	53.4	5	ORANGE	55.6	6
LIPSTICK	39.8	8	PURSE	49.4	5
MOVIE	54.1	5	POPCORN	48.5	7
VITAMINS	49.8	8	HEALTH	56.6	6
NURSE	51.6	5	NEEDLE	55.0	6
HOTEL	52.2	5	BAGGAGE	44.8	7
SHEEP	59.1	5	WOOL	55.5	4
MITTENS	46.5	7	WINTER	62.6	6
GARDEN	60.2	6	HOSE	50.4	4
CHEF	30.5	4	HAT	59.2	3
FUEL	55.8	4	PUMP	52.4	4
SKIN	60.5	4	CREAM	56.3	5
BALLOONS	55.4	8	PARTY	60.5	5
DENTIST	48.3	7	DRILL	52.5	5
HAY	54.3	3	BARN	57.4	4
LEOPARD	46.5	7	SPOTS	54.0	5
MUG	36.3	3	COCOA	47.9	5
ZOO	53.6	3	MONKEY	53.8	6
SAW	67.2	3	WOOD	61.6	4
EXAM	37.2	4	GRADE	54.5	5
GOLF	49.0	4	CLUBS	50.2	5
FOX	54.2	3	HUNT	56.4	4
ESKIMO	47.6	6	IGLOO	36.0	5
AUTUMN	53.5	6	LEAVES	62.2	6
AMBULANCE	43.1	9	SIREN	41.3	5
PHONE	50.6	5	CALL	63.9	4
CHURCH	58.5	6	STEEPLE	43.3	7
PARADE	52.3	6	FLOAT	53.2	5
COLD	64.2	4	SNIFFLES	39.8	8
NET	52.8	3	TENNIS	50.9	6
BALL	62.9	4	BAT	56.4	3
JACKET	53.3	6	LEATHER	55.5	7
FAUCET	41.7	6	WATER	70.8	5
WEB	52.3	3	SPIDER	54.8	6
EGG	57.2	3	CHICKEN	55.7	7
CHECK	61.8	5	BANK	59.0	4
SLIPPER	44.7	7	BALLET	49.4	6

WORD 1	Freq.	Length	WORD 2	Freq.	Length
BULLET	49.6	6	GUN	58.2	3
RUNNER	48.4	6	TRACK	57.5	5
SYRUP	48.5	5	MAPLE	52.1	5
CAMPING	50.5	7	TRAILER	47.1	7
COWBOY	55.3	6	LASSO	43.4	5
TRAIN	59.9	5	STATION	57.8	7
POCKETS	51.8	7	HANDS	63.8	5
HYDRANT	35.8	7	FIRE	63.5	4
WALLET	41.5	6	MONEY	64.9	6
TUB	50.2	3	BATH	51.7	4
CLOUD	56.9	5	SKY	62.2	3
FREEZER	38.4	7	ICE	62.4	3
CLOTH	58.5	5	SEWING	50.5	6
THREAD	55.7	6	STITCHES	44.7	8
COLLIE	37.9	6	SHEEP	59.1	6
MAILBOX	39.8	7	LETTER	63.8	6
TUXEDOS	30.6	7	BALL	62.9	4
CLEANER	46.7	7	MOP	42.4	3
GARAGE	53.8	6	CAR	38.9	3
CANARY	45.5	6	SONG	59.8	4
SLAVE	53.9	5	CHAINS	50.1	6
STADIUM	44.9	7	BLEACHERS	36.8	9
PARROT	51.5	6	CAGE	55.8	4
SECURITY	49.1	8	ALARM	52.2	5
PARK	56.5	4	SQUIRRELS	51.2	9
RADIO	59.3	5	MUSIC	61.8	5
OFFICE	59.1	6	WORK	69.2	4
WEDDING	52.0	7	BRIDE	49.0	5
SAWMILL	43.3	7	LUMBER	53.3	6
HEEL	47.0	4	SHOE	54.1	4
PENCIL	56.9	6	PAPER	65.7	5
COMB	50.1	4	HAIR	61.6	4
THORN	46.0	5	ROSE	58.9	4
OAR	46.7	3	BOAT	62.1	4
STORM	57.5	5	WIND	63.8	4
RIBBON	52.8	6	PRESENT	61.4	7
CRAYONS	45.4	7	KIDS	53.8	4
HANGER	37.8	6	COAT	58.0	4
GUM	50.9	3	BUBBLE	49.4	6
MAP	61.8	3	ROAD	62.9	4
BED	61.6	3	BLANKET	55.0	6
BUCKET	52.6	6	MOP	42.4	3
SPOON	49.0	5	SILVER	59.6	6
SADDLE	54.2	6	HORSE	63.2	5

WORD 1	Freq.	Length	WORD 2	Freq.	Length
FILM	53.9	4	CAMERA	53.9	6
CHIMNEY	50.7	7	SMOKE	57.5	5
SHERIFF	49.4	7	BADGE	42.0	5
BOWL	57.1	4	SOUP	53.4	4
THREAD	55.7	6	NEEDLE	55.0	6
CUP	56.7	3	COFFEE	57.1	6
COURT	56.2	5	JUDGE	54.8	5
NUMBER	68.5	6	COUNT	58.6	5
COW	56.7	3	MILK	61.0	4
CRATER	45.8	6	MOON	62.7	4
CHEESE	55.4	6	MOUSE	55.2	5
TAILOR	47.2	6	PINS	50.4	4
SLED	51.7	4	HUSKY	45.3	5
HIKING	46.3	6	TRAIL	57.1	5
PIRATE	48.9	6	SKULL	50.2	5
SKATE	46.0	5	ROLLER	47.1	6
GALLON	49.0	6	JUG	48.0	3
ENGINE	59.8	6	CAR	64.8	3
HERMIT	43.3	6	CAVE	56.6	4
FLEA	45.4	4	DOG	63.6	3
CREW	56.4	4	SHIP	62.4	4
BARBER	47.6	6	RAZOR	43.7	5
HILL	58.6	4	SLED	51.7	4
SKATES	50.4	6	ICE	62.4	3
CAN	74.6	3	TIN	55.6	3
CROWN	51.4	5	KING	59.8	4
HAMMER	53.1	6	NAIL	53.4	4
ARTIST	51.9	6	PAINT	56.0	5
FARMER	58.6	6	PLOW	50.7	4
SHELL	56.2	5	SEA	65.1	3
WASP	45.5	4	STING	46.9	5
WORM	50.5	4	HOOK	52.6	4
SEED	54.4	4	FLOWER	57.1	6
DESK	57.5	4	SCHOOL	66.9	6
PLAY	64.9	4	STAGE	57.8	5
CANDLE	53.2	6	FLAME	54.2	5
HARBOR	54.3	6	BOAT	62.1	4
CAT	60.2	3	CLAW	45.4	4
DOG	63.6	3	BARK	55.5	4
TIGER	52.4	5	STRIPES	48.4	7
LION	56.4	4	ROAR	54.1	4
SKI	46.2	3	SNOW	62.3	4
MATCH	57.9	5	FIRE	63.5	4
GAME	62.5	4	CARD	55.8	4

WORD 1	Freq.	Length	WORD 2	Freq.	Length
GROCER	42.5	6	STORE	60.9	5
DEVIL	48.7	5	HORNS	53.9	5
SAW	67.2	3	WOOD	61.6	4
PILOT	54.4	5	PLANE	61.2	5
ONION	45.2	5	TEARS	55.5	5
STAR	58.2	4	SKY	62.2	3
SPIDER	54.8	6	WEB	52.3	3
SHEEP	59.1	5	WOOL	55.5	4
FLOOR	62.4	5	WOOD	61.6	4
MUG	36.3	3	BEER	45.0	4
NEST	57.5	4	BIRD	61.6	4
PAPER	65.7	5	NEWS	58.1	4
LACE	49.1	4	SHOE	54.1	4
POLISH	48.0	6	NAIL	53.4	4
BUTTON	53.3	6	COAT	58.0	4
BONE	56.3	4	DOG	63.6	3
USHER	39.3	5	MOVIE	54.1	5
CIRCUS	55.3	6	CLOWN	49.2	5
KETTLE	51.5	6	TEA	55.0	3
LIGHT	66.2	5	LAMP	54.9	4
BRICK	53.5	5	HOUSE	67.0	5
STONE	60.1	5	WALL	60.7	4
APPLE	57.2	5	TREE	64.2	4
FISH	64.5	4	WATER	70.8	5
SNAKE	55.4	5	SKIN	60.5	4
RUBBER	57.6	6	TIRE	51.7	4
TRAIN	59.9	5	TRACK	57.5	5
MOLD	51.9	4	BREAD	58.9	5
BEE	52.7	3	HONEY	52.5	5
CAMEL	50.6	5	HUMP	44.4	4
KEY	59.0	3	DOOR	64.6	4
MOON	62.7	4	STAR	58.2	4
MINER	44.6	5	COAL	57.8	4
CLOTH	58.5	5	DRESS	58.0	5
HOCKEY	42.1	6	ICE	62.4	3
WAVE	57.3	4	OCEAN	61.3	5
BOOK	64.3	4	PAGE	66.3	4
CRADLE	47.5	6	BABY	61.2	4
ALLEY	47.4	5	CAT	60.2	3
RIVER	63.1	5	RAFT	52.0	4
TEPEE	38.9	5	INDIAN	62.6	6
TUTU	31.4	4	BALLET	49.4	6
TRAP	53.6	4	MOUSE	55.2	5
WATCH	62.5	5	WRIST	50.1	5

WORD 1	Freq.	Length	▨	WORD 2	Freq.	Length
HANDS	63.8	5	▨	GLOVES	49.2	6
MEMORIES	48.0	8	▨	DIARY	49.1	5
HEAD	66.4	4	▨	HAT	59.2	3
PEARL	47.7	5	▨	OYSTER	48.1	6
HORSE	63.2	5	▨	STABLE	52.4	6
SCARF	48.7	5	▨	NECK	58.0	4
RING	59.7	4	▨	FINGER	58.1	6
ANGEL	47.3	5	▨	HALO	41.6	4
BUNNY	36.7	5	▨	EASTER	45.2	6
CANDLE	53.2	6	▨	FLAME	54.2	5
NAIL	53.4	4	▨	HAMMER	53.1	6
PICNIC	53.0	6	▨	ANTS	53.1	4
CAKE	56.3	4	▨	BIRTHDAY	56.3	8
SHIP	62.4	4	▨	CRUISE	43.4	6
PEACHES	52.5	7	▨	FUZZ	38.6	4
WAIST	50.9	5	▨	BELT	54.6	4
DANCER	45.6	6	▨	STAGE	57.8	5
CUPID	39.6	5	▨	HEART	62.3	5
DESERT	59.0	6	▨	CACTUS	50.5	6
TRAFFIC	56.2	7	▨	HORN	54.1	4
PRISON	51.5	6	▨	WARDEN	41.3	6

Stimulus Words by Condition

Condition	Position	Type of Trial	MEAN SFI	MEAN # Letters
LH	S1	Primed	42.0	5.0
LH	S1	Unprimed	41.7	5.80
RH	S1	Primed	42.6	5.3
RH	S1	Unprimed	42.9	5.6
LH	S2	Primed	43.4	4.9
LH	S2	Unprimed	41.6	5.9
RH	S2	Primed	43.2	4.8
RH	S2	Unprimed	42.7	5.6

Appendix C: Tables of N400 Mean Area Data

Right Visual Field/Left Hemisphere Stimulus Presentation by Priming by Electrode
RVF = Right Visual Field; P = Primed, U = Unprimed; T3, T5, etc. = Electrode

SUBJECT	Gender	RVFUT3	RVFPT3	RVFUT5	RVFPT5	RVFUP3	RVFPP3	RVFUO1	RVFPO1
1	1	3.536	2.551	1.577	3.32	1.006	3.097	0.638	3.355
2	1	-1.889	2.802	-0.709	3.154	-1.554	2.821	-0.492	3.076
3	1	1.251	1.847	-1.052	-0.498	-0.029	1.924	0.438	1.631
4	1	-1.11	0.264	0.087	2.071	0.284	2.051	-0.659	1.154
5	1	3.123	4.442	6.079	7.578	5.902	7.055	6.024	7.526
6	1	-1.263	-0.214	-0.403	0.002	-1.04	0.55	-0.887	-0.203
7	1	0.428	-2.594	-9.459	-5.603	-8.757	-5.111	-12.056	-6.951
8	1	0.988	2.141	0.514	1.44	0.049	1.337	1.028	0.522
9	1	-1.301	2.102	-2.853	0.65	-2.209	1.218	-3.879	-0.122
10	1	-0.599	1.891	-1.246	0.249	-2.761	1.222	-2.329	0.917
11	2	2.637	1.985	-7.641	-6.611	-6.487	-5.913	-10.235	-7.73
12	2	-4.269	-5.649	-6.026	-4.727	-3.346	-4.173	-3.504	-2.97
13	2	-1.165	-7.736	2.69	-4.17	0.836	-4.998	2.766	-1.665
14	2	4.736	6.58	-1.664	1.561	0.823	4.523	-0.781	4.774
15	2	0.591	0.856	1.505	2.589	2.413	3.761	-0.089	1.288
16	2	0.804	-1.38	-2.601	-3.155	-1.8	-1.255	0.544	1.794
17	2	2.61	3.133	-0.716	0.414	-0.286	0.697	0.232	0.659
18	2	-4.95	-0.997	-3.757	-2.182	-4.106	1.347	-3.782	-1.181
19	2	0.114	2.625	-5.972	-5.122	-2.662	-1.747	-2.664	-0.96
20	2	3.62	1.421	0.579	1.323	-0.2	3.742	-0.666	2.857

Left Visual Field/Right Hemisphere Stimulus Presentation by Priming by Electrode
LVF = Left Visual Field; P = Primed, U = Unprimed; T4, T6, etc. = Electrode

SUBJECT	Gender	LVFUT4	LVFPT4	LVFUT6	LVFPT6	LVFUP4	LVFPP4	LVFUO2	LVFPO2
1	1	2.403	4.673	-1.522	2.36	1.488	3.026	0.068	3.271
2	1	-0.649	1.131	0.376	0.445	-0.043	-0.608	1.691	1.017
3	1	-2.248	-4.369	-3.858	-5.84	-3.421	-5.666	-1.691	-3.918
4	1	-4.116	-2.051	-2.234	-2.117	0.115	-1.088	-0.104	-1.515
5	1	-2.255	-1.877	2.523	2.558	2.88	2.879	3.63	3.467
6	1	-1.281	-1.879	-1.809	-2.148	-3.199	-3.667	-1.996	-1.685
7	1	-5.954	-2.665	-9.769	-3.742	-10.844	-4.977	-10.762	-4.683
8	1	-2.557	1.682	-4.535	-0.598	-4.379	-0.907	-3.727	-0.007
9	1	0.565	0.228	-0.689	-0.295	0.585	0.654	-1.845	-1.279
10	1	-1.661	-1.373	-1.294	-0.512	-0.613	-0.367	-1.251	-0.665
11	2	-4.111	-3.051	-7.561	-6.222	-6.526	-5.16	-7.488	-5.636
12	2	-2.38	0.374	-5.188	-0.013	-1.556	0.89	-0.227	4.681
13	2	-0.85	-0.407	-3.849	-1.485	-0.511	1.895	0.528	3.3
14	2	6.595	1.548	5.078	1.528	7.489	4.792	5.64	4.054
15	2	0.574	2.337	-2.099	1.301	-0.132	3.488	-0.483	2.09
16	2	0.873	2.814	-1.589	0.306	-2.472	1.045	-0.043	2.591
17	2	0.284	3.759	-0.673	4.41	0.456	3.951	1.733	4.338
18	2	-0.091	5.268	1.276	7.681	2.474	8.883	5.005	10.787
19	2	-1.957	-3.176	-3.931	-3.107	-2.382	-1.191	-4.226	-3.051
20	2	0.72	1.69	-2.992	-0.822	-6.998	-0.775	-2.887	-0.059

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