DO STRATEGIC PRIMING PROCESSES DIFFER FOR CATEGORY VS. ASSOCIATIVE PRIMING? AN EVENT-RELATED POTENTIALS STUDY OF PROACTIVE EXPECTANCY STRATEGIES.

By

Linzi Gibson

Submitted to the graduate degree program in Psychology and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master's of Arts

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**Abstract**

An extension of Becker's 1980 semantic priming study challenges the Verification Model by proposing that there are two different priming processes, one at a perceptual level and one at a semantic level. Participants performed a lexical decision task with a category-dominant or associative-dominant list while ERPs were recorded. We predicted that the associative effects would be mediated by facilitation and would influence the N170 and that the categorical effects would be indexed by the N300 for inhibitory effects and the N400 for facilitatory effects.

Inhibition was not seen for unrelated targets in the categorical condition. The fillers in the categorical condition produced an inhibition effect but not a N300 effect. The N170 effect was not significant. An N400 effect was observed only for the associative list. It is suggested that this finding is consistent with a previously proposed (Franklin, et al., 2007) post-lexical semantic expectancy updating account for the N400.

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## Introduction 1

### 1.1 Semantic Priming -

Semantic memory is described as our organized general world knowledge of meanings, concepts and facts. While memories of our own life experiences, otherwise known as autobiographical memory, is part of what makes us unique, the nature of semantic memory is quite similar for all humans. Though the contents of semantic memory are different for each person, there are aspects of semantic knowledge that Americans tend to share in common and these are the aspects that make understanding each other possible. To understand semantic memory, one must understand not just how it is organized but also how attention is used to consciously access its contents. Research in the field of attentional semantic retrieval can also provide information about word recognition in reading. The question of what processes are involved in word recognition has been investigated at great length by cognitive researchers. Introspectively word recognition seems effortless; however, it is an extremely complicated process that is, thus far, not fully understood. Investigating how attentional strategies can facilitate and in some cases inhibit word recognition has been the subject of many studies in the field of attention research. The majority of these studies have focused on behavioral research techniques; however, electrophysiological techniques such as electroencephalography (EEG) can provide insight into attentional processes which goes beyond simple reaction time data.

Numerous methods are used to explore the role of attention in word recognition. One of the principal methods that demonstrates the effects of attention on word recognition is semantic priming. Understanding context effects can provide insight into the attentional processes which influence semantic retrieval as well as the processes involved in word recognition. Semantic priming is defined as the improvement in speed or accuracy in response to a stimulus, such as a word or picture, when it is preceded by a semantically related stimulus (McNamara, 2005). Although semantic priming can be observed with pictures and symbols, most experiments are conducted with words. In a traditional semantic priming experiment, a "prime" word is presented to a subject, which is immediately followed by the presentation of a "target" word that the subject must make some sort of decision about. Priming is usually demonstrated by a significant decrease in reaction time to the target word when the prime and target words are related (CAT-DOG). There are two primary methods for studying semantic priming, the naming task and the lexical decision task. When employing the naming task, the participant is instructed to say that word after it is presented to them. In the lexical decision task the participant is instructed to view the target and then make a decision about whether or not it is word or a nonword. Nonwords are orthographically correct strings of letters; that is to say, they are pronounceable and follow the rules of the English language, but are not real words.

Many studies use a neutral prime to provide a baseline against which to compare the responses to related and unrelated targets. Many different types of neutral primes have been tested over the years including a row of X's, unpronounceable nonword letter strings, and the word "blank" have all been used (Dien, Franklin, & May, 2006). The use of a neutral prime has revealed two different effects with regard to response time, which are known as facilitation and inhibition. Facilitation is a faster reaction time to a related target when compared the neutral prime condition. Inhibition is defined as slower reaction time to an unrelated target when compared the neutral prime condition.

**1.2 Theories of Word Recognition-**

Semantic priming studies have shown that automatic and strategic processes both play a role in word recognition. Automatic processes are highly practiced, involuntary and capacity-free (Posner & Snyder, 1975) (Schiffrin & Schneider, 1977). Strategic processes require attention, are voluntary and capacity-limited. Information about how automatic processes work has given us insight into the organization of semantic memory. Varying the stimulus onset asynchrony (SOA) is a common manipulation researchers use to investigate these two processes. A short SOA will only allow automatic processing to take place whereas a long SOA allows time for strategic processing. The strategic processes involved in word recognition are particularly interesting because examining these mechanisms can provide information about attentional strategies that are particularly helpful in reading and language processing.

The leading model of attention in word processing is Neely's hybrid model of semantic priming, which consists of three independent processes known as spreading activation, expectancy, and semantic matching (Neely, 1977) (Neely, Keefe, & Ross,

1989) (Neely, 1991). The automatic process known as automatic spreading activation (ASA), occurs rapidly and unconsciously, and produces facilitation in the processing of semantically related items but not inhibition in the processing of semantically unrelated items. The two strategic processes in this model are expectancy and semantic matching. A description of these two processes is detailed in a study conducted by Neely and colleagues (1989).

The two strategic processes in this model are expectancy and semantic matching (Neely, 1989). Expectancy operates when related primes and targets are frequently presented together in an experiment. The subject is believed to generate an expectancy set of words that are semantically related to the prime. It is relatively slow acting, consciously controlled, and produces facilitation in the processing of expected items and inhibition in the processing of unrelated items. Semantic matching occurs solely in the lexical decision task. After accessing the lexical information but before accessing the semantic information, subjects check for a relationship between the target and prime. The presence of a relationship biases a "word" response, and the absence of a relationship biases a "non-word" response, which produces facilitation for related word pairs and in some cases inhibition for unrelated word pairs. Neely et al. (1989) investigated these two mechanisms by manipulating two different factors, the relatedness proportion (RP) and the nonword ration (NWR). The RP is the conditional probability that a prime and target are related, given that they are both words. The NWR refers to the probability that a target is a non-word given that it is not related to the preceding prime. As the NWR increases, the absence of a relationship between the prime and target becomes a progressively better indicator that the target is a non-word. The results of two different experiments in this study demonstrated that priming effects increase as a function of RP, and increases in the NWR lead to systematic increases in the non-word facilitation effect, which is a faster response to nonwords primed by words than nonwords primed by a neutral prime. Neely and colleagues concluded that the RP effect is most likely due to expectancy because the higher the RP, the more likely it is that prediction will facilitate target word recognition. The semantic matching is most likely affected by the NWR because when the ratio is high, it is most efficient to check for a relationship between the target and prime to facilitate the response. This was an extremely important study because it provided support for the presence of two different strategic processes involved in semantic priming: expectancy and semantic matching. It is apparent from the results of this study that the composition of stimulus lists used in a semantic priming experiment can have an influence on whether expectancy or semantic matching strategies are employed.

For attention researchers, expectancy is the most important semantic priming process. A leading model of expectancy is the Verification Model (Becker, 1980) of semantic priming. The Verification Model explains expectancy priming as the result of a strategic process involving a search through a list of predicted words known as the "semantic set." If the target is not in the semantic set, then the lexicon is subsequently searched. These two different lists are known as the semantically defined set (SDS), which contains words that are semantically related to the prime and organized by relatedness, and the orthographically defined set (ODS), which contains words that are orthographically similar to the target and organized by frequency. The study consisted of five separate Experiments, and the fifth and final experiment is basis for the present study. All of the Experiments were lexical decision studies with long SOAs of 1050 ms and were designed to influence the strategy of word recognition by changing the nature of the word lists.

The stimuli in these experiments were the category and antonym pairs. These two types of stimuli were chosen because, according to Becker's (1980) Verification Model, they have very different semantic set sizes. When an antonym prime is presented, it has a very small semantic set, sometimes consisting of only one related word. When a superordinate category prime is presented, the semantic set consists of the members of that category and is ordered in terms of relatedness to the prime word. These different semantic set sizes produce very different priming results. According to the Verification Model, a search through an antonym prime's semantic set will be very rapid if the target is related because the set is very small. If the target is unrelated to the prime, there is very little delay in searching the orthographic set because the semantic set is so small. On the other hand, when a categorical prime is presented, the semantic set is very large and when the target is unrelated there is a long delay before the orthographic set can be searched. Experiments One through Four supported this theory by demonstrating that a list of primarily antonyms is characterized by facilitation of related pairs when compared to pairs with a neutral prime. It was also shown that a category-dominant list predominantly produces inhibition effects when comparing unrelated pairs to word pairs with a neutral prime.

With the information gathered from the first four experiments, Becker (1980) went on to examine whether including category pairs in a list of predominantly antonyms would influence word recognition strategies. The goal was to verify whether the priming effects were due primarily to subject strategy rather than the nature of the stimuli. The final experiment, which was the basis for the present study, included the critical antonym and category pairs as well as strongly associated filler word pairs. The strongly associated filler pairs were included so that the stimulus list would be mostly associatively related. The results of Experiment Five showed substantial facilitation effects for both types of critical pairs (associative and categorical) and small interference effects. Because, in Experiment Two, Becker found that the category pairs had larger interference effects when embedded in a list of categorical priming pairs, it seems that the nature of the list had an effect on the word recognition strategy. Becker explained these results with his Verification Model of semantic priming, which is discussed in detail below. This study demonstrated that different types of relationships (e.g., category, antonym, etc.) can produce different priming results, and that the effect of list context can prompt subjects to use different strategies in a lexical decision task.

Multiple studies have shown that inhibition effects are commonly found in categorical priming lists (Becker, 1980) (Neely, 1977). It is interesting that category pairs are the primary stimuli for producing the inhibition effect in lexical decision experiments. The facilitation effect is quite different because it is seen with many different types of stimuli (associations, antonyms, categories, etc.). It is still not clear whether retrieval processes allow us to access one type of relationship faster than another, or if participants are using different strategies to recognize the targets based on the characteristics of the stimuli. According to Becker, only one strategy is being used and the difference between these two types of stimuli is the number of primed target available in the semantic set. Though Becker's Verification Model does seem to reasonably explain the results of his 1980 study, modern theories of cognitive psychology and semantic priming generally discount Becker's theory of "list checking" in the semantic set.

If participants are not systematically searching a list of possible targets during priming experiments, how then do we explain these results? It may be the case that when Becker (1980) attempted to find words which produced different sizes of semantic sets, he introduced an unknown confound because of the stimuli he chose. Category pairs are generally characterized by semantic relationships; things that have a similar appearance, equivalent purposes or behavior, share the same function or have similar defining properties. Antonyms pairs are generally associative relationships, which represent spatial, temporal, and causal links between concepts as well as frequent co-occurrence in language (Skwarchuk & Clark, 1996). Clearly these two types of relationships are very different, and it is possible that different expectancy strategies are utilized by subjects depending on the nature of the list with which they are presented. It is also the case that this theory wasn't fully tested as only the effects of an associative-dominant list were examined and not a category-dominant list.

### 1.4 An Alternative Account

An alternative explanation of expectancy-based priming resulting in facilitation for related highly associated pairs and inhibition for unrelated category pairs may be found by examining parallel distributed processing models and the process of mental imagery. The prominent connectionist view of cognition describes concepts as being patterns of activation across a network of interconnected units (Rumelhart & McClelland, 1986) (Masson, 1995). Each unit represents an aspect or feature of a concept; therefore similar concepts produce similar patterns of activation. During expectancy-based semantic priming experiments, when a prime is presented, a specific pattern of these units is activated. Priming of semantically related concepts (or words) occurs because related concepts have similar patterns of activation; consequently the network gets a head start in processing the target. Although these parallel distributed processing theories can explain facilitation for related concepts, it is difficult to explain inhibition of unrelated concepts that is seen with word lists that are primarily made up of category pairs. It is possible that when a target is presented which is unrelated to the prime, the features of the prime must be deactivated (or inhibited) in the semantic memory network and then the target features must be activated. Because this process takes some time the result is inhibition (Thompson-Schill, Kurtz, &

Gabrieli, 1998). Associates, however, do not always have semantic overlap. In a strategic priming experiment containing primarily associates, far less features would need to be deactivated before the target features could be activated which would not result in inhibition. Furthermore, because the associate pairs have less semantic overlap than category pairs, it may not be an efficient strategy to keep the prime activated in the semantic network.

Morton's classic Logogen Model (Morton, 1964) also provides a non-connectionist alternative to the list-wise model proposed by Becker (1980). According to this model, words are represented by feature counters called logogens. Word recognition takes place when the amount of information in the logogen surpasses the recognition threshold. The context effect that occurs in the Logogen Model is the result of the feature counters being raised above resting level for logogens sharing semantic features with the prime word. Therefore fewer features are needed to recognize a word when it appears in a semantically related context. However, when the target word is unrelated to the prime, it takes longer to raise the feature count above threshold for the unrelated word and the result is inhibition. This account may also explain facilitation and inhibition effects for semantically related stimuli.

We propose that associative priming happens in a qualitatively different way from categorical priming. When a list is made up of predominantly associative pairs, an expectancy strategy can be utilized in which the highly associated word that is predicted is held in visual working memory. In other words, participants are creating a mental representation of the word using imagery (Kosslyn et al., 2001). When the predicted word is generated, facilitation results when the target matches the predicted word, but no more inhibition occurs for unrelated words than for neutral primes. Following this reasoning, it may be the case that two different effects of expectancy are occurring as opposed to the one expectancy effect proposed by the Verification Model (Becker, 1980). The expectancy strategy utilized is a result of the nature of the word pairs in the list. When the list is primarily made up of category pairs, priming occurs in the semantic memory network. When the list is predominantly associative in nature, and the related targets are almost always the strongest associate, it is more efficient to use a strategy in which the prediction of the dominant association is held in visual working memory. It would be of great benefit to have a direct indicator of the perceptual and semantic processes so that researchers can better understand what strategies are being implemented during word recognition.

### 1.3 ERP Components Reflecting Lexical Processing -

As scientific knowledge grows it is increasingly more difficult to design experiments which isolate the mechanisms of interest while controlling for all of the potential confounds that affect attentional strategies. A useful adjunct to behavioral measures is electrophysiological and neuroimaging techniques that can aid in the understanding of the neural mechanisms behind word recognition. The use of electrophysiological measures, specifically event-related potentials (ERPs) recorded using electroencephalography (EEG), has provided useful insight into temporal aspects of word recognition and semantic priming effects as they allow one to directly monitor mental processes as they are occurring. In the present experiment, we hypothesize that different ERPs may separately index semantic facilitation, semantic inhibition, and perceptual priming.

The first such component, the N400, may reflect semantic facilitation. It has been well established that the ERP component known as the N400 is larger (more negative) on trials where the stimuli are semantically incongruent (Kutas & Hillyard, 1980). With regard to semantic priming studies, the "N400 effect" is described as the difference in amplitude between related and unrelated word pairs, the component being more negative for unrelated word pairs. This component is seen over the posterior midline regions of the scalp and peaks at around 400 ms. Researchers have found this effect using many different paradigms including lexical decision tasks and reading for comprehension studies (Kutas & Hillyard, 1980) (Kutas & C.K., 1994) (Bentin, 1987). The N400 has been described as the earliest component to reflect semantic processing (Friederici, 2002).

The second such component, an anterior negativity labeled the N300, was observed in a study conducted by Franklin et al. (2007). This component could very possibly index semantic inhibition to category stimuli. A significant difference in amplitude was seen only when comparing unrelated pairs to symmetrical pairs at long SOAs, and the component was more negative in response to unrelated pairs. The N300 is most often reported in picture priming studies and is more negative for unrelated stimuli, and becomes more positive in response to categorical relatedness (Barrett & Rugg, 1990) (McPherson and Holcomb, 1999) (Federmeier. K.D. and

Kutas, 2002). Furthermore, a number of word studies have reported a similar component although there has not been a consensus on the label (Frishkoff, Tucker, Davel, & Scherg, 2004) (Nobre & McCarthy, 1994) (Misra & Holocomb, 2003) (Holocomb and Grainger, 2006) (Frishkoff, 2007). There are also studies that have classified this slightly earlier frontal component as the N400, ignoring the differences in latency and topography (Kreher, Holocomb, & Kuperberg, 2006) (Kiefer, 2001). Franklin et al. (2007) proposed that the N300 effect reflects proactive expectancy of categorical stimuli and/or semantic similarity. Because there were no neutral pairs included in their stimuli, it was unclear whether the N300 effect was a response to the facilitation effects of expectancy or the inhibition effects of expectancy that are commonly seen in categorical priming studies. Of the three pairs of critical stimuli used in this experiment, forward, backward and symmetrical, the symmetrical pairs were the most strongly associated, this observation was not definitive, but the difference did appear to be qualitative in that no N300 effect at all was observable to the associative pairs, especially given the earlier reports of categorical effects in the N300 for pictures. In any case, it does seem to be the case that the N400 is not the first ERP component that can reflect semantic processing.

If there are in fact two processes involved in the expectancy mechanism of semantic priming, facilitation to related associated pairs and inhibition of unrelated pairs in the context of categorical priming, this theory may help expand our knowledge of the N300 effect. It was suggested by Franklin and colleagues (2007), that this component could possibly index proactive expectancy of semantically related stimuli. However, it may be the case that the N300 effect is actually reflecting the process and responds to the processes involved in categorical priming which lead to inhibition. A follow up study conducted by O’Hare, et al. (2008) co-registered the ERP data of the Franklin et al. (2007) study with functional magnetic resonance imaging (fMRI) data and localized this component to the dorsal posterior cingulate cortex (dPCC). It was argued (O'Hare, Dien, Waterson, & Savage, 2008) that recent studies suggest that the dPCC is involved inhibition (Brown et al., 2006) (Booth et al., 2003) (Rubia et al., 2008). An fMRI study conducted by de Zubicaray et al. (2000) visually presented participants with category exemplars and they were instructed to either nominate the super-ordinate category to which the exemplar belonged (the response initiation condition) or provide a general super-ordinate category to which the exemplar did not belong (the response suppression condition). It was found that the dPCC was activated in the suppression and not the initiation condition. The localization of this component to the dPCC, taken with evidence that categorical priming reliably produces inhibition effects, provides support for the view that the N300 effect reflects the categorical priming.

The last component of interest for the present study is the N170, which we believe may reflect perceptual priming for associated stimuli. The N170 is an ERP component peaking between 150 and 200 ms and is commonly elicited by visual stimuli such as faces, objects, and words. Evidence suggests the lateralization of the N170 depends on the type of stimuli. While the N170 response to objects can be bilateral, the N170 response to faces is commonly right lateralized and the “word

N170" is left lateralized (Maurer, Brandeis, & McCandliss, 2005)(Rossion et al., 2003). The word N170 is thought to emanate from the visual word form area (VWFA) (Brem et al., 2006) (Rossion et al., 2003). The VWFA is located along the left fusiform gyrus and has been shown in neuroimaging studies to become more active in response to words and pseudo-words, when compared to consonant letter strings (Dehaene et al., 2002) (Cohen et al., 2002). This converges with the ERP evidence on the N170, commonly found to be larger (more negative) for words and pseudo-words, compared to non-pronounceable letter strings (Simon, Petit, Bernard, & Rebai, 2007) (Simon et al., 2004). Dehaene and colleagues (2002) concluded that the area dubbed the VWFA reflects sub-lexical (orthographic) processing of words. There are long standing arguments over the possibility for top-down influences on sub-lexical processes. A review by Federmeier (2007) provides a strong argument for both bottom-up and top-down processing in word processing in general. It is possible, although not investigated as of yet, that a top-down, facilitative expectancy strategy may enhance the N170 as a response to a predicted word being held in the VWFA. This lab has data in preparation that found such effects in sentence priming paradigms.

**1.5 The Present Study**

The present study aimed to replicate/extend Becker (1980) in order to challenge the one-process explanation proposed in the Verification Model by finding evidence for multiple expectancy processes indexed by different ERP components. This experiment was based on Experiment 5 (Becker, 1980), with a few changes.

Additional stimuli were included because when conducting ERP research, it is important to include as many trials as possible to obtain a sufficiently high signal-to-noise ratio. In Experiment 5 of Becker's 1980 study, only an associative-dominant list was used. He did not discuss why he did not include a category –dominant list. Because this study is investigating how the nature of a word list can affect attentional strategies, we thought it was important to include both an associative-dominant and category-dominant list. Because Becker's Experiment 4 showed that using low typicality fillers aids in increasing the distinction between the associative and category list (i.e., in a low typicality pair like WOOD-ebony, the target is more readily predicted categorically than associatively), low-typicality filler pairs were used to construct the category-dominant list. This was a between subjects design so participants viewed either the associative-dominant list, or the category-dominant list.

It is predicted that the behavioral results will show substantial facilitation effects for both the highly-associated (LAUGH-cry) and high-typicality category (FABRIC-silk) related pairs in associative-dominant condition and little to no inhibition effects, as Becker (1980) found in Experiment 5. In the category-dominant condition, the expectation is that there will be inhibition effects seen for the unrelated pairs that are matched to both the associative and the categorical related pairs. Becker's Verification model explained these data as being the result of one listwise process. The only difference between these two pairs, according to Becker, is the size of the SDS, with the larger SDS in the category-dominant condition slowing down responses to the unrelated pairs. We predict that there are actually at least two different strategies producing these results. The pattern of facilitation seen in the associative-dominant list is predicted to be the result of the target's presence in visual working memory, facilitating the processing and response to the target word. We hypothesize that in category-dominant condition, participants will be using an expectancy strategy carried out in semantic memory where, according to the connectionist account, similar patterns of activation among related words will produce moderate facilitation and different patterns among unrelated words will cause conflict, resulting in inhibition.

While the behavioral results are compatible with either model, support for our two-process expectancy model, we predict, will be displayed in the ERP effects. Since the Verification Model hypothesizes that only a single process is involved for both the associative-dominant and category-dominant lists, differing only in the size of the SDS, one would expect that the ERPs would similarly differ only in degree. As long as the categorical stimulus pairs are high-typicality, as in the present experiment, we can assume that related targets should generally be a part of the SDS.

Given these assumptions, the one-process model would predict qualitatively similar ERP patterns between the two conditions. For related targets, the ERPs should reflect the search through the SDS, with a longer or more intense search for the category-dominant list. The ODS would generally not be involved in either condition. For unrelated targets, the ERP should again reflect a longer search through the SDS for the category-dominant condition but also a search through the ODS that is equivalent in the two conditions. Thus, there should be a main effect for condition (search time through the SDS) and there should be a main effect for relatedness (accessing of the ODS).

The two-process model would predict qualitatively different ERP patterns between the two conditions. One might expect one relatedness effect to be visible in the categorical-dominant condition (the controlled semantic search) and a different relatedness effect to be visible in the associative-dominant condition (the controlled orthographic search). Both conditions would then default to equivalent automatic processes if the target was not part of the search set.

These two models then lead into different predictions for the ERP components. To the extent that the N170 reflects activity at the orthographic level of analysis, the one-process model might predict a main effect of relatedness reflecting accessing of the ODS whereas the two-process model might predict an attentionally enhanced relatedness effect in the associative condition. To the extent that the N400 reflects activity at the semantic level of analysis, the one-process model might predict a main effect for condition (a longer search through the SDS) whereas the two-process model might predict an attentionally enhanced relatedness effect in the categorical condition.

One other issue of related interest is the N300. If it does indeed reflect behavioral inhibition rather than associative relatedness, as hypothesized, then it should display a relatedness effect only in the category-dominant condition, paralleling the behavioral effects. If it was actually due to a confound with association strength in the Franklin et al (2007) study then the N300 effect should either be stronger in the association-dominant condition (if reflecting a strategic process) or for the associative pairs regardless of condition (if reflecting stimulus properties).

## 2 Methods

### 2.1 Participants-

Seventy-nine University of Kansas undergraduates participated in this experiment for class credit. Due to computer crashes during data collection three subjects were lost and five were omitted for low accuracy (participants were required to have an accuracy of at least 60%). Twelve subjects were dropped for excessive artifacts (for criteria see section 2.7), leaving 59 participants in the final analysis (11 male in the category-dominant condition and 17 male in the associative-dominant condition, average age 19.5 years). All subjects were right-handed, native-English speakers, who had normal or corrected-to-normal vision, no history of neurological trauma or disease, were not taking any psychoactive medications and had never been diagnosed with any attention-related disorders such as attention deficit hyperactivity disorder (ADHD).

### 2.2 Research Design-

This experiment was based on Experiment Five of Becker's 1980 study, with the changes of more stimuli, the addition of a category-dominant list, and the use of low-typicality filler category pairs to enhance list effects in the category-dominant list. Trials consisted of the presentation of a prime word followed by a target letter-string with a long SOA of 1050 ms. The task was to judge the target as either a word or a non-word (binary lexical decision). The critical stimuli were highly associated related pairs, high-typicality categorically related pairs, and their matched sets of unrelated and neutral primed pairs. In addition, there were non-word targets and there were filler pairs to establish the appropriate dominance of the two lists. These conditions were randomized in three different lists. This was a between-subjects design; the participants viewed either the category-dominant or associative-dominant list.

A mixed factorial design was used with one between-factor of List-Type (associative-dominant vs. category-dominant) and two within-factors: Relationship Type (Associated pairs vs. Categorical pairs) X Prime Type (related, neutral, and unrelated stimulus pairs).

**2.3 Stimuli-**

The 63 highly-associated pairs (e.g., KNIGHT-ARMOR) association strengths were no lower than .2 (.3 for critical pairs) according to the University of South Florida free association norms, and were divided into three sets of 21 each (Nelson, McEvoy, & Schreiber, 1982). This included a set of related pairs, a set of unrelated pairs, and a set of neutral pairs (the prime words were replaced by a neutral prime of "XXXXX"). All possible permutations of these three sets were used as counterbalances across subjects. Across the participants, counterbalancing was used to ensure that every word was used equally often in each priming condition across the experiment.

For the categorical stimuli, 63 category names (e.g., FURNITURE, CLOTHING) were selected from an updated and expanded version of the Battig and Montague (1969) normed list (Van Overschelde, Rawson, & Dunlosky, 2004) as well as McEvoy and Nelson (1982) instance norms. The primes are super-ordinate category names that can be represented by a single word. For each of these categories, a high-typicality exemplar was chosen as a target (e.g., RODENT-RAT). One third of these pairs were used as related pairs, one third were used as neutral pairs, and one third were used as unrelated pairs (replacing the prime with a different category name). Each category prime only occurred once.

As determined from the Nelson norms (Nelson, McEvoy, & Schreiber, 1982), the mean prime-to-target associative strengths for the critical pairs were .48859 for the associated pairs and .1381 for the high-typicality category pairs. The mean prime-to-target associative strengths for the filler pairs were .3883 for the associated pairs and .0233 for the category pairs.

Three stimulus lists were constructed, such that across the three lists each highly associated pair and each category was presented once in each of the three priming conditions. Thus, “day-night” might appear in one list as a related pair: “day-night”, in the second list as an unrelated pair: “day-uncle”, in the third list as a neutral pair: “XXXXX-night”.

In addition to these critical pairs, 42 additional highly associated filler pairs were generated for the associative-dominant list and 42 low-typicality category (e.g., CLOTHES-TIE) pairs for the category-dominant list. Because the 63 highly-associated pairs and 63 category pairs described above (the critical pairs) were seen in both lists, the inclusion of these filler pairs is what made these lists either category-dominant or associative-dominant. As previously stated, the reason these filler pairs are low-typicality exemplars is because they help to distinguish the category-dominant list from the associative-dominant list. There were also 42 words that were used as neutral fillers (using "XXXXX" as the prime) for each list. Finally, 63 non-word targets were paired with word primes and 42 non-words with neutral primes for each list.

The overall ratio of words to non-words was 3:1 and the proportion of the word stimuli was as follows: related .27, unrelated .13, and neutral .27. The RP was .44 and the NWR was .60. The critical pairs from each list were matched on several different word parameters including word length, frequency (Kucera & Francis, 1967), lexical decision reaction time (Balota et al., 2007) imagery, concreteness, and orthographic neighborhood (Wilson, 1988). The relationship measures included latent semantic analysis (Landauer & Dumais, 1997) and prime-target association strengths (Nelson, McEvoy, & Schreiber, 1982). The filler pairs from each list were matched with each other on all the same parameters.

The orthographic neighborhood, concreteness and imagery ratings were found using the MRC Psycholinguistic Database (Wilson, 1988). The orthographic neighborhood ratings of the highly-associated and high-typicality category critical pairs were not significantly different: $T_{WJt}/c(1,99) = .118$, ($p$=.73). The orthographic neighborhood ratings of the associated and low-typicality filler pairs were not significantly different: $T_{WJt}/c(1,60) = .1077$, ($p$=.74). The concreteness ratings of the highly-associated and high-typicality category critical pairs were not significantly different: $T_{WJt}/c(1,94) = 2.6134$, ($p$ =.11). The concreteness ratings of the associated and low-typicality filler pairs were not significantly different: $T_{WJt}/c(1,65) = 3.1563$, ($p$ =.079). The imagery ratings of the highly-associated and high-typicality category critical pairs were not significantly different: $T_{WJt}/c(1,97) = 1.6661$, ($p$=.2). The imagery ratings of the associated and low-typicality filler pairs were not significantly different: $T_{WJt}/c(1,65) = .8816$, ($p$=.35).

The critical and filler stimulus pairs were also equated with respect to word length, frequency, lexical decision reaction time (LDRT). The information was gathered from the English lexicon project (ELP) website at Washington University in St. Louis (Balota et al., 2007). The word length ratings of the highly-associated and high-typicality category critical pairs were not significantly different: $T_{WJt}/c(1,89) = .0173$, ($p$=.9). The word length ratings of the associated and low-typicality filler pairs were not significantly different: $T_{WJt}/c(1,65) = .0798$, ($p$=.78). The frequency ratings of the critical pairs were not significantly different: $T_{WJt}/c(1,99) = .2754$, ($p$=.6). The frequency ratings of the associated and low-typicality filler pairs were not significantly different: $T_{WJt}/c(1,63) = .8908$, ($p$=.35). The LDRT ratings of the critical pairs were not significantly different: $T_{WJt}/c(1,99) = .9502$, ($p$=.33). The LDRT ratings of the filler pairs were not significantly different: $T_{WJt}/c(1,65) = .8383$, ($p$=.36).

**2.4 EEG Recording-**

Electrical potentials were recorded at a 250 Hz sampling rate using a high–density, 129-channel electrode net (Electrical Geodesics, Inc). Electrode impedance was measured and kept below 50 kilohms, per manufacturer guidelines for this particular ERP system. ERP data was recorded using Net Station software (version 4.1). A .1 to 100 Hz band pass analog filter was applied to the data as it was collected. The reference electrode during data collection was Cz.

**2.5 Procedure-**

When participants arrived, they were given an informed consent form to read and sign as well as a copy for themselves and were told that they had the right to terminate participation at any time. After the net was applied, participants were seated in a sound-attenuated room. The subjects were then instructed to place their chin in a chin rest that held their head steady 41 centimeters from the PC monitor and a four-button keypad recorded their responses. They were given verbal instructions to keep their movement to a minimum while the experiment was running. Participants were also instructed that they had to stay above 60% accuracy or they would not be allowed to continue the experiment. They were informed of their accuracy every 16 trials. The subjects were instructed to press the first button with their index finger if the target was a word and to press the second button with their middle finger if the target was not a word the right hand counterbalance and vice versa for the left hand counterbalance. Stimuli were presented using E-prime 1.2 (Schneider, Eschman, & Zuccolotto, 2002) on a Dell Dimension 8300 PC.

Each trial began with a fixation in the form of a dot in the middle of the screen. The SOA was 1050 ms. Primes were displayed in uppercase letters for 750 ms slightly above the fixation. The visual angle of the stimuli was 22.4 degrees. Following an inter-stimulus interval (ISI) of 300 ms, an uppercase target letter-string was presented slightly below the fixation and terminated after the subject's response in the lexical decision task. The maximum amount of time allotted for the participant's response was 1000 ms and the inter-trial interval (ITI) was 1000 ms. As well, 20 practice trials consisting of words not used in the experiment itself preceded the experimental presentation.

There were three lists in the experiment with 105 word pairs in each list. The participants saw a total of 315 word pairs during the experiment. Between each list, research assistants checked on participants and allowed them time to rest and move around before the next list began. During the break, channels that had dried out during the list were re-wetted. When the experiment ended participants were debriefed and given an opportunity to ask questions about the study.

**2.6 Behavioral Analyses-**

Reaction times for correct trials that were greater than 100 ms were included in the reaction time analysis, as reaction times lower than this indicated that the participant did not have time to properly process the word pairs. Analyses for reaction times were conducted on the median reaction time scores for each cell for each participant, and analysis of accuracy was conducted on the accuracy score for each participant.

**2.7 ERP Data Analysis-**

The data were filtered using a 30 Hz lowpass filter and were then segmented 200 ms before the stimulus onset and 1000 ms after stimulus onset, retaining only trials with correct responses. A baseline correction of 200 ms epoch was applied before cue onset. Eye blinks were removed using an automated independent components analysis (ICA) routine developed by this lab (available for download at http://homepage.mac.com/jdien07/) using EEGLAB (Delorme and Makeig, 2004). Channels with readings greater than 200 μv, differential average amplitudes over 100 μv, and channels with zero variance were marked as bad. If a channel was marked bad in more than 20% of the trials, then it was marked as being bad across the entire session. If a trial contained more than 12 bad channels or had Electrooculography (EOG) activity in excess of 70 μv after the ICA procedure, the entire trial was thrown out. Data were reviewed using both automated and visual editing for artifacts. Subjects that had less than 15 good trials retained in a single condition were also excluded from the analysis. After artifact detection, bad channels were replaced by means of a routine that utilizes the information from the surrounding channels to interpolate the missing data. All data were then re-referenced to an average reference (Bertrand, Perrin, & Pernier, 1985) (Dien, 1998a) using the PARE correction (Junghöfer, Elbert, Tucker, D. M., & Braun, 1999) to correct for the lack of sampling sites on the bottom of the head. The files were then both individually and grand averaged.

A conventional windowed analysis was conducted by selecting the typical index sites reported in previous studies and the surrounding electrodes. The six electrodes surrounding Pz were chosen as regions of interest with respect to the N400 (channels 54, 55, 61, 62, 68, 79, and 80). The N300 electrodes correspond to the area surrounding Fz (channels 5, 6, 11, and 12) (Franklin et al., 2007). The N170 electrodes surround the area including and just posterior to T5 (57, 58, 63, 64, 65, 69, 70) (Maurer, Brandeis, & McCandliss, 2005). The time windows used in the ERP analysis were 150-250 ms, 250–700 ms and 350-450 ms for the N170, N300 and N400 respectively.

**2.8 PCA ERP Analysis-**

As the grand averaged ERP data is sometimes difficult to interpret due to the overlapping nature of some of the ERP components, a temporo-spatial (Spencer, Dien, & Donchin, 1999) (Dien, Spencer, & Donchin, 2003) principal components analysis (PCA) was performed using the Matlab ERP PCA Toolbox 1.093 (http://homepage.mac.com/jdien07/). The initial temporal PCA variables were voltage readings at each of 300 time points (50 pre-stimulus and 250 post-stimulus). Recordings from 129 electrodes for each of the 10 conditions for each of 59 participants resulted in 76,110 observations. The relational matrix was the covariance matrix. Promax rotation was used (Dien, 1998b) (Dien, Beal, & Berg, 2005), with a Kaiser correction for the Varimax portion of the procedure (Dien, Beal, & Berg, 2005). A spatial Infomax PCA was then performed on each temporal factor (Dien, Khoe, & Mangun, 2007). The factor scores for the channels were the variables and the conditions x participants were the observations. Finally, the portion of the grand average accounted for by each factor was reconstructed for interpretation and analysis (Dien, Tucker, Potts, & Hartry-Speiser, 1997).

**2.9 ANOVA-**

Robust statistics were used instead of ANOVA because ERP data violates many of the assumptions of ANOVA (Keselman, Wilcox, & Lix, 2003) (Dien, Franklin, & May, 2006). To analyze the inferential statistics, Keselman's SAS/IML code for conducting robust statistical tests (http://www.umanitoba.ca/faculties/arts/psychology/) was run in Matlab (http://www.people.ku.edu/~jdien/downloads). A 10% symmetrical trim rule was used to remove outliers. A bootstrapping routine set at 50,000 simulations was used to avoid assuming a normal distribution of the ERP data and the seed for number generation was set at 1000. Additionally, this strategy for analysis uses approximate degrees of freedom to avoid making an assumption of homogeneity of variances and covariances. Information regarding these data analysis techniques is readily available (Wilcox, 2001).

**3 Results**

**3.1 Behavioral-**

A main effect of stimulus type was found in the associative-dominant condition, $T_{WJt}/c$ (1,24) = 7.3007 ($p$=0.019), such that participants showed faster reaction times to the associated pairs (trimmed mean of 532.73 ms) compared to the category pairs (trimmed mean of 543.15 ms). A main effect of relatedness was found in the associative-dominant condition, $T_{WJt}/c$ (2,21.333) = 10.3375 ($p$=0.0019), such that participants were slowest to respond to unrelated pairs (trimmed mean of 551.21 ms) and fastest to respond to related pairs (trimmed mean of 518.71 ms). There was not a significant interaction between stimulus type and relatedness in the associative-dominant condition, $T_{WJt}/c$ (2,21.333)=1.8597 ($p$=0.18). Priming was found for both the category and associated pairs in the associative-dominant condition.

The main effect of stimulus type was not significant in the category-dominant condition, $T_{WJt}/c$ (1,23) = .1937 ($p$=0.66). A main effect of relatedness was found in the category-dominant condition, $T_{WJt}/c$ (2,20) = 16.1675 ($p$=0.00012), such that participants were fastest to respond to related trials (trimmed mean of 531.97 ms) and slowest to respond to the neutral pairs (trimmed mean of 566.29 ms). There was not a significant interaction between stimulus type and relatedness in the category-dominant condition, $T_{WJt}/c$ (2,20)= .2240 ($p$=.8). Priming was found for both the category and associated pairs in the category-dominant condition.

A significant interaction was found between list and relatedness for the filler pairs, $T_{WJt}/c$ (1,43.3692) 58.4977 ($p$<0.0001). The neutral versus related contrast for the associated list yielded a significant result $T_{WJt}/c$ (1,24)=59.1098 ($p$= $p$<0.0001), such that participants were fastest to respond to related trials (trimmed mean of 515.6 ms) and slowest to respond to the neutral pairs (trimmed mean of 573.66 ms). The neutral versus related contrast for the category list yielded a significant result $T_{WJt}/c$

(1,23)=5.8887 ($p$= $p$=.023), such that participants were slowest to respond to related trials (trimmed mean of 572.46 ms) and fastest to respond to the neutral pairs (trimmed mean of 559.17 ms).

*Figure 1.* Trimmed mean reaction times (ms) for the associative-dominant condition.

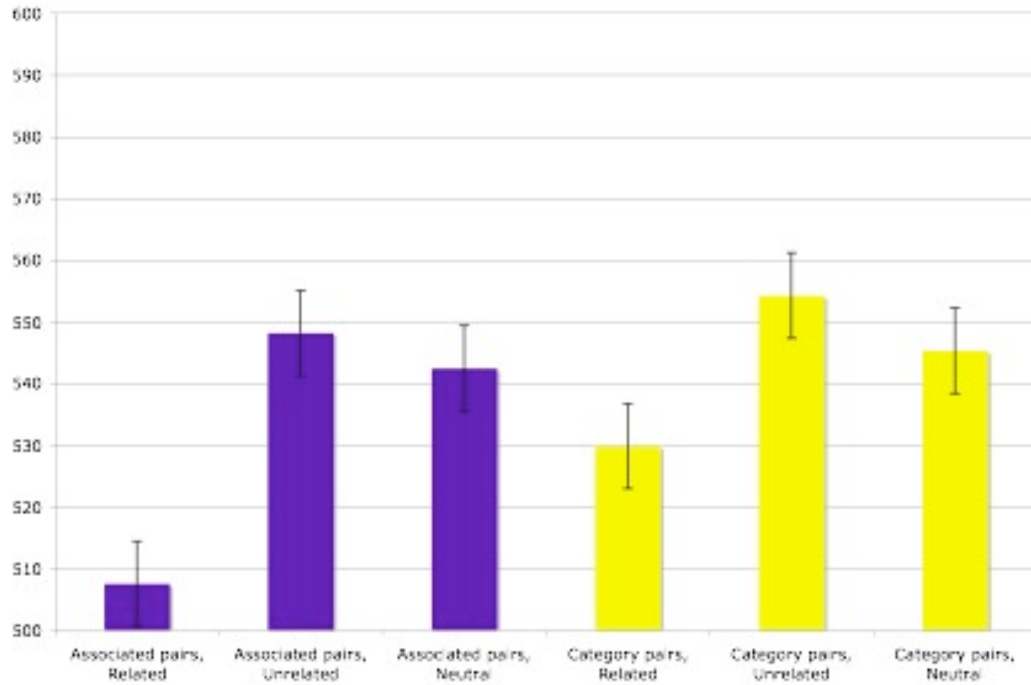


*Figure 2.* Trimmed mean reaction times (ms) for the category-dominant condition.

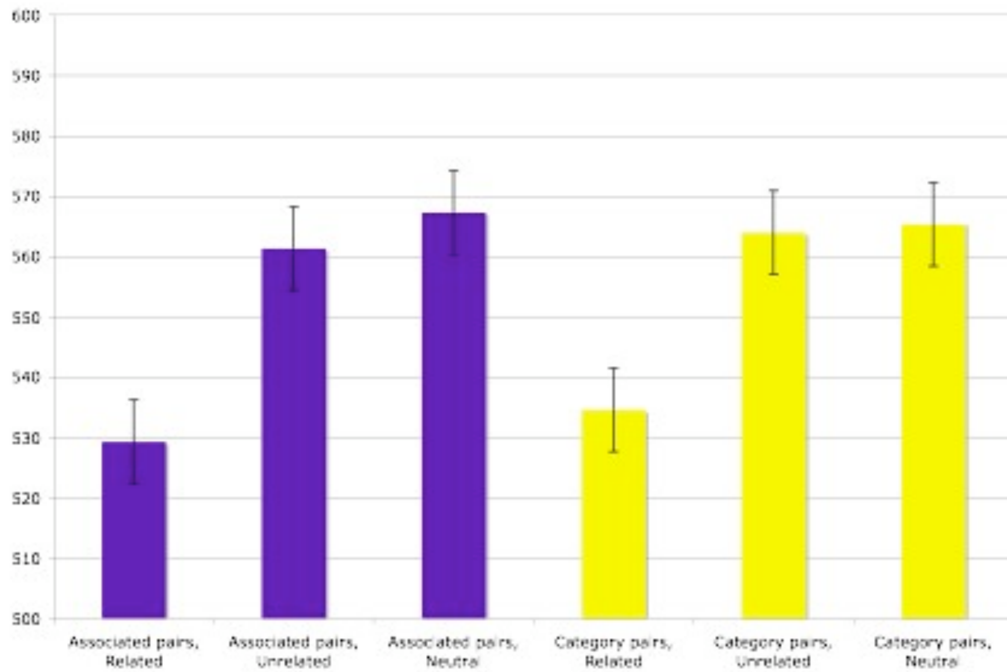
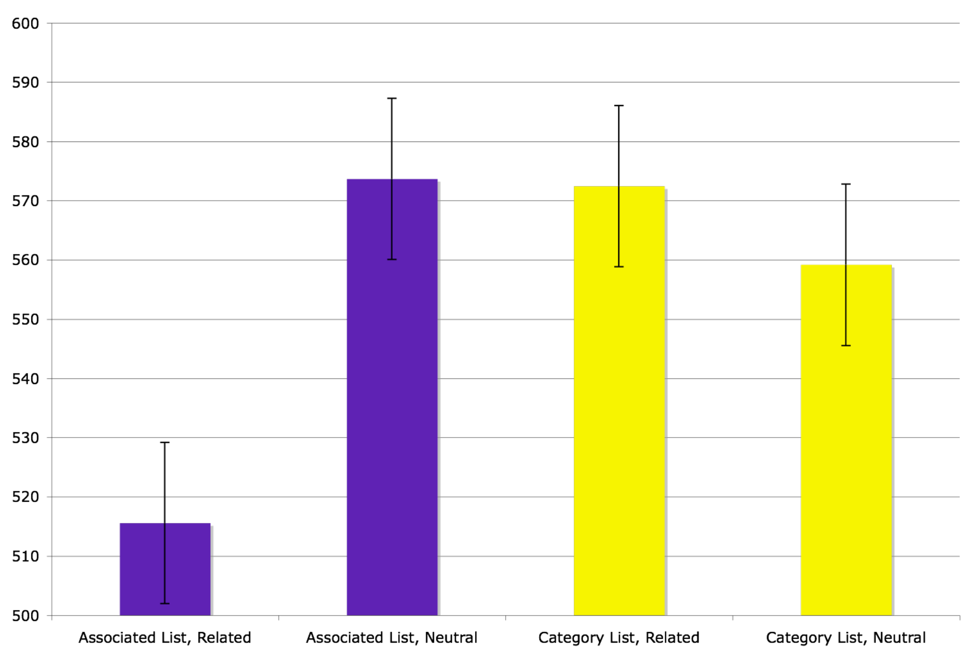



*Figure 3.* Trimmed mean reaction times (ms) for the filler pairs.



Trimmed arithmetic means of the participants' mean accuracy scores for the critical pairs conducted. There was no significant difference found between groups, $T_{WJt}/c$ (1,41) = 0.3849 ($p$=0.54)). There was no main effect of stimulus type in the associative-dominant condition, $T_{WJt}/c$ (1,24) = .4389 ($p$=0.52). A main effect of relatedness was found in the associative-dominant condition, $T_{WJt}/c$ (2,21.333) = 15.7883 ($p$=0.00012), such that participants were more accurate when responding to related trials (trimmed means of 99% associated pairs, 98% category pairs) than the neutral pairs (trimmed means of 95% associated pairs, 94% category pairs) and unrelated pairs (trimmed means of 96% associated pairs, 95% category pairs). There was not a significant interaction between stimulus type and relatedness in the associative-dominant condition, $T_{WJt}/c$ (2,21.333)=.0722 ($p$=0.93).

The main effect of stimulus type was not significant in the category-dominant condition, $T_{WJt}/c$ (1,23) = .7184 ($p$=0.4). A main effect of relatedness was found in the category-dominant condition, $T_{WJt}/c$ (2,20) = 6.0522 ($p$=0.0085), such that participants were more accurate when responding to related trials (trimmed means of 99 associated pairs, 98 category pairs) than the neutral pairs (trimmed means of 96 associated pairs, 97 category pairs) and unrelated pairs (trimmed means of 97 associated pairs, 96 category pairs). There was not a significant interaction between stimulus type and relatedness in the category-dominant condition, $T_{WJt}/c$ (2,20)= .4805 ($p$=.62).

**3.2 Windowed Analysis-**

After visual inspection of the data, the three predicted components were located: the N400, the N300, and the N170. These components displayed experimental effects only in the associative-dominant condition. The category-dominant condition did not yield any significant results. Grand average waveforms of the regions of interest are provided in Figures 4-7.

**N400**- (Figure 8) (350-450 ms) - There was a significant interaction between stimulus type and relatedness: $T_{WJt}/c$ (2,21.333)=4.2042 (*p*= 0.029) at this electrode site. There was a main effect of relatedness in the associative-dominant condition (trimmed means of 3.96 μv related pairs, 2.69 μv unrelated pairs, 3.76 μv neutral pairs): $T_{WJt}/c$ (2,21.333)=8.8022 (*p*= 0.0057) at this electrode site with the waveform being most relatively negative to unrelated pairs and most positive to related pairs. The relatedness effect for the associated pairs in the associative-dominant condition was significant (trimmed means of 4.53 μv related pairs, 2.62 μv unrelated pairs, 3.78 μv neutral pairs): $T_{WJt}/c$ (2,21.333)=29.2307 (*p*= 0.0003). There was not a main effect of relatedness for the category pairs in the associative-dominant condition: $T_{WJt}/c$ (2,21.333)=3.0106 (p= 0.073). The main effect of stimulus type (category/associate) in the associative-dominant condition was nearly significant: $T_{WJt}/c$ (1,24)=3.18 (*p*= 0.077) at this electrode site with the waveform being most relatively negative to category pairs.

**N300**- (Figure 9) (250-700 ms) - There was a nearly significant interaction between stimulus type and relatedness: $T_{WJt}/c$ (2,21.333)=2.5273 (*p*= 0.1) at this electrode site. There was a main effect of relatedness in the associative-dominant condition (trimmed means of .97 μv related pairs, .27 μv unrelated pairs, .47 μv neutral pairs): $T_{WJt}/c$ (2,21.333)=7.4459 (*p*= 0.006) at this electrode site with the waveform being most relatively negative to unrelated pairs and most positive to related pairs. The relatedness effect for the associated pairs in the associative-dominant condition was significant (trimmed means of 1.27 μv related pairs, 0.06 μv unrelated pairs, 0.55 μv neutral pairs): Type, $T_{WJt}/c$ (2,21.333)=9.8536 (*p*= 0.00088). There was not a relatedness effect for the category pairs in the associative-dominant condition: Task, $T_{WJt}/c$ (2,21.333)= 0.5279 (*p*= 0.59). There was not a relatedness effect for the category filler pairs in the category-dominant condition: Task, $T_{WJt}/c$ (2,23)= 2.1972 (*p*= 0.15). The main effect of stimulus type (category/associate) in the associative-dominant condition was not significant: $T_{WJt}/c$ (1,24)=0.1623 (*p*= 0.69) at this electrode site with the waveform being most relatively negative to category pairs.

**N170**- (Figure 10) There was a nearly significant interaction between stimulus type and relatedness: $T_{WJt}/c$ (1,24)=2.8681 (*p*= 0.1) at this electrode site. There was not a main effect of relatedness in the associative-dominant condition: $T_{WJt}/c$ (1,24)=.1257 (*p*= 0.72) at this electrode site. The main effect of stimulus type (category/associate) in the associative-dominant condition was not significant: $T_{WJt}/c$ (1,24)=0.0623 (*p*= 0.8) at this electrode site.

*Figure 4.* Grand average waveforms for the associated pairs in the associative-dominant condition display the anterior N300 effect, the posterior N400 effect and the left-posterior N170 effect.

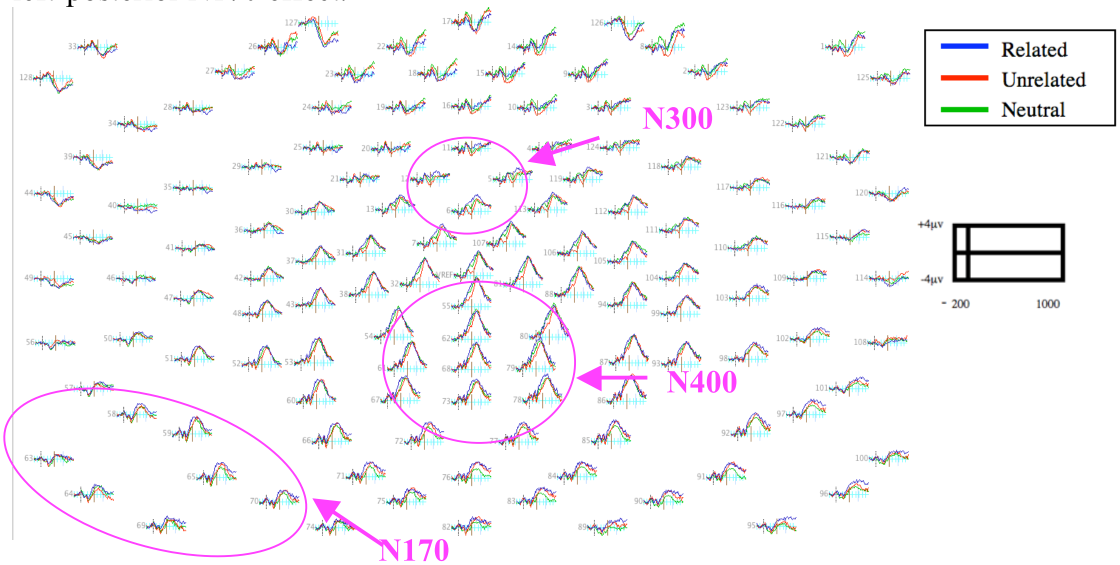



*Figure 5.* Grand average waveforms for the category pairs in the associative-dominant condition do not display significant components.

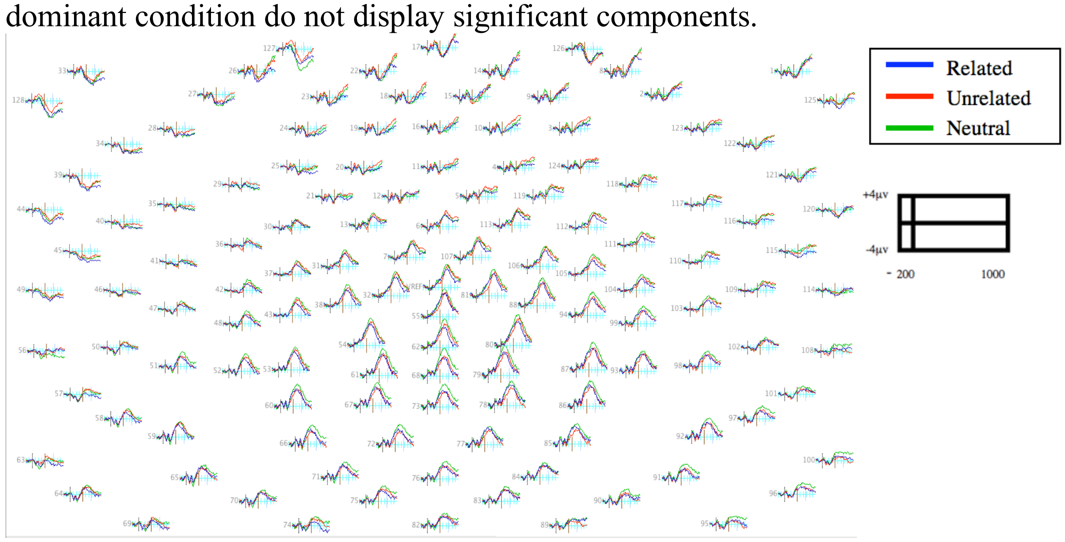


*Figure 6.* Grand average waveforms for the associated pairs in the category-dominant condition do not display significant components.

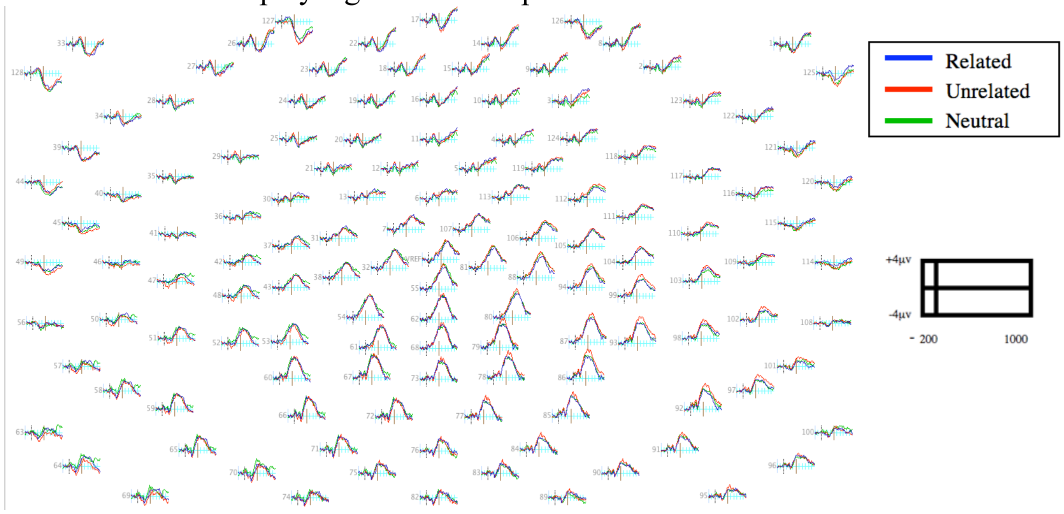



*Figure 7.* Grand average waveforms for the category pairs in the category-dominant condition do not display significant components.

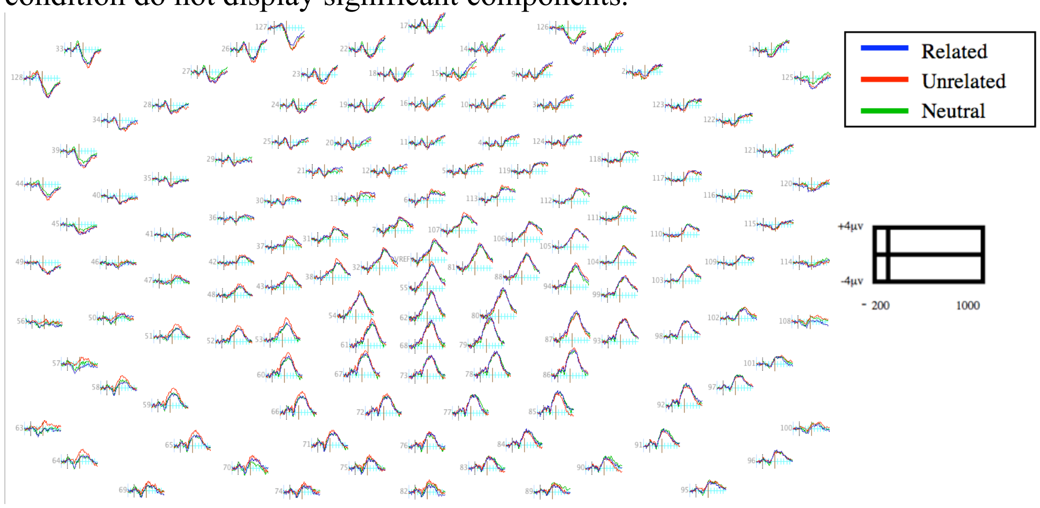


*Figure 8.* Grand averaged waveform of the associated pairs in the associative-dominant condition at Pz displaying the N400.

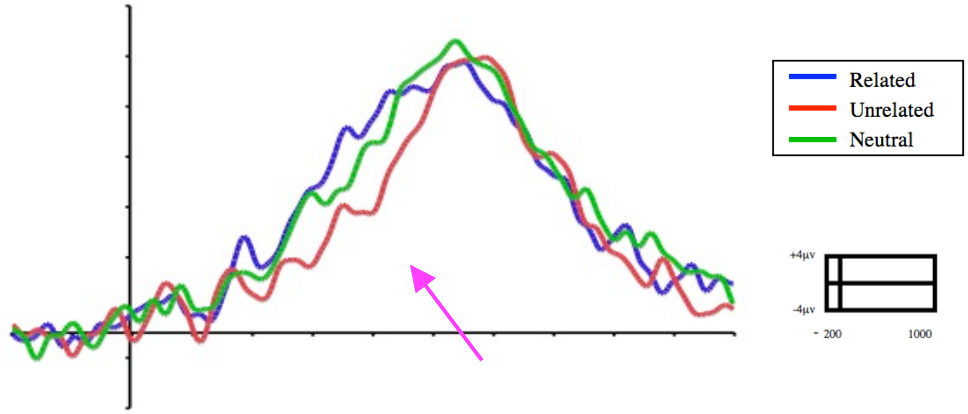



*Figure 9.* Grand averaged waveform of the associated pairs in the associative-dominant condition slightly posterior to Fz displaying the N300.

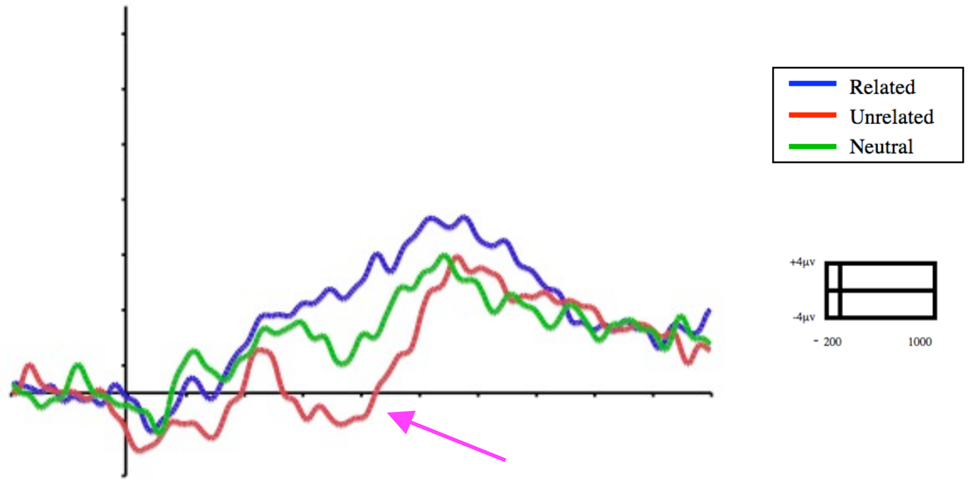
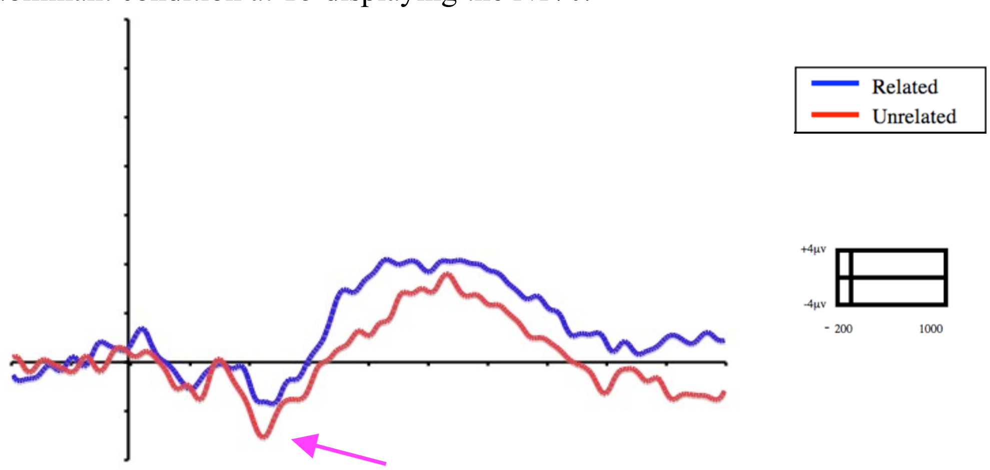



*Figure 10.* Grand averaged waveform of the associated pairs in the associative-dominant condition at T5 displaying the N170.



**3.3 PCA-**A temporo-spatial PCA was conducted on the averaged waveforms for both the associated and category-dominant conditions to clarify scalp topographies of the observed ERP components. Based on a scree test for the associative-dominant condition, there were 9 factors retained which accounted for 91.72% of the total variance in the temporal PCA and 7 factors which accounted for 86.1% of the variance in the spatial PCA. Of the 63 retained factors, 3 factors, which appeared to describe activity of interest based on *a priori* information about the ERP components of interest, were analyzed. Based on the observed scalp topographies, these factors described an anterior-central midline component peaking around 350 ms corresponding to the N300, a posterior midline component peaking at around 350 ms corresponding to the N400, and a posterior left lateralized component peaking at around 150 ms corresponding to the N170.

Based on a scree test for the category-dominant condition, there were 9 factors retained which accounted for 91.2% of the total variance in the temporal PCA and 8 factors which accounted for 89.28% of the variance in the spatial PCA. There were no significant factors of interest among the 72 retained PCA factors for the category-dominant condition.

**N400 Factor**- (Figure 11) This factor was characterized by a negativity peaking at around 350 ms for the associated pairs in the associative-dominant condition. There was a nearly significant interaction between stimulus type and relatedness: $T_{WJt}/c$ (2,21.333)=2.8314 ($p$= 0.080) at this electrode site. There was a main effect of relatedness in the associative-dominant condition (trimmed means of

1.02 µv related pairs, .64 µv unrelated pairs, .95 µv neutral pairs): $T_{WJt}/c$ (2,21.333)=12.2479 (*p*= 0.00072) at this electrode site with the waveform being most relatively negative to unrelated pairs and most positive to related pairs. The main effect of stimulus type (category/associate) in the associative-dominant condition was nearly significant: $T_{WJt}/c$ (1,24)=2.9091 (*p*= 0.085) at this electrode site with the waveform being most relatively negative to category pairs. The greatest peak was over Pz (channel 62). Source localization of the factor accounting for the N400 yielded a temporo-parietal junction location [-43.6 -54.2 27.5] with a solution that accounted for 92.7% of the variance.

**N300 Factor**- (Figure 12) This factor was characterized by a negativity peaking at around 350 ms for the unrelated pairs in the associative-dominant condition. There was a nearly significant interaction between stimulus type and relatedness: $T_{WJt}/c$ (2,21.333)=2.3244 (*p*= 0.11) at this electrode site. There was not a main effect of relatedness in the associative-dominant condition: $T_{WJt}/c$ (2,21.333)=1.5022 (*p*= 0.24) at this electrode site. The main effect of stimulus type (category/associate) in the associative-dominant condition was nearly significant (trimmed means of -.35 for associate pairs and -.63 for category pairs): $T_{WJt}/c$ (1,24)=4.0098 (*p*= 0.052) at this electrode site with the waveform being most relatively negative to category pairs with the greatest peak at Fz. Source localization of the factor accounting for the N300 yielded a posterior cingulate location [19.7 -28.4 13.8] with a solution that accounted for 98.7% of the variance.

**N170 Factor-** (Figure 13) This factor was characterized by a negativity with its greatest peak laterally to the right and slightly posterior to T5 (channel 65) at around 200 ms for the associated pairs in the associative-dominant condition. There was not an interaction between stimulus type and relatedness: $T_{WJt}/c$ (2,21.333)=1.725 (*p*= 0.20) at this electrode site. Source localization of the factor accounting for the N170 yielded a left fusiform gyrus location [45.1 -59.6 -13.2] with a solution that accounted for 95.6% of the variance.

*Figure 11.* PCA waveforms of factor 40 (corresponding to the N400) for the associated pairs in the associative-dominant condition.

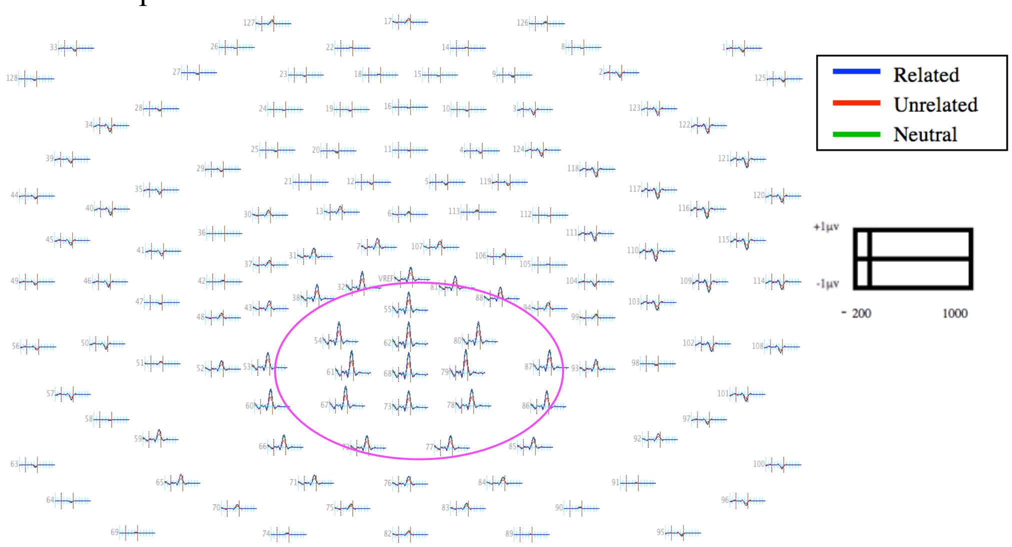
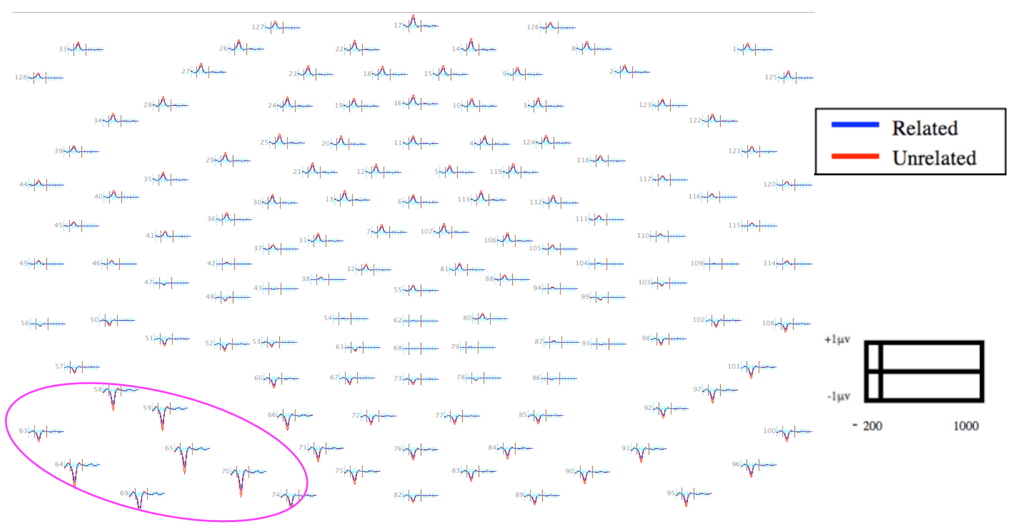


*Figure 12.* PCA waveforms of factor 37 (corresponding to the N300) for the associated pairs in the associative-dominant condition.


*Figure 13.* PCA waveforms of factor 33 (corresponding to the N170) for the associated pairs in the associative-dominant condition.



## 4. Discussion-

### 4.1 Behavioral Results –

We expected that we would obtain the same pattern of effects seen in Becker (1980), namely significant facilitation effects for the related pairs and no significant inhibition effects for the unrelated pairs in the associative-dominant list. These effects were observed in the behavioral data. The results of the category-dominant condition, which Becker (1980) did not carryout, were not as expected. Significant facilitation effects for both types of related pairs were seen in the category-dominant condition, and no inhibition effects were seen for either type. One possibility is that the nature of the category-dominant list as being made up of primarily category pairs was not apparent to the participants. It seems that the low-typicality filler category pairs were so distantly related that they were, as a result, processed as unrelated pairs and did in fact show an inhibition effect. This is revealed by the significantly slower reaction time to the low-typicality related filler pairs compared to the neutral pairs. As a result of this problem, the related pairs are in effect, equally likely to be associated or categorically related because it was the addition of the filler pairs that made the list category-dominant. Alternatively it may be that one does not get the inhibitory effect with such a list even if the subjects do notice all the categorically related pairs. Becker (1980) did not include a category-dominant condition which included associative pairs in this series of experiments. The only condition in which he obtained the inhibition effect was when he used a list made up of solely category-related pairs. Further investigation is needed to determine whether category-dominance of a list is sufficient to evoke inhibition to unrelated pairs.

**4.2 ERP Results –**

**4.2.1 Associative-dominant List –**

An effect in a component appeared in the associative-dominant list between 350-450 ms over the posterior midline, which was more negative for unrelated pairs than for related pairs. The latency, topography and polarity of this component suggest that this is the classic N400. This effect was not seen in the category-dominant condition. A prevalent assumption describes the N400 effect as reflecting semantic incongruity. There has been some argument as to whether or not this component reflects controlled or automatic semantic integration. Deacon et al. (1999) have argued that the N400 effect can reflect both ASA which can last up to two seconds. According to this assumption the N400 should be present in both the category-dominant and associative-dominant list in our study, which was clearly not the case. Others have proposed that the N400 effect reflects ASA and expectancy (Franklin, Dien, Neely, Huber, & Waterson, 2007). The N400 effect has also been shown to reflect semantic matching (Chwillia et al., 1998). If the N400 reflected expectancy processes, we again would expect to find it in both the associated-dominant and category dominant lists, which we did not. It is clear from the wide variety of studies and paradigms that have found the N400 effect that this component is not a reflection of one simple strategy of word recognition in semantic priming. Holcomb (1993) provides good evidence that this component reflects a post-lexical process of controlled integration. Franklin and colleagues (2007) have suggested this post-lexical process is similar to the context updating theory of the P300. This alternative explanation as to why the N400 effect was seen in the associative-dominant list and not the category-dominant list, which describes the N400 in terms of semantic context updating, will be discussed in further detail in section 4.2.2.

There are five main criteria one must consider when identifying an ERP component (Table 1). The component seen in the associative-dominant list had topography, latency and polarity consistent with the characteristics of the N400. There is also a reasonable explanation as to why this component was observed in this study. There is however, a piece of conflicting information that suggests that the N400 effect observed in the associative-dominant condition may actually be the P300, and that is the source of this component. The P300 has sources in the temporo-parietal junction (Dien, J., Spencer, K.M., Donchin, E., 2003) whereas the N400 is shown to emanate from the anterior temporal lobe (Rossell, Price, & Nobre, 2003) (Dien et al., Submitted). A source analysis suggested that the component observed in this study emanated from the temporo-parietal junction, consistent with the localization of the P300 component. It may be that the N400 effect was absent in both the associative-dominant and the category-dominant condition. The latency of the P300 can vary and the topography of the P300 and the N400 are fairly close to each other (the N400 is seen at the posterior midline and the P300 at the central midline on the scalp). There is not, however, an explanation as to why the P300 would be larger for related pairs than for unrelated pairs resulting in a relative negativity for the unrelated pairs. The P300 is larger for targets and it is also larger for rare stimuli. There doesn't seem to be any reason why the participants would perceive the related words as being either targets or rare compared to the category-dominant list (which did not show the effect). Indeed, if the category fillers were seen as unrelated, the related targets would be even rarer there and hence should generate an even stronger P300 effect. Because the cognitive aspects of the P300 explanation are unclear, the N400 account is favored in this situation, although further study is needed to determine if this is in fact the correct interpretation of the present data.

*Table 1.* Criteria used in component identification.

| Component | Topography | Latency | Polarity | Source | Cognitive Explanation |
|---|---|---|---|---|---|
| N400 | √ | √ | √ | | √ |
| P300 | | √ | | √ | |

It was also predicted that the N300 effect would reflect the inhibition effects to unrelated pairs in the category-dominant condition. The results of this study show this hypothesis was not entirely supported. The comparison of highly-associated related, unrelated and neutral pairs in the associative-dominant condition revealed a significant change in amplitude between 250-700 ms over mid-frontal sites, the component being more negative for the unrelated pairs. This effect appears to be the N300 and seems to be reflecting semantic activation rather than inhibition. The N300 analysis of the inhibition effect in the category-dominant condition among the filler pairs showed no significant effects. It has been suggested, but not clearly established, that this component may reflect categorical processing and/or semantic relatedness (Franklin et al., 2007). The study conducted by Franklin et al. (2007) found the N300 effect in symmetrical pairs at long SOAs. Though the symmetrical pairs shared more semantic overlap than backward and forward associatively related pairs, the set of stimuli was not solely made up of category pairs and thus, strong claims cannot be made about the N300 effect as an index of category processing. The mean association strength, according to the Nelson et al (1999) norms, of the symmetrical pairs was also significantly higher than the asymmetrical pairs (Franklin, Dien, Neely, Huber, & Waterson, 2007), which again suggests no conclusions can be confirmed about the N300 effect reflecting pure semantic similarity in this study. The hypothesis being investigated, that the N300 effect is an index of inhibition in the semantic memory network during the expectancy process, was also not supported. An alternative hypothesis is that this component may reflect the processing of highly associated pairs. This account is supported by the present data as there was a significant difference between the related, unrelated and neutral pairs in the associative-dominant condition, the related pairs being more positive than both the neutral and unrelated pairs.

The N170 effect was predicted to reflect the facilitation effects to related pairs in the associative-dominant condition due to the image of the expected word being held in the sensory set. Although visual inspection of the data did suggest a small effect might be present, there was not a significant N170 effect observed in the associative-dominant list. Despite the non-significant results, a source analysis conducted on this component shows that it emanates from the VWFA, which is consistent with previous research on the N170 (Brem et al., 2006) (Rossion et al., 2003).

**4.2.2 Category-dominant List –**

The absence of significant ERP results for the categorical condition is puzzling. The stimuli used in this study were quite complicated and the fact that this list was made up of primarily category pairs does not seem to have been made clear to the subjects. Participants did show facilitation for related pairs but did not show inhibition for unrelated pairs. Although these priming effects were smaller than the effects seen in the associated list, they were not significantly different. It may be that we just needed to choose higher-typicality exemplars to include as filler pairs. The inclusion of these higher typicality pairs may make the dominance of the category pairs clear to the participants and in turn give us more information about whether or not the N300 effects appear in response to the processes involved in categorical priming which lead to inhibition.

Although the N400 has become somewhat synonymous with semantic priming, this is not the first study to find priming effects in the absence of an N400 effect (Brown and Hagroot, 1993). This suggests that the N400 effect is controlled in nature. In fact, studies have shown that the N400 effect can reflect both ASA, expectancy and semantic matching processes (Franklin et al., 2007) (Deacon, Hewitt, Yang, & Nagata, 2000) (Rolke, Heil, Streb, & Hennighausen, 2001) (Chwilla et al., 1998). Franklin and colleagues (2007) suggested that the N400 might reflect semantic context updating, similar to the P300 context updating theory (Donchin & Coles, 1988). The N400, in this case, represents post-lexical updating of expectancies for the benefit of future trials. Because it does not directly reflect either ASA or the expectancy process, the absence of the N400 effect only indicates the absence of this semantic updating process and not the absence of these strategies. This theory can be used to explain the present data because in the case of the categorical list, it is apparent to the participant that multiple words can follow each prime and so the effort to update expectations is not made.

Alternatively, if the N400 effect does reflect semantic integration, the participants may have perceived the category-dominant list as being primarily unrelated and so for some reason they used expectancy but not integration. Rhodes and Donaldson (2008) investigated whether the N400 effect was larger for associative or semantic relationships, as it has already been revealed that these two relationships can produce very different results in priming studies. They employed a recognition memory task and used word pairs that were unrelated, associated but not semantically related, associated and semantically related, and semantically related but not associated. Participants were asked to read and remember word pairs presented in blocks of 16 pairs. The task was designed to ensure that the participants would process the meaning of the word pairs, which later aided recognition during the test phase. The N400 was much smaller for purely associated pairs when compared to unrelated pairs, and this was also the case for associated and semantically related pairs. The purely semantically related pairs did not show a significant difference in amplitude between related and unrelated pairs. In other words, the N400 effect can be seen when comparing associations vs. unrelated pairs, but is not seen when comparing purely semantically related pairs and unrelated pairs.

This is a very interesting finding for those investigating the nature of the N400 because it demonstrated that this component can distinguish between different types of relationships during semantic processing. The authors made the claim that the participants were engaged in conscious/controlled processing while performing this task because they were asked remember the word pairs. Because the N400 effect does not directly reflect ASA, this is a reasonable assumption. It is still unclear whether semantic and associated relationships can be distinguished by the appearance of the N400 in a strategic priming task however, the present study does provide data which suggests the N400 integration process is not applied to categorical relations.

Although the present study did not support the original assumptions with respect to the ERP effects, it does clearly show that these two types of relationships, associates and categories, are processed differently. Due to the lack of priming observed in the low-typicality filler pairs, it may be pertinent to replicate this experiment using filler category pairs with a slightly higher typicality rating. Making this change may result in the participants using the strategy initially predicted and consequently provide evidence that the N300 is an index of proactive expectancy inhibition effects. This unforeseen confound, however, did result in surprising and valuable data regarding the nature of the N400 effect. Additional investigation is needed in order to further support the hypothesis of the N400 effect as a refection of context updating.

**4.4 Applications of Research -**

There are many semantic priming studies conducted with Alzheimer's patients compared to normal controls using stimuli that were either associatively or semantically related. Associative priming was not disrupted in Alzheimer's patients, but priming of purely semantically related words was disrupted in both automatic and controlled conditions (Glosser & Friedman, 1991)(Glosser, Friedman, Grugan, Lee, & Grossman, 1998)(Vaidya, Gabrieli, Monti, Tinklenberg, & Yesavage, 1999). Additionally, Bell and Chenery (2001) found that Alzheimer's patients showed impaired inhibition effects of unrelated pairs but showed large facilitation effects to related pairs under strategic priming conditions. The semantic deficit hypothesis, as it is known, is thought to be a result of deterioration of the brain areas responsible for semantic memory. The alternative explanation that difficulty in semantic processing seen in Alzheimer's disease is due to deterioration of attention and retrieval, and not semantic memory, is still being investigated (Glosser & Friedman, 1991)(Glosser, Friedman, Grugan, Lee, & Grossman, 1998). Because categorical priming and inhibition effects were both disrupted in these patients, it seems that whatever strategy is used to process categorical information is markedly different than the strategy used in associative processing. If research shows that Alzheimer's patient's difficulty in semantic retrieval is due to attention deficits and not semantic processing deficits, the knowledge will have great implications in the understanding of this disease. In the future we may have reliable ERPs which are markers of these strategic processes of facilitation and inhibition due to expectancy. If this alternative explanation is correct, ERPs could possibly serve as an indicator in early diagnosis or progression of diseases like Alzheimer's.

**4.5 Conclusions -**

Unfortunately the results of this study did not fully support the original hypothesis, however, the data does demonstrate the difference between the two types of stimuli and also displays the advantage of using techniques like ERP to gain insight into processes which are not evident from accuracy and reaction time data alone. The analysis of reaction time data lead Becker to propose, though the Verification Model, that there was one process accounting for the associated facilitation effects and categorical inhibition effects. This was a reasonable theory at the time, however the list-wise approach to semantic priming has been largely abandoned in lieu of parallel processing models. The results of the present study have demonstrated that there are at least two distinct strategies being used when processing these two types of relationships during a lexical decision task. Though only a small number of predicted ERPs appeared in the data, it may still be possible to utilize ERPs as indicators of the different strategic processes in word recognition. The absence of the N400 effect in the category-dominant list demonstrates this quite nicely. The hypothesis that the N400 reflects, not ASA or semantic matching, but a post-lexical process in which participants update their semantic expectations

(Franklin, Dien, Neely, Huber, & Waterson, 2007) was supported by the data. This study also adds to the growing body of evidence that there are more ERPs that show influences of semantic processing other than just the typically reported N400. This adds to the argument that the specific cognitive processes underlying these components should be explored.

**References**

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., et al. (2007). The English Lexicon Project. *Behavior Research Methods*, *39*, 445-459.

Barrett, S. E. & Rugg, M. D. (1990). Event-related potentials and the semantic matching of pictures. *Brain and Cognition*, *14*, 201-212.

Becker, C. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition*, *8*(6), 493-512.

Becker, C. A. (1985). What do we really know about semantic context effects during reading? *Reading Research: Advances in Theory and Practice*, *5*, 125-166.

Bentin, S. (1987). Event-related potentials, semantic processing and expectancy factors in word recognition. *Brain and Language*, *31*, 308-327.

Bertrand, O., Perrin, F., & Pernier, J. (1985). A theoretical justification of the average reference in topographic evoked potential studies. *Electroencephalography and Clinicl Neurophysiology*, *62*, 462-464

Booth, D. D., Burman, J. R., Meyer, Z., Lei, B. L., Trommer, B. L., Davenport, N. D., et al. (2003). Neural development of selective attention and response inhibition. *Neuroimage*, *20*, 737-751.

Brem, S., Bucher, K., Halder, P., Summers, P., Dietrich, T., Martin, E., et al. (2006). Evidence for developmental changes in the visual word processing network beyond adolescence. *Neuroimage*, *29*(3), 822-837.

Brown, C. M. & Hagoort, P. (1993). The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience*, *5*(1), 34-44.

Cohen, L., Lehericy, S., Chochon, F., Lemer, C., Rivaud, S., & Dehaene, S. (2002). Language-specific tuning of visual cortex? Functional properties of the Visual Word Form Area. *Brain*, *125*(5), 1054-1069.

Chwilla, D. J., Hagoort, P., & Brown, C. M. (1998). The mechanism underlying backward priming in a lexical decision task: Spreading activation versus semantic matching. *The Quarterly Journal of Experimental Psychology*, *51A*(3), 531-560.

Deacon, D., Hewitt, S., Yang, C. M., & Nagata, M. (2000). Event-related potential indices of semantic priming using masked and unmasked words: Evidence that the N400 does not reflect a post-lexical process. *Cognitive Brain Research*, *9*, 137-146.

Dehaene, S., Le Clec'h, G., Poline, J. B., LeBihan, Cohen, L. (2005). The visual word form area. A prelexical representation of visual words in the fusiform gyrus. *Neuroreport*, *13*, 321-325.

Delorme, A. & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J Neuroscience Methods*, *134*(1), 9-21

Dien, J. (1998a). Issues in the application of the average reference: Review, critiques, and recommendations. *Behavioral Research Methods, Instruments and Computers*, *30*(1), 10.

Dien, J. (1998b). Addressing misallocation of variance in principal components analysis of event-related potentials. *Brain Topogr*, *11*(1), 43-55.

Dien, J., Beal, D. J., & Berg, P. (2005). Optimizing principal components analysis of event-related potentials: matrix type, factor loading weighting, extraction, and rotations. *Clin Neurophysiol*, *116*(8), 1808-1825.

Dien, J., Franklin, M., & May, C. (2006). Is "blank" a suitable neutral prime for event related potential experiments? *Brain and Language*, *97*, 97-101.

Dien, J., Khoe, W., & Mangun, G. R. (2007). Evaluation of PCA and ICA of simulated ERPs: Promax versus Infomax rotations. *Human Brain Mapping*, *28*(8), 742-763.

Dien, J., Spencer, K. M., & Donchin, E. (2003). Localization of the event-related potential novelty response as defined by principal components analysis. *Brain Res Cogn Brain Res*, *17*(3), 637-650.

Dien, J., Tucker, D. M., Potts, G., & Hartry-Speiser, A. (1997). Localization of auditory evoked potentials related to selective intermodal attention. *Journal of Cognitive Neuroscience*, *9*(6), 26.

Dien, J., Frishkoff, G. A., Cerbone, A., & Tucker, D. M. (2003). Parametric analysis of event related potentials in semantic comprehension: evidence for parallel brain mechanisms. *Cognitive Brain Research*, *15*, 137-153.

Dien, J., Michelson, C. A., & Franklin, M. S. (*Submitted*). Splitting the sentence N400 effect into two different ERP components and their source analyses.

Donchin, E. & Coles, M. G. H. (1988). Is the P300component a manifestation of context updating? *Behavioral and Brain Science*, *11*(3), 357-374.

Federmeier, K. D. & Kutas, M. (2003). Picture the difference: Electrophysiological investigations of picture processing in the cerebral hemispheres. *Neuropsychologia*, *40*, 737-747.

Federmeier, K.D. (2007). Thinking ahead: The role and roots of prediction in language comprehension. *Psychophysiology*, 44, 491-505.

Franklin, M. S., Dien, J., Neely, J. H., Huber, E., & Waterson, L. D. (2007). Semantic priming modulates the N400, N300, and N400RP. *Clinical Neurophysiology*, *118*, 1053-1068.

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *TRENDS in Cognitive Sciences*, *6*, 78-84.

Frishkoff, G. A. (2007). Hemispheric differences in strong versus weak semantic priming: Evidence from event related brain potentials. *Brain and Language*, *100*, 23-43.

Frishkoff, G. A., Tucker, D. M., Davel, C., & Scherg, M. (2004). Frontal and posterior sources of event-related potentials in semantic comprehension. *Cognitive Brain Research*, *20*, 329-354.

Glosser, G. & Friedman, R. B. (1991). Lexical but not semantic priming in Alzheimer's Disease. *Psychology and Aging*, *6*(4), 522-527.

Glosser, G., Friedman, R. B., Grugan, P. K., Lee, J. H., & Grossman, M. (1998). Lexical semantic and associative priming in Alzheimer's Disease. *Neuropsychology*, *12*(2), 218-224.

Holcomb, P. J. & Grainger, J. (2006). On the time course of visual word recognition: An event-related potential investigation using masked repetition priming. *Journal of Cognitive Neuroscience*, *18*(10), 1631-1643.

Junghöfer, M., Elbert, T., Tucker, D. M., & Braun, C. (1999). The polar average reference effect: A bias in estimating the head surface integral in EEG recording. *Clinical Neurophysiology*, *110*(6), 1149-1155.

Keselman, H. J., Wilcox, R. R., & Lix, L. M. (2003). A generally robust approach to hypothesis testing in independent and correlated group designs. *Psychophysiology*, *40*, 586-596.

Kiefer, M. (2001). Perceptual and semantic sources of category-specific effects: Event related potentials during picture and word priming. *Memory & Cognition*, *29*(1), 100-116.

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience*, *2*, 635-642.

Kreher, D. A., Holocomb, P. J., & Kuperberg, G. R. (2006). An electrophysiological investigation of indirect semantic priming. *Psychophysiology*, *43*, 550-563.

Kucera, H. & Francis, W. N. (1967). *Computational analysis of present-day American English*.

Kutas, M. & Hillyard, S. M. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, *207*, 203-205.

Kutas, M. & C.K., V. P. (1994). Psycholinguistics electrified: Event-related brain potential investigations. *Handbook of Psycholinguistics*.

Landauer, T. K. & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, *104*(2), 211-240.

Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *21*, 3-23.

Maurer, U., Brandeis, D., & McCandliss, B. D. (2005). Fast, visual specialization for reading in English revealed by the topography of the N170 ERP response. *Behavioral and Brain Functions,* 1-13.

McNamara, T. P. (2005). Semantic Priming: Perspectives from Memory and Word Recognition.

McPherson, W. B. & Holcomb, P. J. (1999). An electrophysiological investigation of semantic priming with pictures of real objects. *Psychophysiology*, *36*, 53-65.

Misra, M. & Holocomb, P. J. (2003). Event-related potential indices of masked repetition priming. *Psychophysiology*, *40*, 115-130.

Morton, J. (1964). A preliminary functional model for language behavior. *International Audiology*, *3*, 216-225.

Neely, J. H. (1977). Semantic priming retrieval from lexical memory of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, *106*(3), 226-254.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology*, *15*(6), 1003-1019.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Lawrence Erlbaum Associates.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. The University of South Florida word associations, rhyme, and word fragment norms.

Nobre, A. C. & McCarthy, G. (1994). Language-related ERPs: Scalp distributions and modulations by word type and semantic priming. *The Journal of Cognitive Neuroscience*, *6*(3), 233-255.

O'Hare, A. J., Dien, J., Waterson, L. D., & Savage, C. R. (2008). Activation of the posterior cingulate by semantic priming: A Co-registered ERP/fMRI study. *Brain Res*, *1189*, 97-114.

Posner, M. I. & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.

Roehm, D., Bornkellel-Schlesewsky, I., Rosler, F., & Schlesewsky, M. (2007). To predict or not to predict: Influences of task and strategy on the processing of semantic relations. *Journal of Cognitive Neuroscience*, *19*(8), 1259-1274.

Rolke, B. B., Heil, M., Streb, J., & Hennighausen, E. (2001). Missed prime words within the attentional blink evoke an N400 semantic priming effect. *Psychophysiology*, *38*(2), 165-174.

Rossell, S. L., Price, C. J., & Nobre, A. C. (2003). The anatomy and time course of semantic priming investigated by fMRI and ERPs. *Neuropsychologia*, *41*, 550-564.

Rossion, B., Joyce, C. A., Cottrell, G. W., & Tarr, M. J. (2003). Early lateralization and orientation tuning for face, word and object processing in the visual cortex. *Neuroimage*, *20*(3), 1609-1624.

Rubia, K., Halari, R., Smith, A. B., Mohammed, M., Scott, S., Giampietro, V., et al. (2008). Dissociated functional brain abnormalities of inhibition in boys with pure conduct disorder and in boys with pure attention deficit hyperactivity disorder. *Am J Psychiatry*, *165*(7), 889-897.

Rumelhart, D. E. & McClelland, J. L. (1986). Parallel Distributed Processing - Vol. 1: Foundations, 554.

Schneider, A., Eschman, A., & Zuccolotto, A. (2002). *Prime User's guide*. Pittsburgh, PA: Psychology Software Tools, Inc.

Shiffrin, R. M. & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, *84*, 127-190.

Simon, G., Bernard, C., Largy, P., Lalonde, R., & Rebai, M. (2004). Chronometry of visual word recognition during passive and lexical decision tasks: An ERP investigation. *Intern J Neuroscience*, *114*, 1401-1432.

Simon, G., Petit, L., Bernard, C., & Rebai, M. (2007). N170 ERPs could represent a logographic processing strategy in visual word recognition. *Behavioral and Brain Functions*, *3*(21), 1-11.

Skwarchuk, S. L. & Clark, J. M. (1996). Choosing category or complimentary relations: Prior tendencies modulate instructional effects. *Canadian Journal of Experimental Psychology*, *50:4*, 356-370.

Spencer, K. M., Dien, J., & Donchin, E. (1999). A componential analysis of the ERP elicited by novel events using a dense electrode array. *Psychophysiology*, *36*, 409-414.

Thompson-Schill, S. L., Kurtz, K. J., & Gabrieli, J. D. E. (1998). Effects of semantic and associative relatedness on automatic priming. *Journal of Memory and Language*, *38*, 440-458.

Vaidya, C. J., Gabrieli, J. D. E., Monti, L. A., Tinklenberg, J. R., & Yesavage, J. A. (1999). Dissociation between two forms of conceptual priming in Alzheimer's Disease. *Neuropsychology*, *13*(4), 516-524.

Van Overschelde, J. P., Rawson, K. A., & Dunlosky, J. (2004). Category norms: An updated and expanded version of the Battig and Montague (1969) norms. *Journal of Memory and Language*, *50*, 289-335.

Wilcox, R. R. (2001). Fundamentals of modern statistical methods.

Wilson, M. D. (1988). The MRC Psycholinguistic Database: Machine Readable Dictionary, Version 2. *Behavioral Research Methods, Instruments and Computers*, *20*, 6-11.

**Appendix A**
**Critical Pairs- Highly Associated**

| Prime | Target | Prime | Target |
|---|---|---|---|
| READ | book | DRUNK | sober |
| LEADER | follower | TOAD | frog |
| PLUS | minus | SWEET | bitter |
| DAY | night | TODAY | tomorrow |
| DOCTOR | nurse | TOGETHER | apart |
| FRAME | picture | DAWN | dusk |
| LIME | lemon | FAT | skinny |
| MAN | woman | WEB | spider |
| CHILD | adult | BOW | arrow |
| BLACK | white | GOLD | silver |
| BOY | girl | NICKEL | dime |
| SING | song | PRESENT | gift |
| SON | daughter | CIRCLE | square |
| STUDENT | teacher | UNCLE | aunt |
| SUPPLY | demand | TOP | bottom |
| THREAD | needle | SAND | beach |
| STING | bee | STANDING | sitting |
| ASLEEP | awake | SPOON | fork |
| WIDE | narrow | ARTIST | painter |
| JELLY | jam | ITCH | scratch |
| CLEAN | dirty | BUYER | seller |
| FOOD | eat | THIN | thick |
| KEY | lock | PUCK | hockey |
| BROTHER | sister | THUNDER | lightning |
| NAVY | army | SCREAM | yell |
| HILL | mountain | WILD | tame |
| SEA | ocean | SWEEP | broom |
| GARBAGE | trash | WIFE | husband |
| BUCKLE | belt | KNIGHT | armor |
| STRONG | weak | BRIDE | groom |
| DEAD | alive | REAP | sow |
| CARPET | rug | | |

**Critical Pairs- High-typicality Category**

| Prime | Target | Prime | Target |
|---|---|---|---|
| EMOTION | love | CANDY | gum |
| RODENT | rat | SPORT | soccer |
| JEWELRY | ring | BREAD | wheat |
| SEASON | fall | BATHROOM | toilet |
| NOISE | horn | CIRCUS | clown |
| ROYALTY | king | HAIR | blonde |
| LIQUID | water | FABRIC | silk |
| COLOR | blue | NUT | walnut |
| WEAPON | gun | TIME | minute |
| CAMP | tent | BUILDING | brick |
| FARM | cow | HAT | baseball |
| METAL | iron | BOAT | stern |
| HORSE | saddle | SNAKE | rattle |
| ALCOHOL | beer | SPEECH | noun |
| MONEY | dollar | SPICE | pepper |
| MEAT | beef | APPLIANCE | stove |
| INSECT | ant | VEGETABLE | carrot |
| RELATIVE | cousin | BODY | arm |
| FLOWER | rose | ROOM | bedroom |
| MEAL | dinner | SCIENCE | chemistry |
| MATH | addition | LENGTH | inch |
| TREE | oak | CRIME | theft |
| FURNITURE | chair | SHAPE | triangle |
| CITRUS | orange | FACE | nose |
| TOY | doll | GOVERNMENT | democracy |
| DISEASE | cancer | MUSIC | rap |
| DIRECTION | north | ATOM | nucleus |
| TOOL | hammer | FOOTBALL | receiver |
| DISTANCE | mile | SURGERY | scalpel |
| FRUIT | apple | EXPLOSIVE | dynamite |
| DANCE | ballet | DRUG | marijuana |
| COSMETIC | lipstick | | |

**Appendix B**

**Filler Pairs for Associative-Dominant List**

| Prime | Target |
|---|---|
| SMALL | huge |
| SMILE | frown |
| FRIEND | foe |
| OLD | young |
| INSIDE | outside |
| FLOAT | sink |
| KILL | murder |
| SUNRISE | sunset |
| SHORT | tall |
| MINE | yours |
| FEEL | touch |
| COLD | hot |
| LAUGH | cry |
| PRETTY | ugly |
| VACATION | trip |
| MOTHER | father |
| POOR | rich |
| SAME | differ |
| HARD | soft |
| LOOSE | tight |
| SEEK | hide |
| MINIMUM | maximum |
| QUIET | loud |
| MOVIE | film |
| SMART | dumb |
| MAJORITY | minority |
| SMOOTH | rough |
| PRINCE | princess |
| INHALE | exhale |
| MALE | female |
| POSITIVE | negative |
| LION | tiger |
| TENNIS | racket |
| PLANET | earth |
| STREET | road |
| PAIL | bucket |
| LEAF | tree |
| SMOKE | cigarette |
| HOG | pig |
| CALL | phone |
| COUCH | sofa |
| COAT | jacket |

**Filler Pairs for Category-Dominant List (Low-typicality)**

| Prime | Target |
|---|---|
| FUEL | solar |
| REFERENCE | manual |
| WOOD | ebony |
| WINDSTORM | twister |
| WEATHER | sunshine |
| WATERWAY | bay |
| OFFICE | congress |
| VOICE | low |
| VEHICLE | cab |
| STONE | jade |
| STATE | Wisconsin |
| OPIUM | speed |
| TRAIN | freight |
| DOG | pointer |
| GARDENING | seeds |
| CAR | Saturn |
| MILITARY | chief |
| COUNTRY | Greece |
| CLERGY | preacher |
| CITY | London |
| COLLEGE | Texas |
| ELEMENT | lead |
| ENERGY | gas |
| FASTENER | bolt |
| GYMNAST | acrobat |
| CLOTHES | tie |
| MEDICINE | physician |
| UTENSIL | cup |
| CAREER | police |
| DWELLING | hotel |
| FISH | minnow |
| HERB | salt |
| FOOTWEAR | boot |
| INSTRUMENT | organ |
| DRUM | kettle |
| BEVERAGE | coffee |
| GREEN | pea |
| BIRD | cardinal |
| BURIAL | funeral |
| DAIRY | cream |
| COIN | Indian |
| WRITE | quill |

**Appendix C**

**Non-Word Pairs**

| Prime | Target | Non-word |
|---|---|---|
| PROTEIN | beans | reans |
| BRUISE | ulgy | utly |
| VOLUME | voice | voige |
| REBEL | angel | amgel |
| NOTE | card | carf |
| BASKET | eggs | aggs |
| CUSTOM | design | dasign |
| MISTAKE | forgive | borgive |
| TAPE | radio | ridio |
| DIAL | clock | cloch |
| PUMP | hose | hosy |
| OUTLINE | trace | frace |
| SHORE | coast | coalt |
| ART | crafts | crafth |
| SLIDE | park | parg |
| EFFORT | ease | eake |
| BANANA | gorilla | goralla |
| GRIND | crush | cruth |
| OLIVE | pit | rit |
| QUILT | patch | parsch |
| SHADE | shadow | shedow |
| BRAT | jerk | jeck |
| LICK | spit | spet |
| HANG | ten | teb |
| CITIZEN | member | rember |
| NYLON | rope | roke |
| DAMAGE | harm | herm |
| BLOW | away | amay |
| ABILITY | talent | lalent |
| IRON | wrinkle | brincle |
| WORM | dirt | dirp |
| PISTOL | shoot | shooh |
| METER | reader | reaker |
| SYMBOL | cross | closs |
| YAWN | bored | rawn |
| BURDEN | stress | strass |
| WRIST | ankle | askle |
| LOW | down | duwn |
| JOINT | knee | snee |
| CEREAL | oatmeal | oatseal |
| PLOW | tractor | tramtor |
| BIKE | rack | rach |
| BORDER | rim | riw |
| JAZZ | blues | bluen |
| VAULT | pole | pule |

| | | |
|---|---|---|
| LIZARD | animal | anemal |
| ECSTASY | pleasure | pleadure |
| TAN | bronze | brunze |
| ROBE | cover | coxer |
| MANNER | polite | polote |
| IGNORE | avoid | avoir |
| KNOT | string | strind |
| RIVER | flow | flod |
| CHANNEL | station | stasion |
| RAW | cooked | cooced |
| SONIC | sound | sould |
| KICK | hurt | hult |
| TORCH | flame | glame |
| NORMAL | regular | regutar |
| CAUTION | yellow | yallow |
| BEARD | shave | cheve |
| PRIZE | reward | rewurd |
| RELAX | calm | walm |
| DRILL | hole | hule |
| PRESS | media | mudia |
| GLOW | shine | chone |
| JAR | lid | nid |
| UNITE | join | jone |
| TIRE | flat | flet |
| CULTURE | society | sodiety |
| VIRUS | flu | plu |
| JUNGLE | monkey | nonkey |
| SHACK | hut | hup |
| VALVE | heart | heert |
| QUARREL | argue | arbue |
| DISH | bowl | kowl |
| NAME | person | pelson |
| ZONE | twilight | twilicht |
| OBEY | command | comrand |
| BLUR | vision | vition |
| NAPKIN | wipe | wige |
| ALBUM | photo | phato |
| GOLF | club | clug |
| RESCUE | help | helk |
| GAMBLE | bet | zet |
| INCLINE | steep | skeep |
| HANDLE | care | cire |
| WAX | candle | camdle |
| JUSTICE | law | lar |
| GERM | bacteria | bacturia |
| TRAIT | gene | gune |
| TUMOR | brain | braim |
| LEDGE | cliff | gliff |

| | | |
|---|---|---|
| COTTAGE | cheese | chiese |
| KETTLE | pot | fot |
| TOMB | grave | trave |
| ELK | moose | koose |
| WEAVE | sew | siw |
| SALAD | lettuce | littuca |
| SCREW | driver | drider |
| CHUNK | piece | pieve |
| COOKBOOK | recipe | recate |
| SALARY | fee | fey |
| CREASE | fold | jold |
| CRAWL | walk | walf |
| LAUNCH | rocket | tocket |
| BARGAIN | sale | sahe |
| GATHER | collect | collict |
| BLUEBERRY | muffin | muppin |
| ADULTERY | cheat | chead |
| NECK | head | heag |
| LADDER | climb | clind |
| COWGIRL | cowboy | cawbay |
| CUSS | swear | slear |
| CLOUD | sky | sby |
| CEILING | roof | reet |
| ANXIOUS | nervous | nirvoud |
| CONCERN | worry | dorry |
| KIND | nice | hice |
| BISON | buffalo | tuffago |
| TWIG | branch | bransh |
| CHECKERS | game | rame |
| MARROW | bone | bome |