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Corresponding Author: Dr. Erin M. Buchanan, Ph.D.

Corresponding Author's Institution: Missouri State University

First Author: Erin M Buchanan, Ph.D.

Order of Authors: Erin M Buchanan, Ph.D.; Nathan Nunley, B.S.

Abstract: The N400 waveform carries new insight into the nature of linguistic processing and may shed light into the automaticity of priming word relationships. We investigated semantic and associative word pairs in classic lexical decision and letter search tasks to examine their differences in cognitive processing. We used normed database information to create orthogonal semantic and associative word relationships to clearly define N400 waveforms and priming for these pairs. Participants showed N400 reduction for related word pairs, both semantic and associative, in comparison to unrelated word pairs. This finding was consistent across both lexical decision and letter search tasks, indicating automatic access for both types of relatedness. Non-word pairs showed N400 waveforms that resembled unrelated word pairs, indicating the controlled examination of non-advantageous words. Reaction time data nearly mirrored the EEG findings: priming was found for semantic and associative word relationships, while non-word pairs were generally slower than unrelated word pairs.

Suggested Reviewers: Peter Hagoort
peter.hagoort@mpi.nl
researcher in psycholinguistics and familiar with EEG information.

Keith Hutchison
khutch@montana.edu
familiar with the differences in associative and semantic priming, database norms

Markus Kiefer
markus.kiefer@medizin.uni-ulm.de
Familiarity with N400 and semantic priming

Paloma Mari-Beffa
pbeffa@bangor.ac.uk
Familiarity with N400 and priming research

Donna Kreher
dkreher@neurocog.psy.tufts.edu
Familiarity with N400 and semantic priming.

Juan Silva-Pereya
jfsp@u.washington.edu
Familiarity with N400 and semantic priming.

Opposed Reviewers:

July 11, 2011

Dr. S. Small
Editor, *Brain and Language*

Dr. Small,

I am writing for *Brain and Language* to consider "The N400's 3 As: Association, Automaticity, Attenuation (and Some Semantics Too)" as a regular article for publication. This article has not been previously published and is not currently under review elsewhere. The research in this paper was completed with approval of the Internal Review Board at the University of Mississippi.

Several meta-analytic studies have shown that *semantic* priming is often mixed with *associative* relationships, without discerning between the two forms of word connectedness. Our study used normed databases to create stimuli that were orthogonal or "purely" semantic and associative. We tested participants on traditional priming tasks (lexical decision and letter search) while their N400 waveforms were recorded. The combination of response time data and N400 attenuation presented a picture of clear automatic associative priming and support for underlying automatic semantic activation. Our channel data indicated different processing by gender, and this finding warrants further investigation. These results elucidate the underlying cognitive processes for both relationship types and how language is connected in the brain, which would be of interest to psycholinguistics, cognitive psychologists, and wide array of researchers who are simply interested in our language system. Thank you in advance for you time and consideration.

Sincerely,

Erin Buchanan
Assistant Professor
Missouri State University
Department of Psychology
901 S National Ave.
Springfield MO 65897
Email: erinbuchanan@missouristate.edu
Phone: 417-836-5592
Fax: 417-836-8330

***Statement of Significance**

The current study used normed databases to specify experimental stimuli until purely associative and semantic relationships. That stipulation allowed us to study unique N400 effects in a lexical decision and letter search task. We found attenuated waveforms, which indicates analogous underlying language processes that are automatic.

***Highlights**

- Norms were used to create orthogonal stimuli to study priming N400 waveforms.
- Associative relationships were shown to have a N400 attenuation and RT priming.
- Automatic activation for information was seen across tasks and measurements.
- Channel spectrum figures display different patterns of activation by gender.

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The N400's 3 As: Association, Automaticity, Attenuation (and Some Semantics Too)

Erin M. Buchanan

Missouri State University[a]

Nathan Nunley

University of Mississippi[b]

Corresponding Author:
Erin M. Buchanan
[a]Department of Psychology
Missouri State University
901 S National Ave
Springfield, MO 65897
Phone: 417-836-5592
Fax: 417-836-8330
Email: erinbuchanan@missouristate.edu

[b]Department of Psychology
University of Mississippi
P.O. Box 1848
University, MS 38677

Author Note

Author order is listed alphabetically. The authors would like to thank John Young and Matthew Reysen at the University of Mississippi for their comments on previous drafts of this paper.

Nathan Nunley is now a graduate student at the University of Alabama and can be contacted at nrnunley@crimson.ua.edu.

Abstract

The N400 waveform carries new insight into the nature of linguistic processing and may shed light into the automaticity of priming word relationships. We investigated semantic and associative word pairs in classic lexical decision and letter search tasks to examine their differences in cognitive processing. We used normed database information to create orthogonal semantic and associative word relationships to clearly define N400 waveforms and priming for these pairs. Participants showed N400 reduction for related word pairs, both semantic and associative, in comparison to unrelated word pairs. This finding was consistent across both lexical decision and letter search tasks, indicating automatic access for both types of relatedness. Non-word pairs showed N400 waveforms that resembled unrelated word pairs, indicating the controlled examination of non-advantageous words. Reaction time data nearly mirrored the EEG findings: priming was found for semantic and associative word relationships, while non-word pairs were generally slower than unrelated word pairs.

Keywords: association, semantics, priming, N400, EEG, lexical decision, letter search

The N400's 3 As: Association, Automaticity, Attenuation (and Some Semantics Too)

Semantic facilitation through priming occurs when a related cue word speeds the processing of a following target word (Meyer & Schvaneveldt, 1971). For example, if a person is reading about a YACHT race, the word BOAT is easier to process because of the previous activation in semantic memory. Research suggests that priming transpires by both automatic and controlled processes. The automatic model proposes that related words are linked in the brain due to overlapping features (Collins & Loftus, 1975). The target words are activated without conscious control due to automatic spreading activation within related cognitive networks. Lexical and feature networks are thought to be stored separately, so that semantic priming is the activation from the feature network feeding back into the lexical level (Stolz & Besner, 1996). The overlap of the second word's semantic relatedness makes word recognition easier because it, in essence, has already been processed. The controlled process model proposes that people actively use cognitive strategies to connect related words together. Neely (1991) describes both expectancy generation and post lexical matching as ways that target word processing may be speeded. In expectancy generation, people consciously attempt to predict the words and ideas that will appear next, especially in sentences. Whereas in post lexical matching, people delay processing of the second target word so that it can be compared to the cue word for evaluation. In both cases, the target word is quickened by its relationship to the cue word.

Traditionally, priming has been tested with a simple word or nonword decision called a lexical decision task. Participants are shown a cue or priming word, followed by a related or unrelated target word for the word/nonword judgment. Priming occurs when the judgment for the target is speeded for related pairs over unrelated pairs. Lexical decision tasks have been criticized for their inability to distinguish between automatic and controlled processing, so both a

single lexical decision task and masked priming have been introduced to negate controlled processing (Ford, 1983). In a single lexical decision task, participants assess both the cue and target word so that they are not as explicitly paired together. Experimenters might also mask or distort the cue word, so that participants do not believe they can perceive the cue word. Even though words are garbled, word perception occurs at a subliminal level and often facilitates the target word with automatic activation.

Event related potentials (ERP) are used to distinguish both the nature of priming and the automaticity of priming. ERPs measure brain activation as processes occur, with relatively good temporal resolution through an electroencephalogram (EEG). The N400 is a negative waveform occurring 400 msec after the participant is presented with a stimulus (Brown & Hagoort, 1993). The N400 has been described as a "contextual integration process", in which meanings of words are integrated together (Silva-Pereya, Rivera-Gaxiola, Aubert, Bosch, Galan, & Salazar, 2003). When presented with related words, there is an attenuation of the N400; meaning a more positive waveform when compared to unrelated word presentation. This difference in waveforms indicates a lessened contextual integration process because word meanings are already activated.

Brown and Hagoort (1993) tested a lexical decision task paired with masked priming. No differences were found in the N400 wave between related and unrelated words in the masked prime condition. Brown and Hagoort concluded that this finding indicated that semantic activation was a controlled process, because attenuation only occurred when words were known. This condition supposedly rules out automatic processes, because the masked prime condition only allowed automatic processes to take place. Masked priming did not allow the participants to consciously name the prime words they had seen, so they were not able to purposefully employ conscious cognitive strategies in processing these words. However, Deacon, Heweitt, Yang and

Nagata (2000) have found that with shorter stimulus onset asynchronies (SOAs), this effect of masked priming disappears. SOAs are the time interval between the prime word presentation and the target word appearance. Short SOAs are thought to only allow for automatic processing because the controlled, attention based processing has not had time to occur. Their study showed the masked primes long enough to enhance priming, while remaining imperceptible. With these modifications, Deacon et al. found equal attenuation for the masked and unmasked primes. This result would indicate that automatic activation was taking place, as the masked prime condition did not allow controlled processes to take place. Keifer (2002) has found similar results in the N400 using different masking levels, which kept judgment ability of prime words below chance. Rolke, Heil, Streb, and Hennghausen (2001) used the attention blink rapid serial visual presentation (RSVP) paradigm, which can be compared to masked priming, and showed automatic activation of semantic information even when targets were missed or "blinked".

Letter search tasks have also been usedto reduce semantic priming by focusing attention on the lexical level instead of a feature meaning level (Friedrich, Henik &, Tzelgov, 1991). In this task, participants are asked to determine if cue and target words contain a specific letter presented. Stolz and Besner (1999) stipulate that this eliminated or reduced priming indicates non-automatic semantic priming. In Smith and Besner's (2001) letter search and lexical decision study, they found that the letter search task eliminated semantic priming when compared to unrelated word pairs and the lexical decision task. However, Mari-Beffa, Valdes, Cullen, Catena, and Houghton, (2005) found ERP evidence for semantic processing of the prime word during letter search tasks with the attenuation of the N400.

The next step in this line of research would be to investigate the effect, if any, of the type of relatedness shared between the prime and target words. Words can be related in many ways,

but here we focus on semantic and associative relationships. Associative word pairs are words that are linked in one's memory by contextual relationships, such as BASKET and PICNIC (Nelson, McEvoy &, Schreiber, 2004). Another example would be a word pair like ALIEN and PREDATOR, which would be associatively linked for Americans due to the movies and popular culture. Semantic word pairs are those linked by their shared features and meaning, such as WASP and BEE (McRae, Cree, Seidenberg, & McNorgan, 2005).

Associative and semantic relationships between words are experimentally definable by the use of normed databases. Maki, McKinley, and Thompson (2004) took the online dictionary, WordNet (Fellbaum, 1998), and used software by Patwardhan and Pederson (2003) to create a database of words displaying the semantic distance between individual words. This database displays the relatedness between two words by measuring how semantically close words appear in hierarchy, or the JCN (for the Jiang & Conrath formula, 1997). JCN measures the word pairs' informational distance from one another, or their semantic similarities. Therefore a low JCN score demonstrates a close semantic relationship. Another useful database, created by Nelson et al. (2004), is centered on the associative relationships between words. Participants were given cue words and asked to write the first word that came to mind. These responses were asked of and averaged over many participants. The probability of a cue word eliciting the target word is called the forward strength (FSG). For example, when participants are shown the word LOST, the most common response is FOUND, which has a FSG of .75 or occurs about 75% of the time.

Both Lucas (2000) and Hutchison (2003) have examined "semantic" priming studies and found that many experimental stimuli are a mix of both semantic and associative relatedness. When associative relatedness is included in word pairs, the associative boost increases the level of priming found over unrelated word pairs (Moss, Ostrin, Tyler, & Marslen-Wilson, 1995).

With the databases described above, orthogonal word pair stimuli can be created to examine associative and semantic priming separately (Buchanan, 2009). The current study examined the relationship between N400 activation, priming task, and word relationship type. Participants were given both a single lexical decision and letter search task, along with separate semantic, associative, and unrelated word pairs. It was expected that the N400 modulation might vary from the different types of word relation, which would indicate differences cognitive processing and word organization.

Method

Participants.

Twenty undergraduate students were recruited from a large southern University (13 women and 7 men), and all volunteered to participate. All participants were English speakers. The experiment was carried out with the permission of the University's Internal Review Board, and all participants signed the corresponding consent forms. One participant's data was corrupted and could not be used, and another participant was excluded for poor task performance (below chance), leaving eighteen participants (12 women and 6 men).

Apparatus.

The system used was a 32 Channel EEG Cap connected to a NuAmps monopolar digital amplifier, which was connected to a computer running SCAN 4.5 software to record the data. This SCAN software is capable of managing continuous digital data captured by the NuAmps amplifier. $STIM^2$ was used to coordinate the timing issues associated with Windows operating system and collecting EEG data on a separate computer. $STIM^2$ also serves as the software base for programming and operating experiments of this nature. The sensors in the EEG cap are sponges injected with 130 ml of electrically conductive solution (non-toxic and non-irritating).

Also, to protect the participants and equipment, a surge protector was used at all times during data acquisition. The sensors record electrical activity just below the scalp, displaying brain activation. This data was amplified by the NuAmps hardware, and processed and recorded by the SCAN software.

Materials.

This experiment consisted of 360 word pairs separated into pairs in which the target words were unrelated to the prime (120), semantically associated to the prime (60), associatively related to the prime (60), or were nonwords (120). We used only a small number of related word pairs to try to reduce expectancy effects described in the introduction. These 360 pairs were split evenly between the lexical decision and letter search task, therefore, each task contained 60 unrelated pairs, 30 semantically related pairs, 30 associatively related pairs, and 60 nonword pairings. The ratio of yes/no correct answers for words and nonwords in the lexical decision task was 2:1 and 1:1 yes/no decisions in the letter search task. Splitting the nonword pairs over both the letter search and lexical decision task created a higher yes/no ratio for the lexical decision task, which was controlled for by mixing both tasks together.

The stimuli were selected from the Nelson et al. (2004) associative word norms, and Maki et al. (2004) semantic word norms. The associative word pairs were chosen using the criteria that they were highly associatively related, having an FSG score greater than .5; with little or no semantic similarities, determined by having a JCN score of greater than 20. An example of an associative pair would be DAIRY-COW. The semantic word pairs were chosen using the criteria that they had a high semantic relatedness shown in a JCN of 3 or less; and were not associatively related, having an FSG of less than .01 (e.g., INN-LODGE). The unrelated words were chosen so that they had no similarities (were unpaired in the databases), such as

BLENDER and COMPASS. For non-word pairs, the target word had a letter changed so that it was no longer a real word, but the structure was left intact to require that the participant process the word cognitively (PUND). These stimuli were tested for differences in word length, neighborhood size, frequency, lexical decision, and naming response times using the English Lexicon Project norms (Balota, Yap, Cortese, Hutchison, Kessler, Loftus, et al., 2007). They were found to be the same across data type using a mixed ANOVA, $F(15, 1310) = 1.217$, $p = .251$. Stimuli norms can be provided upon request.

Procedure.

Testing occurred in one session consisting of six blocks of acquired data, broken up by brief rest periods. Before each participant was measured, the system was configured to the correct settings, and the hardware prepared. This setup consisted of inserting sensor sponges into the appropriate slots of the EEG cap and securing the cap to the participant's head with a Velcro chinstrap. Next two ground sensors (baseline scalp electroconductivity without underlying brain activity) were placed on the right and left mastoid bones, or the slightly protruding bones just behind each ear. With the cap and sensors in place, the electrically conductive solution was applied to the sensors with an automatic pipette. Once the participant was fully prepared, the impedance value of the signal received from their scalp was measured to ensure accurate readings. In the event of too much impedance (not enough electrical conductivity), manual measures were taken to remedy the problem: applying pressure to expand the sensor sponges, pressure to the scalp to complete the circuit, more solution added to increase conductivity, etc. Once impendence values were low, the participants were asked to blink their eyes rapidly a few times to establish a base for determining eye blink artifacts in the data. Once these baselines were acquired the experiment began.

We used a modified version of Smith and Besner's (2001) lexical decision and letter search task combination. The lexical decision involved the participants observing a word onscreen and deciding whether or not it was a word or non-word (such as TORTOISE and WERM) using pre-determined button presses. The letter search task involved the participants observing a word onscreen and deciding whether it had repeated letter (like the repeated letters in DOCTOR as opposed to no repeated letters in NURSE) using pre-determined button presses. The word would be presented onscreen, and would stay there until the participant pressed the corresponding keys for yes and no. The "1" and "9" keys were used on the number row of the keyboard, in the participant's lap to help eliminate muscle movement artifact in the data.

Participants were first given instructions on how to perform the lexical decision task, followed by 15 practice trials. Next, they were given instructions on how to judge the letter search task, followed by 15 practice trials. Participants were then given a practice session with both letter search and lexical decision trials mixed together. Trials were color coded for the type of decision participants had to complete (i.e. letter search was green, while lexical decision was red). The experiment made use of 6 sets of 60 randomly assigned word pairs for a total of 360 trials. These trials were presented in Arial 19 point font, and the inter-trial interval was set to two seconds to allow complete recording of the N400 waveform. Between blocks participants were allowed to rest and move around to prevent fatigue from sitting still.

Results

EEG Data

N400 Waveform Analysis. The data were cleared of artifact data using EEGLAB, an open source MATLAB tool for processing electrophysiological data. The program automatically scanned for and removed muscular artifacts caused by eye blinks. Next, the datasets were

visually inspected and any remaining corrupted sections were removed manually. Ninety percent of the data was retained across all trials and stimulus types after muscular artifact data were removed. The data were combined by task and stimulus type exclusively for the second word in each pair. Five sites were chosen to examine priming for nonwords, associative and semantic word pairs based on a survey of the literature. FZ, FCZ, CZ, CPZ, and CZ were used from the midline. OZ was excluded due to equipment problems across all participants. Using MATLAB, the N400 area under the curve was calculated for each electrode site, stimulus, and task. The area under the curve for the N400 ranged between 300-500 msec for participants, and average peak latency was around 405 msec after stimulus presentation.

Lexical Decision Task. After each set was processed as described in the data processing section, differences from normal processing were calculated by subtracting unrelated word pair averages from each stimuli type. These stimuli were then tested with a single sample t-test comparing each processing difference from zero. The following hypotheses were examined:

- Non-word pairs may show significantly more negative waveforms (more negative area) due to the need to search the lexicon before a decision can be made.
- Semantic word pairs will have significantly positive values because priming will decrease the need to search the mental lexicon.
- Associative word pairs may have significantly different values from unrelated word pairs, but a direction is not predicted. More positive values would indicate automatic activation similar to semantics, while more negative values would indicate a need to search the mental lexicon.

Figure 1 depicts the N400 curves for the selected electrode sites, and Table 1 presents t-test values for the following conclusions. Nonwords were not found to be significantly more

negative than unrelated word pairs, which may indicate a controlled lexicon search for both types of stimuli. Both associative and semantic N400 attenuation were found across frontal and midline sites, while neither CPZ nor associative PZ showed reduction. In Figure 1, associative and semantic N400 waveforms are well above the unrelated word pairs, indicating automatic priming for both types of relatedness, even when stimuli are controlled for opposing relationships.

Letter Search Task. The same five sites were analyzed as the lexical decision task. Again, data were subtracted from unrelated word pairs averages and then compared against zero with single sample t-tests.

The following hypotheses were expected:

- Since task demands require a focus at the lexical level, nonword pairings should not show significant differences from unrelated word pairs. However, if word processing is automatic in a letter search task (Maria-Beffa et al., 2005), then nonwords pairs may show more negative waveforms as participants search the lexicon for the word pair.
- Semantic and associative word pairs may have significantly positive values because priming will decrease the need to search the mental lexicon; however some research literature indicates that letter search tasks eliminate semantic priming (Smith & Besner, 2001). Positive values would indicate a priming effect, which is evidence for activation spreading automatically within the mental lexicon. More negative or nonsignficant values would indicate processing at the lexical, but not semantic, level.

Figure 2 portrays the N400 waveforms for the letter search task, and Table 2 contains the t-test values for the following conclusions. Although the average nonword waveform appears to be much lower than unrelated waveform at many sites, the variance across subjects was very large,

and no significant differences were found. This finding could indicate that "wordness" did not matter since participants were searching at a lexical level for specific letters. Nearly all sites showed significant associative and semantic attenuation for the N400 waveform, semantic CZ being the only exception. In comparison, this result seems to suggest that letter search does not inhibit automatic activation of word meaning and association. The nonsignificant relationship between nonwords and unrelated word pairs could be either statistical power or a controlled search process, regardless of task demands.

***Channel Spectrum Differences*.** Figure 3 shows the channel spectrum map for all sites and stimuli, separated by gender. The images were examined by both tasks and word relationship and found to have the same picture of activation. Our sample size is fairly small for male participants (N=6), but the different configurations for gender were striking. Female participants, examined individually, showed varied patterns that averaged to an overall activation in the parietal region. Male participants all displayed large left hemisphere frontal lobe dominance, which could be attributed to Broca's area. We acknowledge the limitations of our small sample and EEG mapping inadequacy, but present these findings as an interesting avenue for future research.

Task Performance.

Task data were analyzed for correctness in the lexical decision and letter search tasks individually. Error rates were tested with a 2X4 (task by stimulus) repeated measures ANOVA. Overall, performance in the letter search task (M=.97, SD=.02) was equal to the lexical decision task (M=.97, SD=.02), $F(1,13)=1.54$, p=.24. The interaction between task type and stimuli was also not significant $F(3,39)=1.74$, p=.18. The different types of stimuli showed a difference in performance, $F(3,39)=9.85$, $p<.001$, between nonwords (M=.94, SD=.03, $t(13)=-3.02$, p=.01) and

unrelated word pairs (*M*=.97, *SD*=.01); nonwords and associative word pairs (*M*=.98, *SD*=.01, *t*(14)=-5.55, *p*<.001); and nonwords and semantic word pairs (*M*=.98, *SD*=.02, *t*(14)=-3.45, *p*=.01). The other stimuli comparisons were all non-significant, and averages by task can be provided upon request.

Reaction Time Performance.

Reaction time data were excluded for incorrect trials. Average reaction times were calculated for each task type and stimulus. The Van Selst and Jolicoeur (1994) 3 standard deviation outlier trimmer procedure was used to eliminate very long reaction times. Next, associative, semantic, and nonword conditions were subtracted from their matching unrelated word conditions. Figure 4 depicts the priming differences for each condition. Each stimulus difference was analyzed with a single sample t-test against zero to examine for priming.

Letter search task. All conditions in the letter search task were significantly primed over unrelated words pairs, while nonwords were significantly slower than unrelated word pairs. As shown in Figure 4, associative words pairs were almost 200 msecs faster than unrelated word pairs, $t(17) = 3.54$, $p < .01$, and semantic word pairs were also around 200 msecs faster than unrelated word pairs, $t(17) = 6.38$, $p<.01$. Nonwords were significantly slower than unrelated word pairs by about 200 msecs, $t(17) = -5.18$, $p<.01$. Given previous research, it was slightly surprising that semantic word pairs would be primed during a letter search task, however, the current word list has also shown this effect in Buchanan (2009), and this effect matches N400 results.

Lexical decision task. Priming was found for associative word pairs in the lexical decision task, a marginal effect semantic word pairs, and slowing for non-word pairs when compared to unrelated word pairs. Associations were about 120 msecs faster than unrelated

word pairs, $t(17) = 2.99$, $p<.01$. Semantic word pairs were primed approximately 85 msecs over unrelated pairs, which approached significance, $t(17) = 1.93$, $p=.07$. Semantic priming was expected in the lexical decision task, and this effect was most likely due to our small sample size. Nonwords were again 200 msecs slower than unrelated word pairs, $t(17) = -5.24$, $p<.01$.

Discussion

These experiments were designed to explore the differences between N400 activation in the brain following presentation of semantic-only, associative-only, and unrelated word pairs in priming tasks. The N400 data and reaction time data present picture of associative and semantic priming during both lexical decision and letter search task. Because both tasks were designed to reduce controlled processing of cue-target relationships, these findings imply automatic activation of word meanings and associations, even when task demands do not warrant word activation. Nonword activation is more problematic to interpret, as N400 waveforms are not different from unrelated word pairs, but reaction time data is much slower. These results, taken together, may illustrate a controlled process search of the lexicon requiring the same activation levels. When an unrelated target word is found in the lexicon, controlled search is terminated, while searching for a nonword continues for more time before the search is terminated.

Since findings were roughly similar for associative and semantic word pairs, we can postulate that the activation processes for these types of word relatedness are also roughly similar. This experiment cannot separate if the cognitive architecture is different for associations and semantics, but that the automatic mechanisms for priming are comparable. One limitation is that the long stimulus onset times may have allowed for controlled processing in the reaction time data, but the consistent N400 attenuation suggests a quick search of the lexicon like an automatic activation process. Finally, differences in activation across gender need to be

explored. Although not conclusive due to sample size, we found that male activation across stimuli was focused in traditional left Broca's area, while female activation averaged to central parietal areas.

To date, research has focused on semantic priming and its automaticity without many controls for associative relationships embedded in word pairs. Certainly there is overlap between meaning and context use of words, but these differences can be studied separately using available databases (Hutchison, 2003). Our current study has supported findings by Maria-Beffa et al. (2005), who showed activation during letter search tasks, along with the many studies on automatic activation during masked priming (Kiefer, 2002; Deacon et al., 2000).

Limitations do exist within these experiments. As previously mentioned a larger sample size would increase the power coefficient of the findings. Future studies should focus on the extent of priming in semantic word pairs during a letter search task, which is a controversial topic within the literature. Since our study limited relatedness to associations or semantics, upcoming experiments could examine the interaction between word relationship type of N400 attenuation. Kreher, Holcomb, and Kuperberg (2006) have shown that N400 waveform differences can be attributed to different strengths of semantic relatedness in a linear fashion. With more exploration into the exact priming nature of associations and semantics, we may begin to discover their cognitive mechanisms.

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Table 1.
Mean, Standard Errors, and t-value differences from zero for the Lexical Decision Task.

	M	*SE*	*t*	*p*
FZ				
Nonwords	-2.265	168.635	-0.013	0.989
Associative	411.678	127.475	3.229	0.005
Semantic	561.302	180.526	3.109	0.006
FCZ				
Nonwords	57.872	139.514	0.415	0.683
Associative	477.977	162.512	2.941	0.009
Semantic	546.612	175.775	3.110	0.006
CZ				
Nonwords	33.937	212.387	0.160	0.875
Associative	535.405	159.983	3.347	0.004
Semantic	344.305	205.014	1.679	0.111
CPZ				
Nonwords	13.564	186.628	0.073	0.943
Associative	512.804	139.324	3.681	0.002
Semantic	388.388	165.088	2.353	0.031
PZ				
Nonwords	130.817	188.113	0.695	0.496
Associative	508.754	211.413	2.406	0.028
Semantic	443.707	177.847	2.495	0.023

Note. DF = 17 for all t-tests.

Table 2.
Mean, Standard Errors, and t-value differences from zero for the Letter Search Task.

	M	*SE*	*t*	*p*
FZ				
Nonwords	-2.265	168.635	-0.013	0.989
Associative	411.678	127.475	3.229	0.005
Semantic	561.302	180.526	3.109	0.006
FCZ				
Nonwords	57.872	139.514	0.415	0.683
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Note. DF = 17 for all t-tests.

Figure Captions

Figure 1. N400 waveform averages for the lexical decision task separated by electrode site.

Figure 2. N400 waveform averages for the letter search task separated by electrode site.

Figure 3. Channel Spectrum maps averaged across task type (Lexical Decision or Letter Search) and word relationship type (Nonwords, Semantic, Associative). Female participants (*N=12*) are presented in the top portion, and male participants (*N=6*) are presented in the bottom portion. The left maps are at 300 msec after stimulus presentation, while the right maps are 500 msec after stimulus presentation.

Figure 4. Priming reaction time averages for task type (Lexical Decision or Letter Search) and word relationship type (Nonwords, Semantic, Associative). These scores are subtracted from Unrelated word pairs for difference processing. Error bar represent standard error of the mean.

Figure

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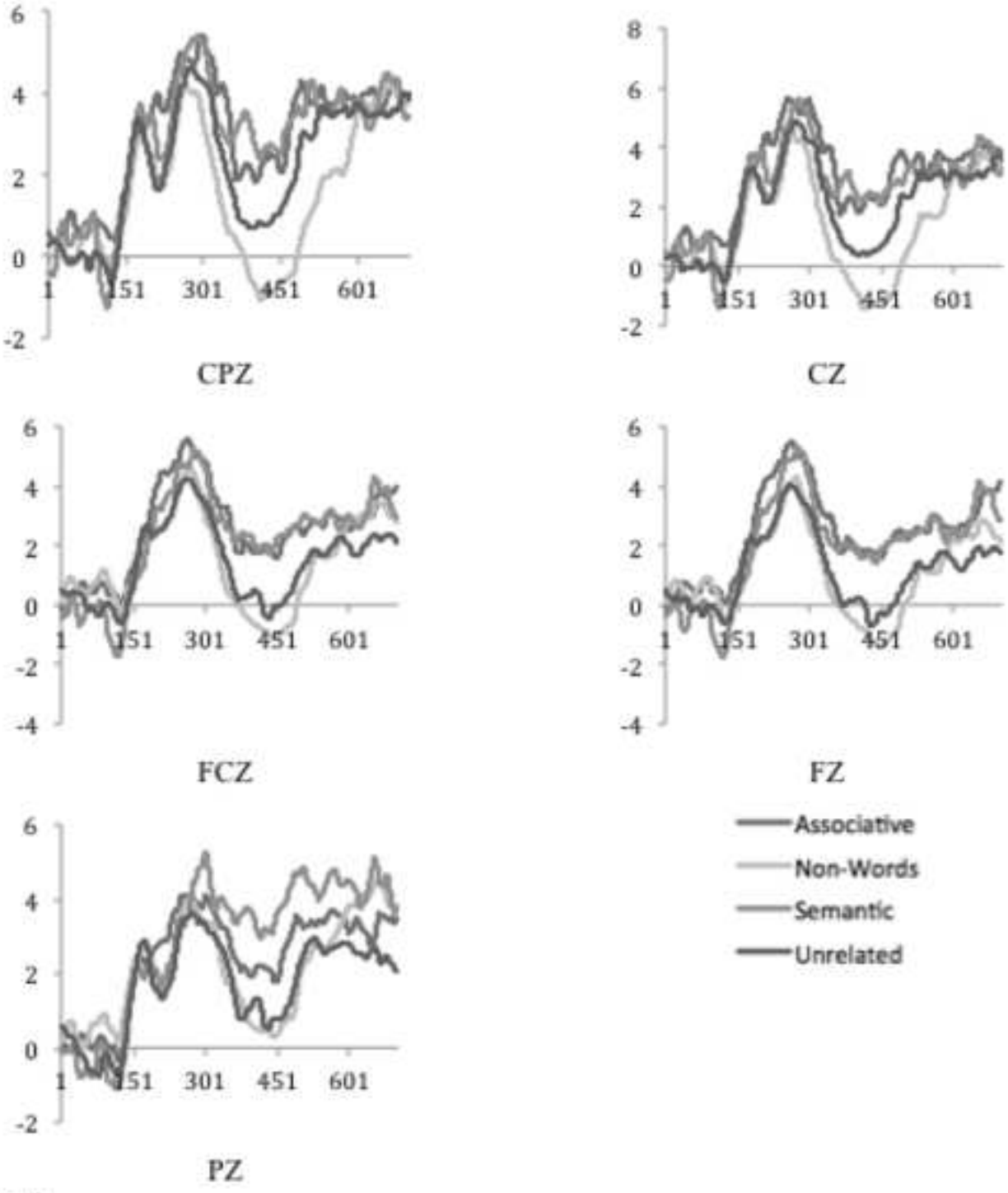

Figure 1.

Figure

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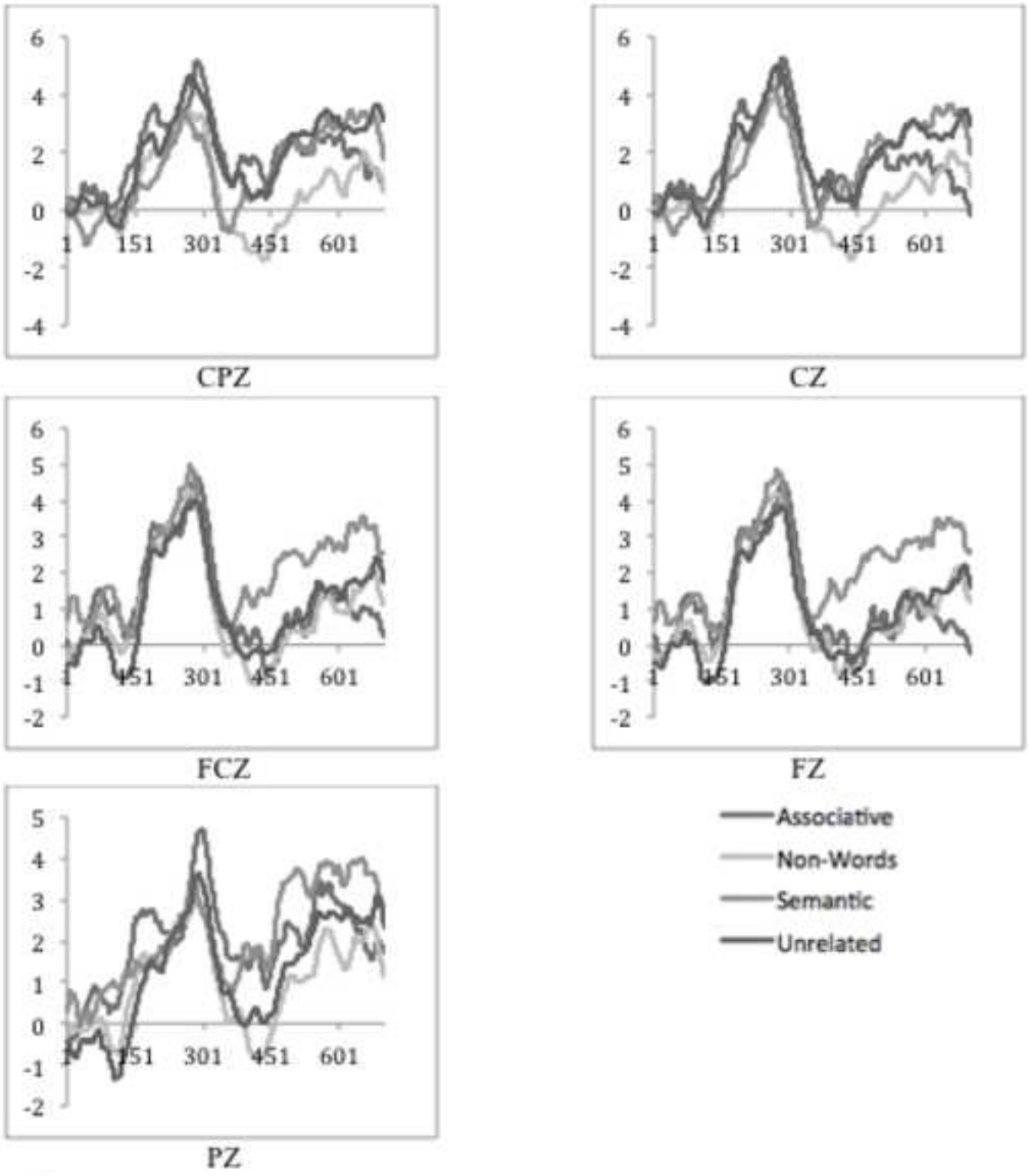

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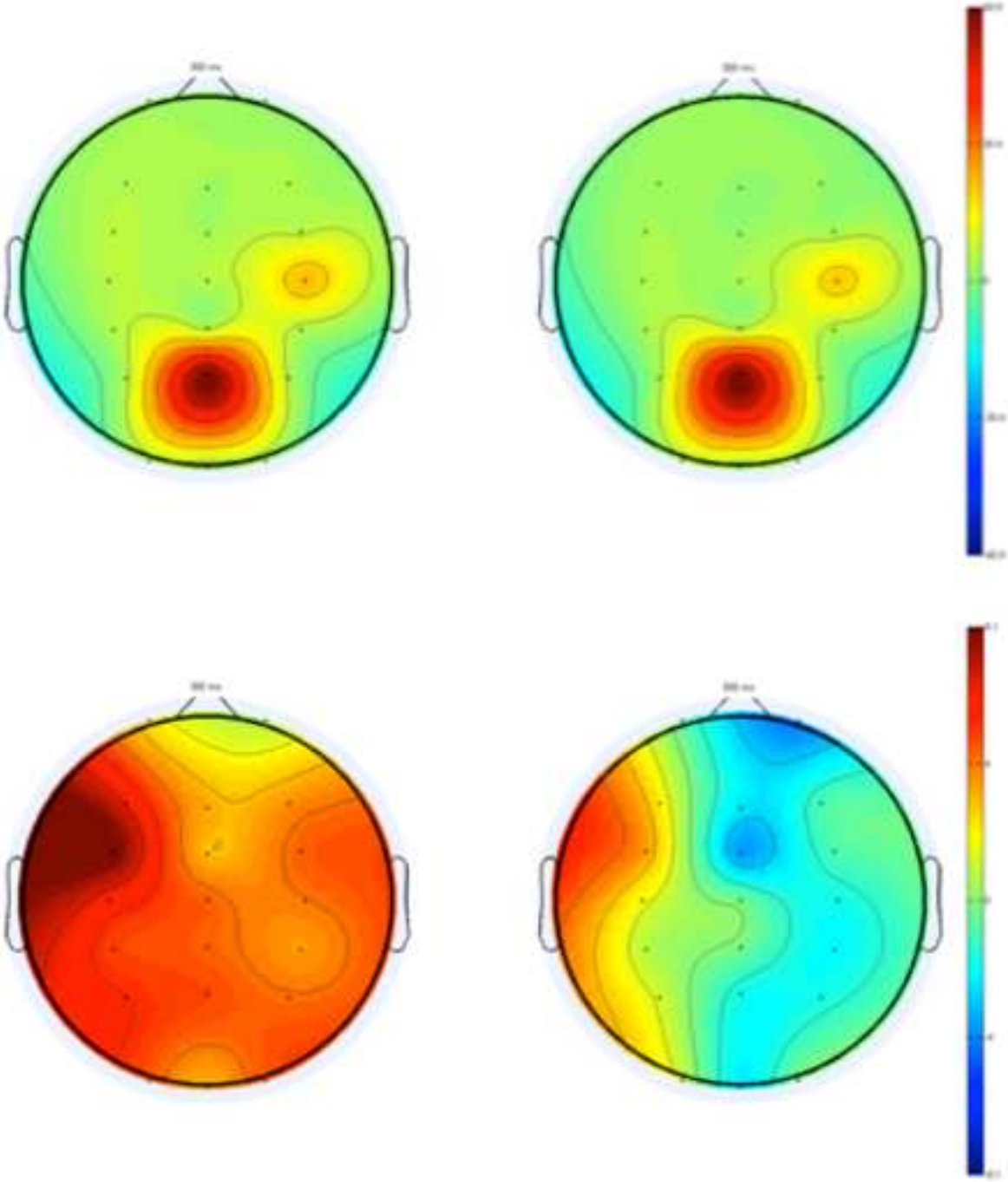

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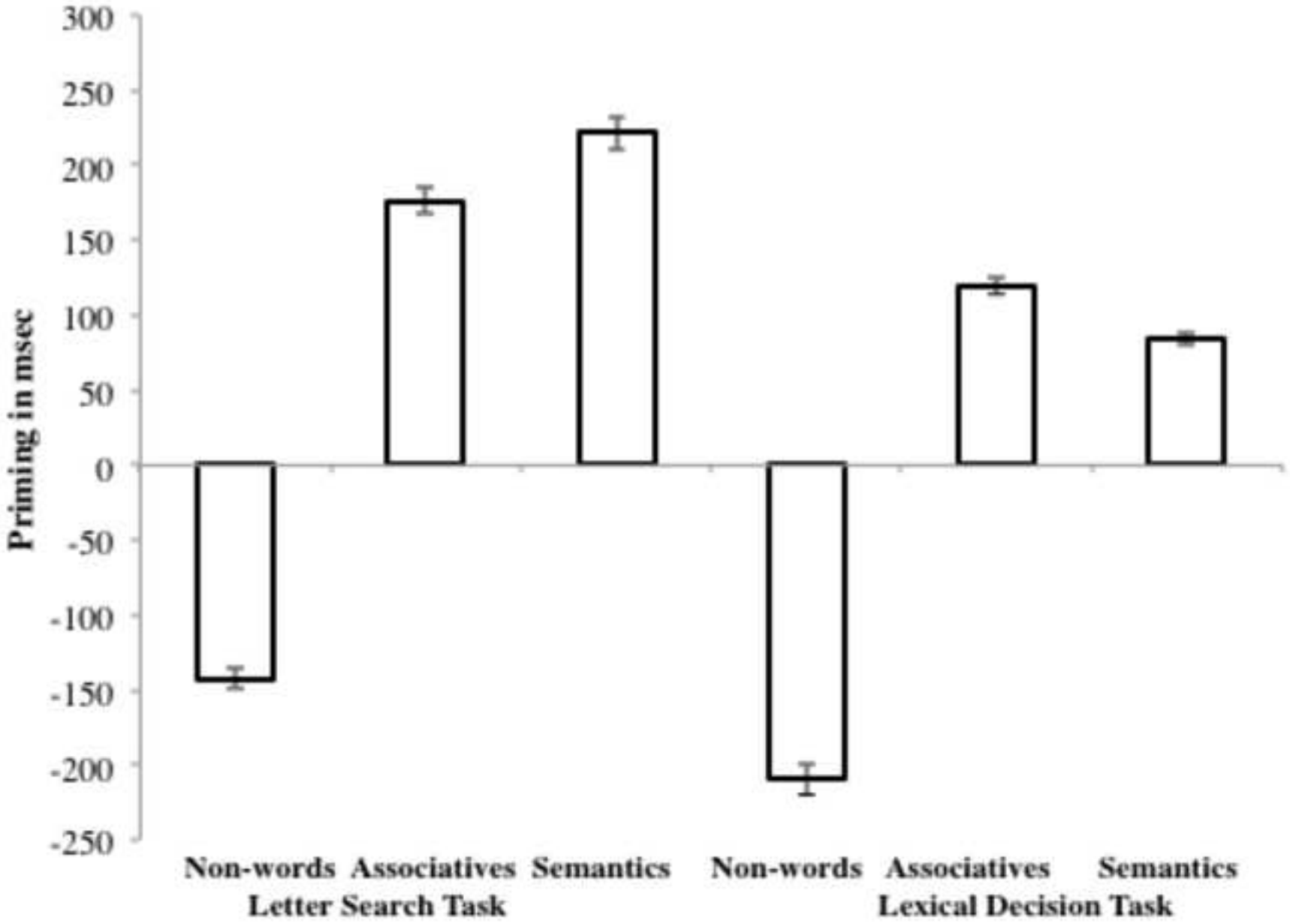

Figure 4.