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The Electrophysiology of Written Informal Language

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THE ELECTROPHYSIOLOGY OF WRITTEN INFORMAL LANGUAGE

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I dedicate this thesis to several people: my family, my fiancé, my advisor, and my colleagues. Mom, Dad, and Evan, your encouragement throughout my education has been tremendous. Your confidence in me has been a driving factor throughout my academic career. Julie, your unwavering support has been incredible. You have made an incredible sacrifice moving to Kentucky, and for that I am extremely grateful. I am so happy that I have you in my life. Lance, your willingness to help has always been appreciated. Between countless emails and meetings, you have been the main factor underlying my graduate school success. I have truly enjoyed working with you and I hope that we stay in touch. And to my friends, thank you for always being there. I find it amazing how we have become so close in only two years. To all of you, thank you for everything.

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Language is an essential component of human behavior. It is ubiquitous, but more importantly, it is malleable and it is constantly changing. Part of the dynamic nature of informal communication is the introduction and adoption of new linguistic elements. Online communication provides a window into this informal public discourse; therefore, it may be useful for testing hypotheses about the processes underlying the acquisition and use of new words. The comprehension of informal language may lead to an understanding of how these new informal words are integrated into our mental lexicon.

The current study was an electroencephalographic (EEG) investigation of the brain processes that underlie informal language. We recorded event-related potentials while participants engaged in a lexical decision task. For this experiment, participants made judgments about Twitter targets primed with semantically related or unrelated words. Classic psycholinguistic studies have shown very specific event-related potentials (ERPs) for semantic processing. Most notably, the N400 event-related potential component is an index of lexical expectancy and semantic relatedness. In contrast to the literature, we did not find classic N400 priming effects. However, our results revealed marked differences between informal and traditional targets. Our results suggest that informal language is more difficult to process than traditional language.

Chapter 1: Introduction and Literature Review

Languages provide a basis for human relationships and interactions. Effective communication is dependent on our ability to organize concepts into coherent thoughts and to communicate them to others. It is equally important to be able to receive information that can generate new coherent thoughts. The style of language adapts to changes in the human communication environment. An example of such an adaptation occurred in the 1980s with the introduction of the short-message service (SMS). SMS drastically altered interpersonal communication (Crystal, 2008) by defining the linguistic environment commonly used in text messaging. SMS communication often consists of abbreviated words such as acronyms and symbols.

Psychological research has adapted with the changes in texting language in an attempt to understand how new language elements are processed, acquired, and utilized in daily communication. As new online social networks are generated, the informal language used changes. For example, hash-tag expressions (e.g., #WCW meaning ‘woman crush Wednesday’) have become popular. Previous research (see Berger & Coch, 2010; Ganushchak, Krott, & Meyer, 2010, 2012 for examples) examining language used in text messaging has found that these linguistic elements are processed similar to traditional words.

Cognitive psychological models have represented language as a network of interconnected concept nodes. Each node is able to activate the nodes to which it is connected. This model of language has been described in the *spreading activation theory* (Collins & Loftus, 1975; Collins & Quillian, 1969). The concept nodes allow us to make internal mental connections that facilitate communication and human interaction. Spreading activation provides an attempt to illustrate the cognitive processing of language with a focus on how exposure to a concept or word can influence the mental representation of related elements.

Insights into the temporal aspects of the physiological components of language have been gained from the use of event-related potentials (ERPs). ERPs have been particularly useful for isolating specific temporal components of language comprehension. This technology provides excellent temporal information, with some spatial information. Although electrode activity can be clustered using statistical tests, only general inferences based on electrode locations can be made. The ability to conceptualize when language processing occurs in the brain is an important tool for testing hypotheses within the field of psycholinguistics to better understand the neural mechanisms of human language.

This thesis will synthesize literature on how the mind connects concepts and will discuss theoretical models of language processing. Additionally, the recent changes in informal language will be examined. New language items are continuously generated within new online social networks and this paper will discuss the usefulness of examining newly generated online language. Specifically, the following synthesis will support the need for an electrophysiological examination of new informal language items and will discuss the electrophysiological mapping of cognitive processes.

Spreading Activation Theories

Originally designed as a way to encode information in computer memory, the spreading activation theory suggests that conceptual "nodes" interact with each other using linear paths of communication between concepts. That is, node 1 activates node 2, which activates node 3, creating pathways that will integrate with each other (Collins & Quillian, 1969). As the activation spreads between nodes, a pathway is developed and is used in both the production and understanding aspects of communication processes. Collins and Loftus (1975) adapted the spreading activation theory to include semantic processing and language, subsequently referred to as the *spreading activation theory of semantic processing*. When a semantic concept is activated, the activation automatically spreads to all other concepts that are associated with the initial concept node (e.g., *cat* activates *dog*, which in turn activates *bark*, which in turn activates *tree*). This activation creates a linear path of activated concept nodes (see Figure B1).

The hypothesized spreading activation theory operates under some important assumptions. First, the spreading of activation attenuates as it travels from the initial concept activation. In theory, the activation from *cat* to *dog* would be strong, however the activation from *cat* to *tree* would be weaker because the distance between the initial and final concept node is greater. A second assumption is that prolonged focus on a semantic concept elicits strong activation. Third, multiple concept activations will combine to increase the network size as more connections are generated. These large semantic networks are grouped by semantic similarity and create our lexical dictionary (Collins & Loftus, 1975).

In contrast, some theorists have disagreed with the Collins and Loftus model, saying that the spreading of activation is non-sequential (Nelson, Kitto, Galea, McEvoy, & Bruza, 2013). Figure B2 illustrates an alternate network theory of semantic processing suggested by Nelson, McEvoy, and Pointer (2003) referred to as the *spooky-activation-at-a-distance theory*. Nelson and colleagues suggest that activation of a target will rapidly spread to its paired associates, such that activation is shared between the associates. A higher number of connected concepts would suggest that the semantic networks are much larger and that the collective associative strengths of these semantic connections are much stronger than connections in other activation models such as spreading activation theory.

More recently, Galea, Bruza, Kitto, Nelson, and McEvoy (2011) have proposed the “Entanglement Model,” which applies quantum mechanics to mental word representations. This model suggests that activation of a target simultaneously spreads to all available associates, however the associates hover between an active and inactive state, competing for activation. The entire semantic network is activated when the representation is fully activated, generating a large number of connections. Although there are important differences across the theories, there is commonality across all models: activation does spread and a node can have increased activity as a result of activation occurring within the semantic network.

Semantic Priming

An understanding of semantic network processing provides insight into how the mind accesses mental representations. Semantic priming provides one way to observe semantic network processing. Semantic priming is an effect that has been observed when word recognition is facilitated by exposure to a related prime word. According to McNamara (2005), semantic priming can be broken down into two distinct processes: expectancy and matching. These processes can be simplified as forward thinking (expectancy) and backward thinking (matching); expectancy may generate potential target outcomes and matching may search for a relationship after the target had presented.

The temporal characteristics of semantic priming can be assessed behaviorally by manipulating the stimulus onset asynchrony (SOA). Past research has suggested that an SOA of 50 ms is far too rapid for significant priming to occur, whereas an SOA of 100 ms has generated priming effects (Ratcliff & McKoon, 1981). These effects have been commonly reflected in reaction times (Chwilla, Brown, & Haggort, 1995). Furthermore, semantic priming effects have been observed in an assortment of tasks, such as cross-modal priming paradigms (Tabossi, 1996), free association tasks (Nelson, McEvoy, & Schrieber, 1991), lexical-decision tasks (Luck, Vogel, & Shapiro, 1996), and studies measuring event-related potentials (see Kutas & Federmeier, 2011 for review).

Event-Related Potentials (ERPs)

The use of non-invasive brain imaging has facilitated the advancement of scientific approaches to studying physiological language processes. ERPs refer to time-locked neural activity measured using brain electroencephalography (EEG). ERPs provide insight into when, and to what extent, changes in electric potential due to processing are occurring (i.e., temporal information) Additionally, ERPs can provide limited spatial information. ERP analyses are focused on the shifts in a targeted ERP waveform at a specific point in time. These shifts represent alterations in the negative or positive going nature of waveforms reflecting localized differences in scalp potential and are in response to a salient time-locked event such as the stimulus onset or participant response. Specific ERPs are referred to as components, with each component representing a response to a different type of stimulus (e.g., the N170 is a negative shift peaking at 170 ms in response to facial stimuli; Luck & Kappenman, 2011). Moreover, ERPs have been used to measure cognitive functioning for decades, and have provided valuable information regarding psycholinguistics (Kutas & Van Petten, 1988).

ERPs and Semantic Priming

Several ERP components have been associated with psycholinguistics, such as the N400 (semantics) and P600 (syntax). Generally, each component would be present in response to some variation of task, stimulus, or response. For example, the P600 component (i.e., a positive shift with amplitude peaking at roughly 600 ms post stimulus onset) is often associated with repairing or correcting syntactical or semantic violations. The P600, known as the syntactic positive shift (SPS), presents over posterior electrodes (Luck & Kappenman, 2011). Whereas the P600 reflects late processing, earlier semantic processing is reflected by the N400.

Kutas and Hillyard (1980a, 1980b) discovered a linguistic component at 400 ms that was sensitive to semantic abnormality. The N400 component is a negative deflection that peaks between 250 and 500 ms following the onset of a stimulus. The N400 has been associated with context dependent semantic processing, such that greater N400 amplitude is observed when stimuli are unexpected or unrelated, compared to a stimuli that are expected or related (see Kutas & Federmeier, 2011; Lau, Phillips, & Poeppel, 2008 for reviews). Kutas and Hillyard (1980a) initially examined the N400 using variations of cloze probability in a sentential paradigm. A high cloze probability refers to a high likelihood that a specific word would end a sentence given the sentence context preceding the last word. A low cloze probability refers to a low likelihood that a specific word would end a sentence given the sentence context preceding the last word. They found greater N400 amplitudes for unexpected terminal words compared to expected terminal words (e.g., The dog chased the cat through the *chair* versus The dog chase the cat through the *house*).

The N400 effect has been observed in a variety of tasks, independent of sentence processing. Bentin et al. (1985) integrated words and non-words into a semantic priming paradigm and measured the electrophysiological differences between words that were preceded by a prime, and those that were not. The results displayed attenuated N400 amplitude for target words that were preceded with a related prime word. Moreover, Chwilla et al. (1995) provided converging evidence that using semantically related primes in a lexical decision task did reduce N400 amplitudes. Together, these results indicate that semantic processing is facilitated (or not disrupted) with the use of related primes compared to unrelated primes.

A variety of task manipulations within a semantic priming procedure can affect the N400. Some examples of these manipulations include the use of backward (strong target-prime relationship) and forward (strong prime-target relationship) priming (Franklin, Dien, Neely, Huber, & Waterson, 2007), cueing the participants' attention to the prime (Holcomb, 1988), manipulating the degree of semantic similarity (Koivisto & Revonsuo, 2001), having participants make relatedness judgments (Kreher, Holcomb, & Kuperberg, 2006), or manipulations of word expectancy (Kutas & Hillyard, 1984). Additional factors that influence the N400 include task variations like letter searches, masked priming, or stimulus degradation (Brown, Hagoort, & Chwilla, 2000; Holcomb, 2007), repetition priming (Rugg, 1987), semantic matching, and expectancy (Franklin et al., 2007). These data provide decades worth of evidence showing that the semantic priming paradigm is a reliable procedure for observing some ways that words influence one another during reading.

While the semantic priming task has been an important approach for observing semantic processing, there has been some disagreement about the level of processing (e.g., orthographic, phonologic, or semantic) that the N400 represents. For instance, changes in N400 amplitude have been hypothesized to demonstrate both pre-lexical activation and post-lexical activation; in other words, pre-word processing or post-word processing. In a pre-lexical model, the N400 would represent activation due to automatic processing or automatic spreading of activation (Deacon, Dynowaska, Ritter, & Grose-Fifer, 2004 Heil, Rolk, & Pecchinenda, 2004; Kiefer, 2002). In contrast, a post-lexical model would imply that word meaning was already accessed. Thus, the N400 represented semantic association after the activation of a target (Chwilla, Kolk, & Mulder, 2000).

Arguing against the post-lexical view, Deacon, Hewitt, Yang, and Nagata (2000 suggested that the N400 represented automatic pre-lexical activation at an orthographic (i.e., spelling) and phonological (i.e., sound). Deacon and colleagues believed the N400 was pre-lexical, but attributed it to some degree of top-down processing and not solely semantic processing. They found that N400 effects were observed when real words had been transposed into orthographically similar non-words that had some context. Additionally, similar research has suggested that pseudowords (i.e., non-words that resemble real words in orthography and phonology) generate N400 effects due to semantic activation (Coch & Mitra, 2010; Laszlo & Federmeier, 2009). In these studies, the presence of the N400 effect suggested that the brain was processing the orthographic or phonological variant, and was pre-lexically using top-down processing to apply semantic information. Alternatively, some theories suggest that the N400 effect represents multi-level (i.e., simultaneous orthographic and semantic) processing (Laszlo & Federmeier, 2011).

Language Differences

Research on the N400 semantic priming effect has extended beyond the constraints of a single language. Cross-linguistic priming studies have suggested that regardless of the native language, semantic information can be accessed from both native and secondary languages. Moreover, these effects have been demonstrated both behaviorally (Jin, 1990) and electrophysiologically (De Bruijn, Dijkstra, Chwilla, & Schriefers, 2001; Kerkhofs, Dijkstra, Chwilla, & DeBruijn, 2006). Research using the Dutch language suggested that prime words in a non-native language could still generate N400 priming effects even when targets were in the native language.

Similarly, differences in language have also been observed in N400 latency. Hahne (2001) compared N400 amplitudes between monolingual German speakers and bilingual Russian speakers who learned German as a second language. Hahne observed similar N400 patterns across groups, however amplitudes were reduced and latencies were extended for bilinguals. Additional research has suggested that N400 amplitudes in the non-native language tend to peak approximately 40 ms later than the native language (Moreno & Kutas, 2005).

Some researchers have shifted their focus toward modern interpretations of language such as informal language (i.e., text messaging language, online social network language, acronyms, slang, etc.). With an increase in acronym prevalence, attention needed to be given to acronym processing. Izura and Playfoot (2011) conducted a study using an acronym-naming task, where participants were exposed to numerous acronyms varying on factors like familiarity and orthography. They also collected information on age of acquisition, imageability, and number of orthographic neighbors. Together, these data suggested that studies using acronyms should pay special attention to the orthographic, phonological, and semantic characteristics of acronyms.

Further research on acronym processing has suggested that common letter strings (e.g., HDTV for high-definition television) may be processed like real words. Laszlo and Federmeier (2008) provided evidence that acronyms were able to generate N400 differences with similar latency (duration), morphology (shape), and spatial distribution to traditional English words. They have also suggested that nonsense acronyms (i.e., illegal letter strings like XTDF) can generate N400 effects, as an illegal letter string may violate the sense of expectancy or the activation of stored semantic information. These findings indicate that informal language may be processed much like traditional language. Moreover, some evidence has suggested that some informal language (i.e., abbreviations and acronyms) may be processed like a second language (Berger & Coch, 2010; Ganushchak et al., 2010, 2012).

Research on informal language has also looked at texted English. Using English words translated into “text-speak” (i.e., informal abbreviations that share phonological properties but differ in orthography; for example, c@ instead of cat or l8r instead of later), Berger and Coch (2010) found that text speak elicited classic N400 effects. Interestingly, the N400 effects observed in the text speak condition resembled N400 effects found in previous bilingualism N400 studies (see Hahne, 2001; Moreno & Kutas, 2005). Specifically, N400 amplitudes for informal words peaked 60 ms later than traditional English words. Taken together, these data provide converging evidence that informal language (e.g., text speak) may be processed much like a second language. Although, these results may be representative of sentence-level processing and not word-level processing.

Chapter 2: Overview of the Current Study

The relationship between informal and traditional language is not well understood. Within the past several years, researchers have examined common acronyms and texted English (Berger & Coch, 2010; Ganushchak et al., 2010, 2012; Laszlo & Federmeier, 2008). However, informal language is not stagnant; it is ever changing in parallel with communication technology developments (e.g., social media platforms). The goal of this study is to examine the relationship between novel informal language and traditional language. Whereas previous studies have examined common acronyms (e.g., HDTV, CPR) and phonologically congruent shortcuts (e.g., c@ instead of cat), we were interested in novel stimuli isolated from the social media platform Twitter.

Similar processing between language used on Twitter and traditional language could suggest that informal language networks operate like a second language. That is, fluent informal language users may be considered bilingual. In this case, both languages would share lexical and semantic processing abilities. If informal and traditional languages do not appear to be analogous, then the case may be that informal language is simply a semantically rooted subset in our pre-existing traditional language. Evidence for this possibility may manifest in longer processing times for informal language as it requires longer processing times due to translational interference.

To test this relationship between informal and traditional language, we recorded EEG data while participants engaged in a lexical decision task. In the task, both real words and non-words were primed with either a semantically related word or a semantically unrelated word. We hypothesized that related primes would facilitate the recognition of both traditional and informal words (e.g., *captain* – *pilot* and *funny* – *lol*). For the EEG data, we predicted that unrelated prime words preceding both traditional and informal words would elicit larger N400 amplitudes than related prime words. Figures B3 and B4 depict the behavioral and electrophysiological hypotheses.

In this study, the effects of several independent variables were examined. Prime type was manipulated by using both semantically related and unrelated primes. Language type (or word type) was manipulated by exposing participants to both informal and traditional English targets. Dependent measures included electroencephalography (EEG; event-related potentials), behavioral reaction times (RTs), and familiarity scores on an informal language assessment. General familiarity was assessed to determine the degree of exposure participants have with informal language.

Chapter 3: Materials and Methods

Participants

Participants were 16 Introductory to Psychology students (*M* = 18.68, *SD* = 2.49) recruited from the Western Kentucky University Study Board. All participants were native English speakers with no history of severe neurological deficit. Of the 16 students, 14 were female, and 14 were predominantly right handed. All participants signed an informed consent document approved by the Western Kentucky University Institutional Review Board. Participants received one Study-Board credit per half hour of their participation as well as $20.00 in cash provided by the Western Kentucky University Graduate Studies Student Grant. Our sample originally included 18 participants, but two participants were excluded from data analysis due to falling below a task accuracy of 80%.

Stimuli

For this experiment, the public communication on the Twitter online social network (OSN) was the source of informal words. Public data was harvested over multiple sessions using code written in Java. Harvested Twitter data included the date of the composed message, the general geographical location of the composed message, and the Twitter user ID number (which was then converted to a different identification number for confidentiality purposes). Communication was gathered for a geographical location defined by central latitude and longitude coordinates and a radius. Using Microsoft Excel and a program written in the lab, a frequency histogram was created to break down and organize the words in order by total number of occurrences. Once the word frequencies were organized, any word occurring once (i.e., a singleton) was deleted because the word was not regularly used in the original messages, and was not deemed to be an important component of the OSN language.

As word information was now organized, a comparison database was necessary to differentiate traditional English and non-English words. For the purposes of this experiment, the MOBY Words II list via Project Gutenberg was used as our reference text (Ward, 2002). The MOBY Words II list is a large English word database. Microsoft Excel was used to isolate Twitter words that were absent from the MOBY Words II reference list. Repeating words (i.e., orthographic extensions of a root word) were condensed into the base word (e.g., lolololol was converted to *lol*) and any punctuation marks were deleted for the sake of parsimony. Punctuation marks were only removed if they were attached to a word but not if they were integrated into an apparent symbol or emoticon. The majority of the harvested words were identified as *abbreviations*, *slang vernacular*, *emoticons* or words that were *compressed* by removing one or more letters. In order to reduce the effect of familiarity confounds, abbreviations that represented a proper noun (i.e., a city, state, college, or name) were removed from the target list. A list of 344 words was compiled, categorized, and reduced to a working list sorted by the aforementioned groupings. Semantic priming conditions were created and applied to the target lists: a semantically congruent word, and a semantically incongruent word that was similar in length and frequency to the semantically congruent word. Appendix C contains all informal targets (sorted by abbreviation or acronym) with all prime pairings. Traditional targets were matched on word length with the informal targets.

Procedure

Participants arrived at the Cognitive and Behavioral Neuroscience Lab and were greeted by the experimenter. A basic overview of the event-related potential data collection procedure was read. Participants were informed that an EEG net would be used to measure electrical conductance on the skull. Participants were informed that by the end of the experiment, their hair would be wet as the EEG net would be soaked in a solution consisting of distilled water, potassium chloride, and baby shampoo. Participants were informed that a blow dryer and towels would be readily available for use after the experiment. Following a description of the EEG net procedure, participants were provided a copy of the stamped Informed Consent document (approved by the Western Kentucky University Institutional Review Board on March 24, 2014; #14-377). Participants were asked to read over the document, ask any pertinent questions, and then sign the document. The experimenter signed as witness and the informed consent documents were placed in storage.

Following the informed consent, head measurements (i.e., circumference, nasion-inion, and meatus-meatus) were taken. The participant's vertex was marked with a red water-soluble marker. All measurements were recorded on the experimental protocol sheet. After making the measurements, the participants were asked to remove any electronic devices or car keys from their pockets. Participants completed an interactive PDF of a demographic questionnaire, the

Brief Edinburgh Handedness Questionnaire, and a neuropsychological screening. Participants took approximately ten minutes to fill out all of the computerized forms.

As participants were completing the forms, the experimenters created the electrolyte solution and soaked the appropriately sized EEG net. After the net passed a basic functioning test, the participants were placed in the net. If the electrode net passed all inspections, then the experiment would begin. Following completion of the experiment, the participants were paid $20.00. The participants were thanked for their participation before they left the lab.

Equipment and Laboratory Software

Stimuli were generated and organized in the Western Kentucky University Semantics Laboratory. All EEG data were collected and analyzed in the Western Kentucky University Cognitive and Behavioral Neuroscience Laboratory. EEG data were collected and analyzed with NetStation EEG Data acquisition software. E-Prime experimental design software was used to create and run the lexical decision task, which was displayed on a 19-inch Dell Monitor.

Lexical Decision Task

Participants engaged in a lexical decision task that required them to make judgments about words. All stimuli were presented in 14-point white Arial font on a solid black background (consistent with the white on black presentation of Berger & Coch, 2010). Participants were presented with a fixation cross for 200 ms followed by a blank screen for another 200 ms. Immediately after the blank screen, a prime word presented for 84 ms; the prime was either semantically related or unrelated to the upcoming target word. Following the duration of the prime, another blank screen presented for 200 ms. Depending on the specific block, either an informal word or traditional word target presented until the participant provided their response (i.e., word or non-word). The left button (1) signaled a “word” response, whereas the right button (4) signaled a “non-word” response. If the participant did not respond within a 4000 ms time period, the next trial automatically started (see Figure B5 for a depiction of the task). There was a 1000 ms inter-trial interval.

Four task versions were used with each containing two blocks of informal targets and two blocks of traditional targets. Participants were assigned to a version (see Table A1) depending on which version was next in the version log (N = 4 for all task versions). Within each block, there were four types of pairings. Table A2 represents each pairing.

As this experiment had a within-subjects design, every participant was exposed to each block version containing all four language blocks of randomized trials. Each language block consisted of 120 trials leading to a total of 512 trials (i.e., 32 practice trials and four 120-trial blocks). Reaction times were recorded. A short break separated each block in order to give the participants a resting period.

Following the lexical decision task, a familiarity assessment (i.e., the Informal Language Familiarity Assessment; ILFA) consisting of 66 informal words from the task was given. In this assessment, participants were asked to read a series of informal words (including two non-words used as distractors) and asked to rate their familiarity with a word on a 1-5 Likert scale. Participants were instructed that familiarity referred to their degree of exposure to the word. On this scale, one (1) denoted minimal exposure, whereas five (5) denoted high exposure.

Behavioral Analyses

To investigate the semantic priming effect, two techniques could have been used. First, difference values could be calculated for each participant. Each participant was exposed to each target once following a related prime and once following an unrelated prime. The amount of priming associated with each target could be calculated by subtracting the related prime reaction time from the unrelated prime reaction time. Any positive deviation from zero represented facilitation in recognition and could be interpreted as a semantic priming effect. However, this type of analysis is focused on individual targets and would be overly sensitive to missing data and individual differences.

The second option involves examining the prime within-subject variable at the group level. This approach would allow us to examine the differences between prime type accounting for all targets, thus providing a bigger and more generalizable picture. This group-based analysis is not as sensitive to target level differences since it operates on the group means for prime type. For our analyses, we chose the second approach and used a series of Paired-Samples *t*-tests to analyze prime differences within traditional and informal language separately.

Additionally, we were interested in overall reaction time differences between informal and traditional words collapsed across unrelated and related primes. For this analysis, we used a paired samples *t*-test to compare mean reaction times. All statistical tests had an alpha criterion of $p < .05$, and effect sizes were calculated for each. Incorrect and non-word trials were removed from the analyses to eliminate noise while simultaneously removing outliers (e.g., RTs outside of a 200 ms – 2000 ms range).

EEG Recording

All EEG data were collected using 128-electrode Hydrocel Geodesic sensor nets. Waveform data were amplified and recorded using NetStation EEG Acquisition Software. While offline, electrode nets were placed on the scalp of the participant and aligned to the VREF electrode (i.e., the marked vertex). All proper adjustments were made such that the electrode midline (Nasion, Fz, VREF/Cz, COM, Pz, Oz) was set in a straight line through the middle of the scalp. Ocular electrodes (i.e., 126, 127) were placed on bilateral suborbital ridges. All mastoid and ocular electrodes were adjusted using the adjustment straps. Once online, band pass filters were set to the range of .3Hz to 30Hz with an amplitude scale of 30 microvolts. All electrodes were manually adjusted so that impedance levels remained below a 70 kilo-ohm (k□) threshold.

EEG Analysis

EEG data were initially filtered using a high-pass of 0.3 Hz and a low-pass of 30 Hz. Participant data was then segmented into 850 ms epochs (i.e., a 100 ms pre-target onset to 750 ms post target onset). In order to reduce noise, only correct and real-word trials were included in the analyses. As a result, the number of segments varied across participants. Following segmentation, data were manually inspected for noise and any bad channels were removed. During data collection, ocular artifacts (i.e., eye blinks) were measured. Using an ocular artifact removal script, noise associated with eye movement was removed from the analysis. Following ocular artifact removal, the data were averaged, combining all participant data into the eight categories listed in Table A3.

The category averages were combined into a grand average file with all averaged participant data for each condition. After visual inspection of the grand averages, thirteen electrodes from the posterior temporal region (see Appendix D) were selected for analysis (57, 58, 59, 60, 61, 64, 65, 66, 67, 68, 69, 70, and 73). These specific electrodes were chosen based on their similar pattern of waveform differences post 250 ms (see Figure B6). An internal consistency analysis was conducted on the selected electrodes across all within-subjects variables for each participant. The reliability analysis (see Table A4) revealed that Cronbach's $\alpha = .97$, suggesting that the selected electrodes were a cohesive measure of the desired constructs.

ERP waveforms were locked to the target onset (time = 0) and included a 100 ms pre-target baseline. For the prime type analysis, visual inspection of the EEG data revealed four epochs of interest where there were clear waveform separations (i.e., 0-240 ms, 240-400 ms, 400-560 ms, and 560-850 ms). These data were analyzed with a 2 (prime type; unrelated, related) by 4 (epoch; 0-240 ms, 240-400 ms, 400-560 ms, 560-850 ms) repeated measures analysis of variance (rmANOVA). The analysis was conducted on both informal and traditional words separately. For the word type analysis, visual inspection of the waveform revealed only three epochs of interest (i.e., 0-240 ms, 240-500 ms, and 500-850 ms). These data were analyzed with a 2 (target word type; informal, traditional) by 3 (epoch; 0-240 ms, 240-500 ms, 500-850 ms) rmANOVA. The analysis was conducted on the grand average voltage collapsed across prime type (i.e., related and unrelated prime types were averaged).

Chapter 4: Results

Behavioral Results: Reaction Times

The series of paired samples *t*-tests revealed prime type differences in both traditional and informal language. However, the effect of prime was only significant within traditional language (see Figure B7). On average, related primes preceding traditional targets (M = 739.05, SD = 166.39) facilitated faster reaction times than unrelated primes preceding traditional targets (M = 762.05, SD = 171.41). $t(15) = -2.496$, $p = .025$, $d = .14$. For informal language (see Figure B8), the data only suggested a semantic priming trend, such that related primes preceding informal targets (M = 958.75, SD = 187.54) only moderately facilitated faster reaction times than unrelated primes (M = 977.59, SD = 198.81). However, the paired samples *t*-test revealed this trend was non-significant, $t(15) = -1.061$, $p = .305$, $d = .10$.

When analyzing the prime type data, we noticed an interesting word level trend. These data revealed that averaging across both related and unrelated primes, informal language targets were taking roughly 217 ms longer to process than traditional language targets. With only a non-significant trend for informal semantic priming, we shifted our attention towards overall informal language processing. A paired samples *t*-test was conducted on mean reaction times collapsed across prime type (unrelated and related primes). On average, informal words (M = 967.83, SD = 189.41) elicited longer reaction times than traditional words (M = 750.68, SD = 168.18), $t(15) = 6.875$, $p < .01$, $d = 1.74$ (see Figure B9). This result suggests that informal words were significantly more difficult to process. We attributed this difference in processing time to participants actively decoding informal language targets in ways that are efficiently processed with traditional word targets.

Behavioral Results: Familiarity

The Informal Language Familiarity Assessment (ILFA) revealed a relatively high overall familiarity with informal language (M = 4.12, SD = .045). Two distractors were originally included on the form and yielded a familiarity score of M = 1.03, SD = .04. These distractors were removed from the overall familiarity calculation. A reliability analysis conducted on the ILFA yielded a Cronbach's alpha of .942. Taken together, these results suggest that our participants were familiar with the stimuli being used and that our assessment was an excellent measure of informal language familiarity. An analysis of the relationship between the overall ILFA score and the average reaction time for informal words revealed a non-significant association, $r = -.187$, $p = .509$.

EEG Results: Prime Type on Informal Words

Upon visual inspection of the informal word waveforms, robust differences between prime types were evident, suggesting that physiological priming differences were present (see Figure B10). The 2 x 4 rmANOVA on informal words revealed a main effect of prime type, time, and a prime type by time interaction. Unless otherwise noted, the assumption of sphericity was not violated or corrections regarding sphericity resulted in negligible changes in the reported results. If the results were consistent with previous N400 effects, then unrelated primes should elicit greater negativity (i.e., in microvolts; mv) in the 250 ms to 500 ms time period. However, our analysis revealed the opposite: targets preceded by related primes elicited greater negativity than targets preceded by unrelated primes in this time range.

There was a main effect of prime type such that targets preceded by related primes (*M* = -.829 mv, *SE* = .034) generated greater negativity than targets preceded by unrelated primes (*M* = -.561 mv, *SE* = .054), *F*(1, 40) = 71.770, *p* = .000, □□^{2} = .642 (see Figure B11). Pairwise comparisons confirmed that targets preceded by related primes generated more negativity than targets preceded by unrelated primes, *p* = .000. For time, there was a main effect such that the 560-850 ms epoch (*M* = -2.118 mv, *SE* = .038) was associated with greater negativity than the 0-240 ms epoch (*M* = .265 mv, *SE* = .148), the 240-400 ms epoch (*M* = .078 mv, *SE* = .075), and the 400-560 ms epoch (*M* = -1.005 mv, *SE* = .045), *F*(1.474, 58.961) = 153.443, *p* = .000, □□^{2} = .793 (see Figure B12). Pairwise comparisons confirmed that all voltage differences between epochs were statistically significant at *p* = .000 with the exception of the difference between the 0-240 ms and 240-400 ms epochs. Finally, there was a significant prime type by time interaction such that targets preceded by related primes in the 560-850 ms epoch (*M* = -2.269 mv, *SE* = .051) generated the greatest negativity, whereas targets preceded by unrelated primes in the 0-240 ms epoch (*M* = .291 mv, *SE* = .144) generated the least negativity, *F*(2.562, 102.462) = 29.271, *p* = .000, □□^{2} = .423 (see Figure B13).

Collectively, the revealed effects are contradictory to the original hypotheses of this study. Initially, it was predicted that semantically targets preceded by unrelated primes would generate greater negativity within the general 250 -500 ms epoch. However, our results suggest that negativity did present within that window, but in response to targets preceded by related primes rather than unrelated primes. A paired samples *t*-test on the 400-560 ms epoch confirmed that targets preceded by related primes (*M* = -1.32 mv, *SD* = .35) generated greater negativity than targets preceded by unrelated primes (*M* = -.686 mv, *SD* = .33), *t*(40) = -11.120, *p* = .000. Combined with the behavioral data, these results provide evidence that informal language may not be processed as efficiently as traditional language in a semantic priming paradigm.

EEG Results: Prime Type on Traditional Words

Visual inspection of the traditional word waveforms also revealed robust differences between prime types (see Figure B14). The 2 x 4 rmANOVA on informal words revealed a main effect of prime type, time, and a prime type by time interaction. The main effect of prime type revealed that targets preceded by related primes (*M* = -.446 mv, *SE* = .047) generated greater negativity than targets preceded by unrelated primes (*M* = .048 mv, *SE* = .047), *F*(1, 40) = 674.812, *p* = .000, □□^{2} = .945 (see Figure B15). Pairwise comparisons confirmed that within each epoch, targets preceded by related primes generated more negativity than targets preceded by unrelated primes, *p* = .000. For time, there was a main effect such that targets in the 560-850 ms epoch (*M* = -1.211 mv, *SE* = .020) had greater negativity than the 0-240 ms epoch (*M* = .325 mv, *SE* = .161), the 240-400 ms epoch (*M* = .447 mv, *SE* = .079), and the 400-560 ms epoch (*M* = -.359 mv, *SE* = .061), *F*(1.850, 72.146) = 62.754, *p* = .000, □□^{2} = .617 (see Figure B16). Finally, there was a significant prime type by time interaction such that targets preceded by related primes in the 560-850 ms epoch (*M* = -1.607 mv, *SE* = .028) generated the greatest negativity, whereas targets preceded by unrelated primes in the 240-400 ms epoch (*M* = .659 mv, *SE* = .094) generated the greatest positivity, *F*(3, 117) = 136.908, *p* = .000, □□^{2} = .778 (see Figure B17).

EEG Results: Word Type

Visual inspection of the waveform (see Figure B18) suggested that word type differences were present. The examination of word type differences involved a similar collapsing of data, such that unrelated and related prime voltages were averaged into one dependent factor. A 2 x 3 rmANOVA on the average voltage revealed several effects. Most importantly, there was a main effect of word type such that informal words produced greater negativity (*M* = -.919 mv, *SE* = .046) than traditional words (*M* = -.512 mv, *SE* = .042), *F*(1,60) = 702.71, *p* = .000, □□*2* = .921 (see figure B19). Pairwise comparisons confirmed that informal words did generate greater negativity than traditional words, *p* = .000. For time, there was a such that the 500-850 ms epoch yielded greater negativity (*M* = -1.48 mv, *SE* = .034) than the 0-240 ms epoch (*M* = -.25 mv, *SE* = .11) and the 240-

500 ms epoch (*M* = -.412 mv, *SE* = .092), *F*(1.813,108.774) = 56.338, *p* = .000, □□^{2} = .484 (see Figure B20). Finally, there was a significant interaction such that informal words in the 500-850 ms epoch generated the most negativity (*M* = -1.733 mv, *SE* = .062), whereas traditional words in the 240-500 ms epoch generated the least negativity (*M* = -.100 mv, *SE* = .088), *F*(2,120) = 33.04, *p* = .000, □□^{2} = .355 (see Figure B21).

Summary

Collectively, our results provide some evidence for differences in semantic processing across traditional and informal language. Unfortunately, the results were not consistent with our hypotheses, and in some cases, the results were the opposite of previous semantic priming research. In sum, we observed a behavioral semantic priming effect for traditional language, however these data were not reflected in the EEG results. For informal language, we did not observe any significant semantic priming effect, although the data were trending towards a priming effect. Unfortunately, the EEG data did not support this trend and suggested an opposite effect. Interestingly, we did discover converging evidence that informal language is more difficult to process. Our analyses revealed a significant 217 ms difference between overall informal and traditional word recognition with significantly greater EEG negativity for informal language later in the epoch that is typically noted for the N400. All results, theoretical implications, and future directions will be discussed in the discussion and limitations segment.

Chapter 5: Discussion and Limitations

The goal of this study was to investigate whether informal language was processed similarly to traditional language. We used both behavioral (reaction times from a lexical decision task) and electrophysiological (event-related potentials) measures in an attempt to capture similarities and differences across both prime relatedness and language formality. In our study, we specifically investigated whether or not informal words isolated from the social networking website Twitter would be processed like real words. If informal words had their own semantic representation in the language network, then theoretically, activation should have been able to spread between prime and target. Behavioral evidence for this claim would include significantly shorter reaction times when related primes preceded a target in a lexical decision task. Electrophysiological evidence would include larger N400 amplitudes for targets following unrelated primes in the 250-500 ms time window. If we found evidence that informal words were processed analogously to traditional words, then the claim could be made that informal language may be processed like a second language. Unfortunately, our results for informal language only revealed a non-significant behavioral trend with no converging electrophysiological evidence to support that claim.

Informal Words Are Not Real Words

Collectively, our data have suggested that informal words may not be processed as words themselves, but rather as a code for a traditional word or sequence of traditional words. Our study revealed several interesting results. First, priming effects were present in both traditional and informal language.

Although the traditional language was associated with a significant priming effect, the effect in informal language was merely a non-significant trend. Second, longer reaction times were found in response to informal language than to traditional language. Third, analysis of our EEG data revealed an inverse N400 effect such that with informal words, related primes were generating greater negativity in our epoch of interest as well as overall greater negativity for informal language. Taken together, these data suggest that informal language requires greater processing capacity and that there may be a cost associated with switching between processing a traditional prime and an informal target. Moreover, semantic connectivity between traditional and informal word pairings may utilize a much greater portion of one's semantic network than traditional-traditional pairings.

In a previous study from our laboratory, we demonstrated that when primes were words found within the target acronym (e.g., laugh primed lol), recognition of the informal target was facilitated compared to unrelated primes (unpublished; Hahn, Blaetz, & Walters, 2014). In this case, traditional words were able to semantically connect to informal words. These results allowed us to make the claim that cross-linguistic facilitation was evidence for informal word representations in our language networks. In our current study, we used two different types of stimuli: acronyms and abbreviations. For the acronyms, semantically related primes were not found within the informal target (e.g., *funny* primed *lol*). For the abbreviations, semantically congruent primes were used (e.g., *friend* primed *dawg*). Rather than connecting directly to the targets (i.e., *lol,* *dawg*), the prime (i.e., *funny, friend*) likely connected to several other semantic associations (e.g., joke, hilarious, laugh; bro, dude) before reaching the target. Alternatively, the semantic network could simply have a much weaker connection between prime and target, rather than an indirect connection. Moreover, the hypothetical semantic network is much more complicated as additional associative links were present (Galea et al., 2011). The activation would eventually spread to the word laugh, which would in turn activate the remaining target components using top-down processing. However, activation strength would attenuate prior to activating the entire target. Given the nature of informal targets, it is possible that the presence of multiple semantic associates weaken the facilitative priming effects between traditional and informal targets because a greater number of associates could diminish the strength of any single associative link (see Figures B22 and B23).

Although a facilitative trend did present for informal language, it is more important to note the overall reaction times for informal language. When compared to traditional targets, informal targets took a significant 217 ms longer to process. This result, independent of a facilitative trend, suggested that acronyms and other informal targets required much greater processing capacity than traditional targets. It could be that informal targets simply do not have their own representations in the language network. If an informal word did have its own representation, then theoretically, activation should have spread directly from prime to target and we would have observed facilitative reaction time effects comparable to traditional language. Given that informal targets took a much greater amount of time to process, informal acronym targets may be processed as sequences of words and compressed text may be expanded into the full representation of the word. Therefore, prolonged reaction times may reflect active decoding and expansion during each trial. For example, rather than processing “lol” as one word, participants may process it as three words (i.e., “laugh, “out,” and “loud”). In the event of an abbreviation, the delayed reaction time may represent the translation from abbreviation to full word. The expected one-to-one mapping appeared to manifest as a one-to-n mapping, where n represents the number of words encoded by the acronym (see Figures B24 and B25). This hypothesis is consistent with reaction times being greater for informal words compared to traditional words.

Additionally, our informal word EEG data are consistent with this interpretation of the previous behavioral results. The literature describing the N400 priming effect demonstrates that targets preceded by unrelated primes should generate greater negativity than targets preceded by related primes, typically peaking between 250 and 500 ms (Bentin et al., 1985; Chwilla et al., 1995). However, our EEG data revealed the opposite effects. At roughly 400 ms, our priming data suggest that targets preceded by related primes generated greater posterior temporal negativity, and our language formality data suggest informal language generated greater negativity. For the priming EEG data, we interpreted the greater negativity for targets preceded by related primes as the cost of switching from traditional language to an informal language decoding process. During all of the informal experimental trials, primes were traditional words and targets were informal words. When a related informal acronym target appeared, participants were then forced to switch from single word processing to multiple word processing in order to decode and match the meaning of the acronym or abbreviation to the related prime. In short, the greater negativity for related primes represented the cost of decoding traditional-informal word pairings.

For unrelated primes and informal language, the lack of negative shift in the epoch of interest could be attributed to a lack of semantic representations for informal targets. For example, if “lol” simply did not have its own representation, then no possible semantic connections exist within the network. Therefore, there is nothing to disrupt. Additionally, the delayed negative shift for both prime types could further represent the decoding process.

Previous N400 studies depend heavily on highly contextual sentences with real words instead of word pairs (see Kutas & Federmeier, 2011 for review). Although Berger and Coch (2010) examined informal language, their stimuli were direct translations of real words that were phonologically identical but orthographically different. For our experiment, we used compressed stimuli that were not phonologically equivalent and therefore required different processing. Although a degree of phonetic overlap presented in some of the abbreviated stimuli, both acronym and abbreviated targets still required expansive processing. Overall, we found that informal language produced significantly greater negativity than traditional language. Given the knowledge that larger N400 amplitudes (i.e., greater negativity) suggest greater semantic disruption, this result provides more evidence that participants were actively decoding the targets and that informal word-processing was more difficult.

Traditional Word Effects

For traditional language, we failed to produce the classic N400 effect. Broad and increasing negativity began at roughly 350 ms continued until the end of each trial. These EEG data were contradictory to the significant priming effect we observed in our behavioral data. If our results had been consistent with previous literature (Bentin et al., 1985; Chwilla et al., 1995), then targets preceded by unrelated primes should have generated a greater negative shift between 250 and 500 ms than targets preceded by related primes. Our results depict widespread divergence that is not explained by our behavioral data that are consistent with the previous behavioral literature. This inconsistency between the behavioral and expected physiological results may indicate the presence of flaws in the experimental design and programming of the task. The unexpected results could have been due to the use of a semantic priming paradigm rather than the high context sentence paradigm.

There has been some disagreement about whether the N400 effect is due to pre- or post-lexical processes (Chwilla et al., 2000; Deacon et al., 2000; Heil, Rolk, & Pecchinenda, 2004; Kiefer, 2002). Pre-lexical processing would imply that changes in the N400 amplitude were representative of activation spreading from prime to target, whereas post-lexical processing would assume a post-target integration approach. We hypothesized that targets preceded by unrelated prime words would generate greater N400 amplitudes for both informal and traditional targets. Under this hypothesis, we argued for the pre-lexical approach, such that activation of related traditional English prime words would spread to informal word representations in the semantic network. Specifically, this would suggest that the brain activated a semantic connection between the related prime representation and target word representation. Conversely, we also assumed that targets preceded by unrelated prime words would not spread their activation to the target words, thus eliciting the larger N400 shift for words that followed unrelated primes. If activation did not spread to the informal item, then this would provide evidence that a semantic connection may not exist between the related prime and the informal target word.

Our results do not fit with either the pre- or post-lexical approach. If our data reflected pre-lexical processing, we would have observed N400 ERP effects in both language types. Targets preceded by unrelated primes would have generated a greater negative shift in the 250-500 ms waveform than targets preceded by related primes. In contrast, an N400 with delayed onset and latency could have represented a post-lexical process. Given that no clear N400 effects were observed, our data do not conform to either suggested account. It is quite possible that our semantic priming paradigm did not provide enough contextual constraint to observe priming ERP effects. For the informal language data specifically, the results may purely be a function of the traditional versus informal differences between prime and target.

Limitations and Future Directions

This study had several limitations that need to be discussed. First, this experiment had a relatively small sample size (*N* = 16). Although ERP studies generally employ a small sample, we may have been able to detect larger behavioral and physiological priming effects with a larger sample. Second, our prime duration and inter-trial interval (ITI) may not have been long enough to capture reliable effects. Participants were exposed to the primes for 84 ms and were given 4000 ms to respond to a target word. On average, participants took approximately 700-800 ms for traditional words and 900-1000 ms for informal words. Immediately following their response, they experienced a 1000 ms ITI. The next trial would begin with a 200 ms fixation cross, followed by a 200 ms blank screen. For comparison, Bentin and colleagues presented their stimuli (both primes and targets) for 1,000 ms and used a 2,500 ms ITI. We chose to use a shorter prime duration and ITI given our previous study, and in an attempt to capture more automatic processing. Third, the experiment may not have an adequate number of trials. The trials were constrained by the number of informal targets that were isolated from Twitter.

Finally, accessibility to and utilization of Twitter was not equivalent across participants. Whether or not a participant has a Twitter account (only 69% of the participants had accounts) may or may not accurately reflect the participant's exposure to the informal language that is commonly present in tweets. Participants may become familiar and use informal language in digital forums besides Twitter. Although variability is good, our sample included some participants who reported using Twitter only one time throughout the past year. Such participants may not be very familiar with the informal language used as stimuli.

Future directions should include changes to the methodology. First, a larger number of novel Twitter words could be used. This would require a much larger data harvest and isolation process, however it could lead to a more representative sample of new informal words. Second, two changes to the task could be made. A future study could lengthen the duration of the prime word and the inter-trial interval. The 84 ms prime duration may have been too fast for a connection between traditional and informal languages to be made. Given the longer processing times required for informal language, participants might benefit from a longer stimulus duration and interval between trials. Third, novel Twitter words could be applied to a different paradigm. In this task, we used a semantic priming model. Future research could apply newly acquired Twitter words to the classic terminal word-sentence paradigm used frequently in N400 effect research.

Moreover, the corresponding EEG could be re-filtered using a 0.01Hz high-pass and a 30Hz low-pass. Previous literature has exhibited inconsistencies in band-pass values; therefore we utilized a more constraining filter in our study. Upon exploratory re-analysis of our EEG data using a .01Hz high-pass, we discovered a visual attenuation in our inverse N400 effect. In some electrodes, a minor change in effect direction presented, however, the direction of our result was primarily consistent with our previous results. Interestingly, the overall differences between informal and traditional formality appeared to increase. In Figure B26, the EEG data are presented with a 0.3 Hz high-pass filter and with a .01 Hz high-pass filter. Visual inspection of the two electrode collections suggests that there are some waveform changes introduced by the filtering choice, but the changes would not alter the direction of the results. In other words, using the .01 Hz high-pass filter would not make the waveforms consistent with the classic N400 effect. Future studies could potentially demonstrate classic N400 effects after re-designing the experimental task, collecting data from a larger sample, and filtering the EEG data using a 0.01Hz – 30Hz band-pass range.

Conclusions

In sum, the results of this study have suggested that informal language appears to be processed differently than traditional language. Our experiment has provided behavioral and physiological evidence for the claim that informal words used on Twitter may not have their own semantic representations. Furthermore, informal language as a whole may require greater processing than traditional language. This could be a function of informal language acting as a subset of traditional language that requires decoding and translation. These claims are in opposition to previous literature suggesting that common acronyms and texted English are processed like traditional language. Our data suggest that informal language operates differently than traditional language in a semantic priming paradigm and does not appear to be its own language.

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Appendix A

Tables 1-4

Table 1

Version Block Order

Version Number	Block 1	Block 2	Block 3	Block 4
V1	Informal	Informal	Traditional	Traditional
V2	Traditional	Traditional	Informal	Informal
V3	Informal	Traditional	Informal	Traditional
V4	Traditional	Informal	Traditional	Informal

Table 2

Stimulus Pairings

Prime Type	Target Type
Related	Real Word
Related	Non-Word
Unrelated	Real Word
Unrelated	Non-Word

Table 3

Category Pairings

Word Formality Type	Prime Type	Target
Informal	Related	Real Word
Informal	Unrelated	Real Word
Informal	Related	Non-Word
Informal	Unrelated	Non-Word
Traditional	Related	Real Word
Traditional	Unrelated	Real Word
Traditional	Related	Non-Word
Traditional	Unrelated	Non-Word

Table 4

Reliability Matrix (Cronbach's Alpha)

Word Formality	0-240ms	240-500ms	500-750ms
Traditional	0.98	0.98	0.98
Informal	0.98	0.97	0.92
Epoch Average	0.98	0.975	0.95
Overall Average		0.97	

Appendix B

Figures 1 - 26

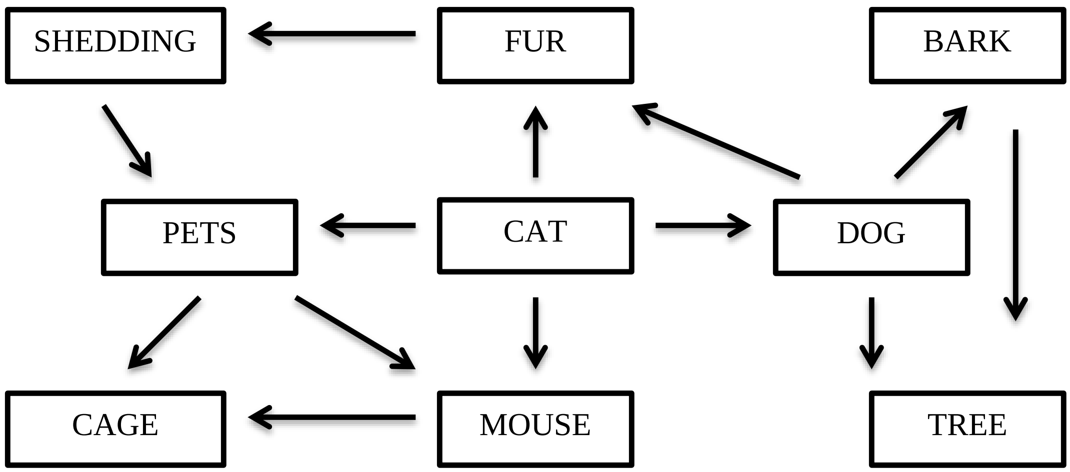

Figure 1. A diagram of the *Spreading Activation* model proposed by Collins, A.M., & Loftus, E. F. (1975).

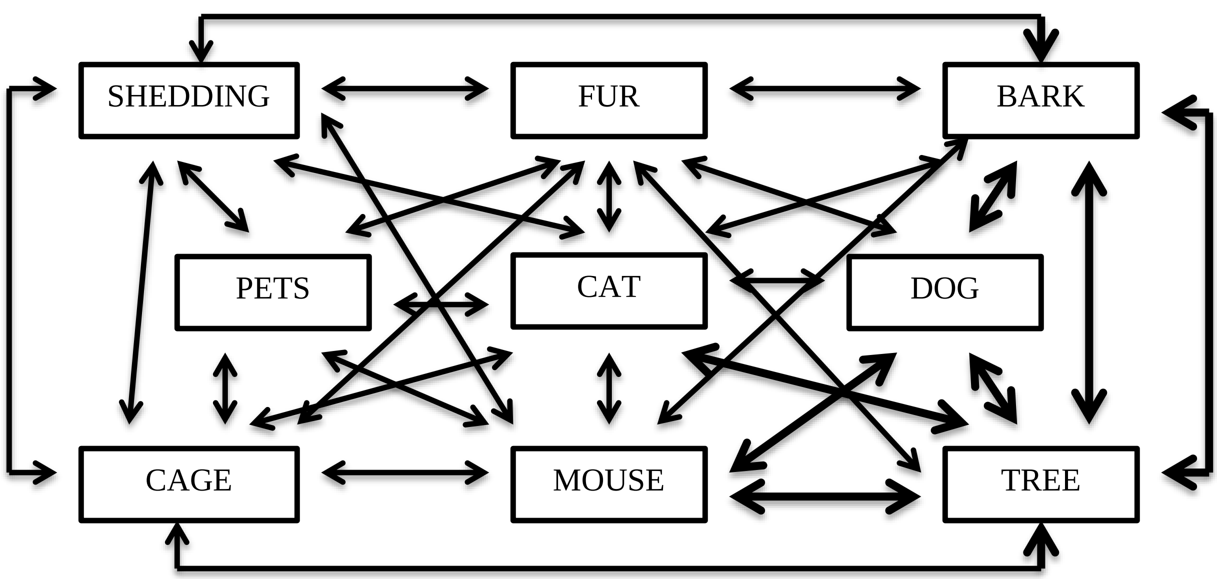

Figure 2. A diagram of the *Activation-at-a-Distance* model proposed by Nelson et al., 2003).

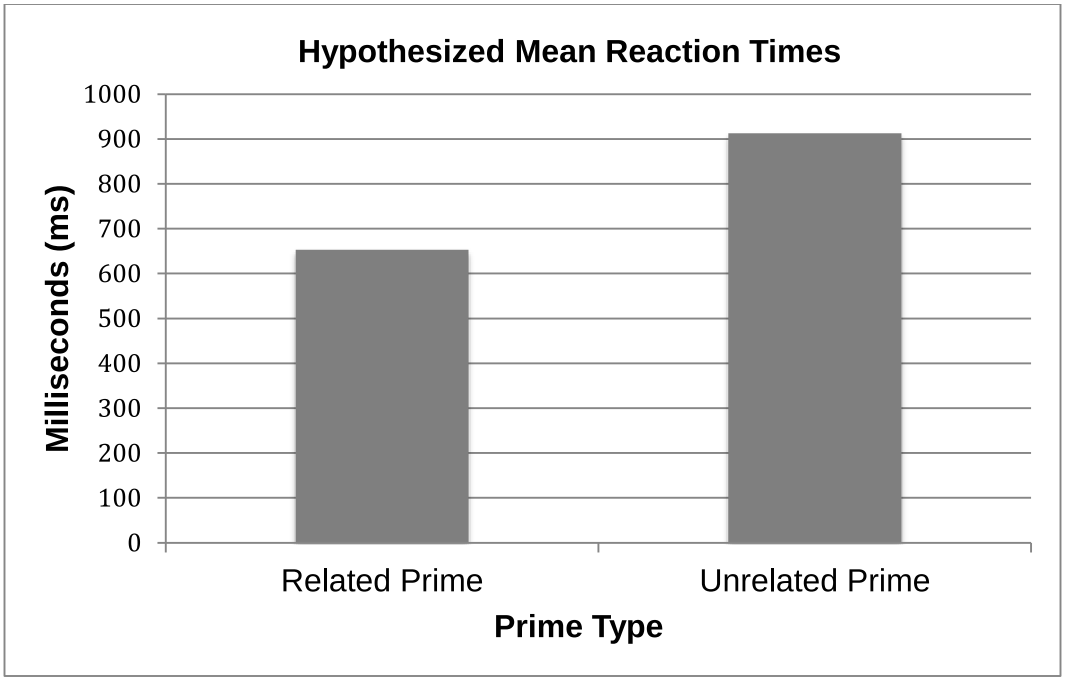

Figure 3. Depiction of behavioral hypothesis.

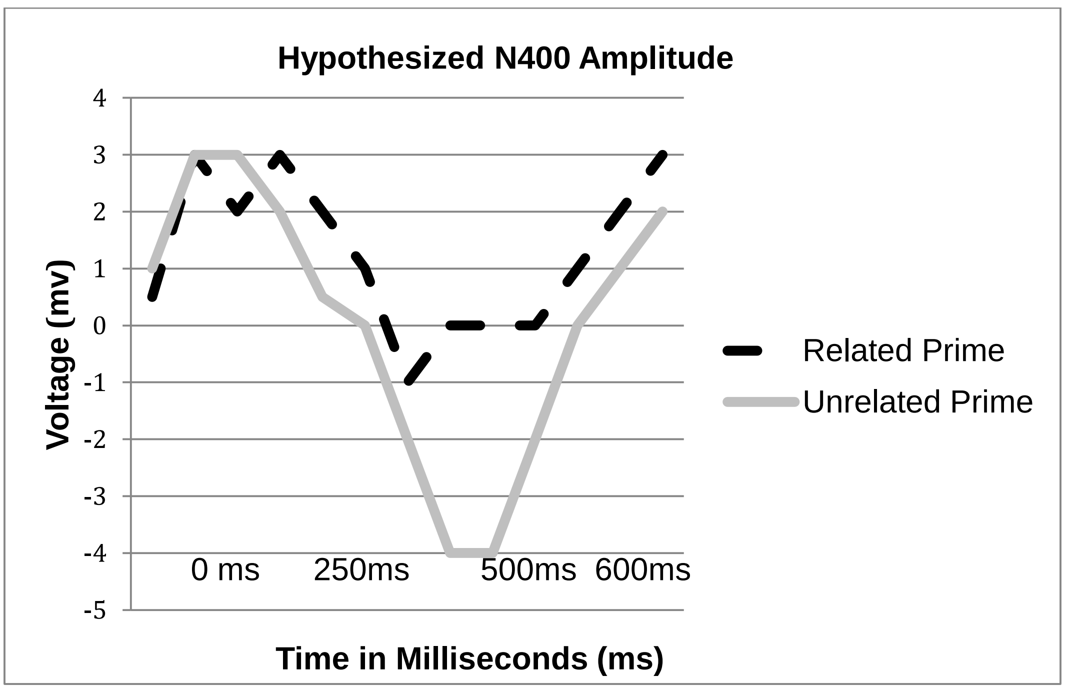

Figure 4. Depiction of electrophysiological hypothesis.

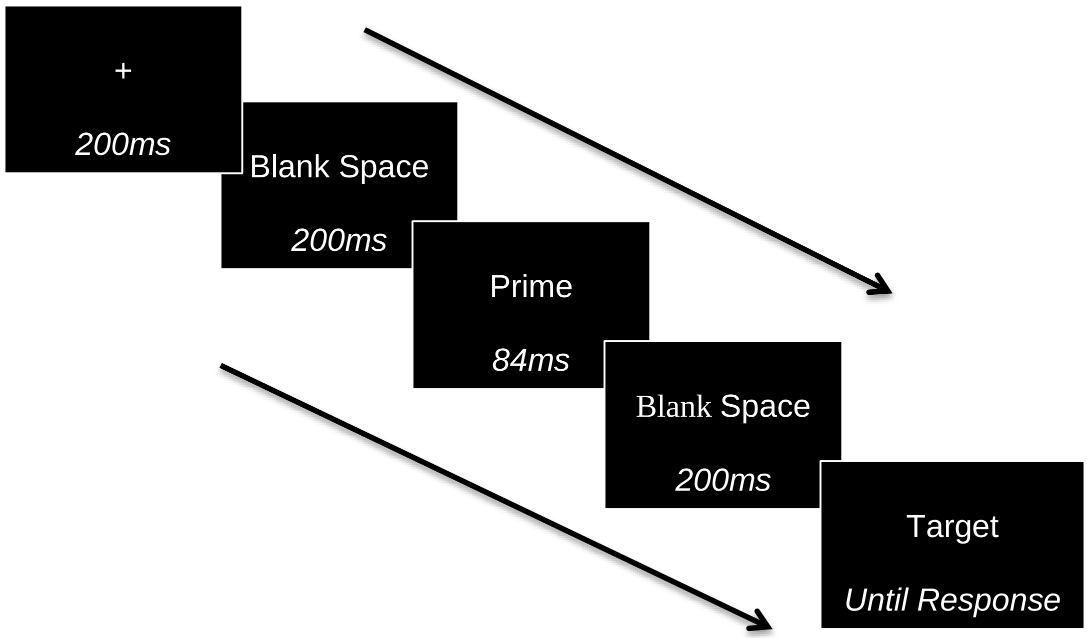

Figure 5. A graphic depicting a single trial of the lexical decision task.

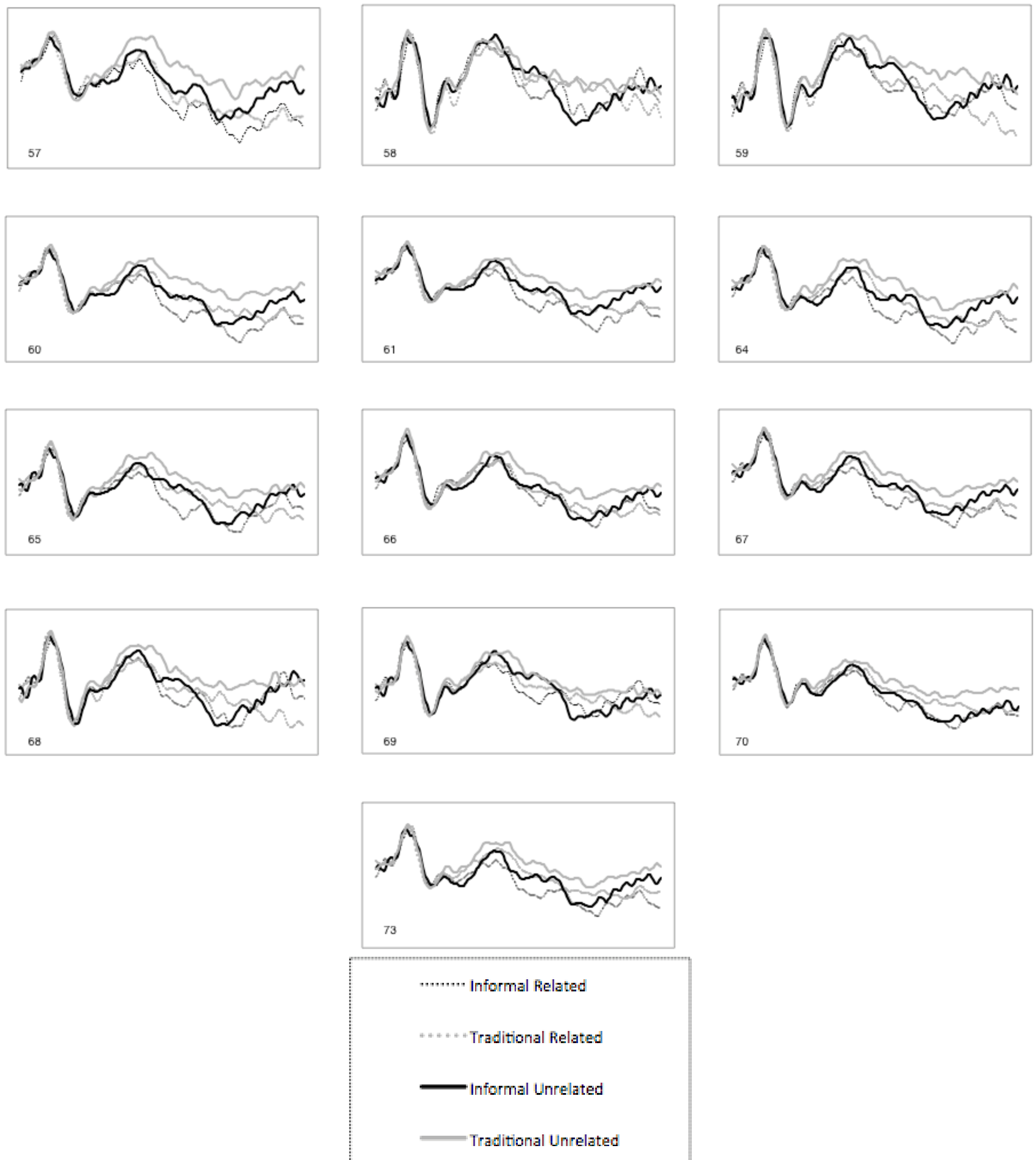

Figure 6. Visual consistency inspection of the waveforms filtered with 0.3Hz high-pass and a 30Hz low-pass. Positive is plotted upward and negative is downward.

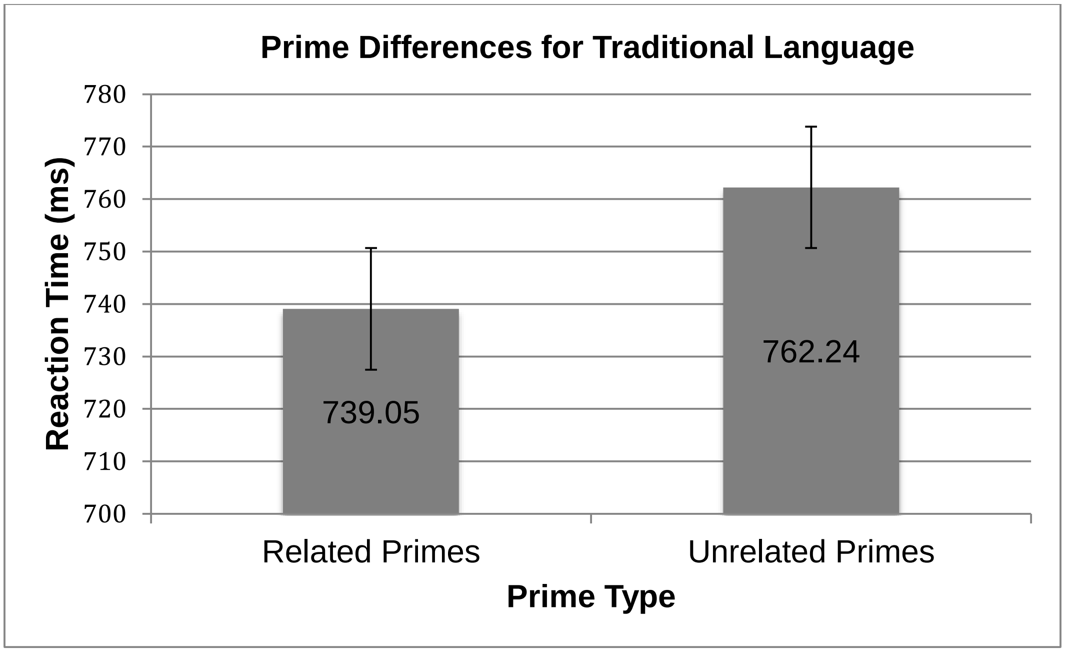

Figure 7. Prime differences for traditional language. Error bars represent standard error.

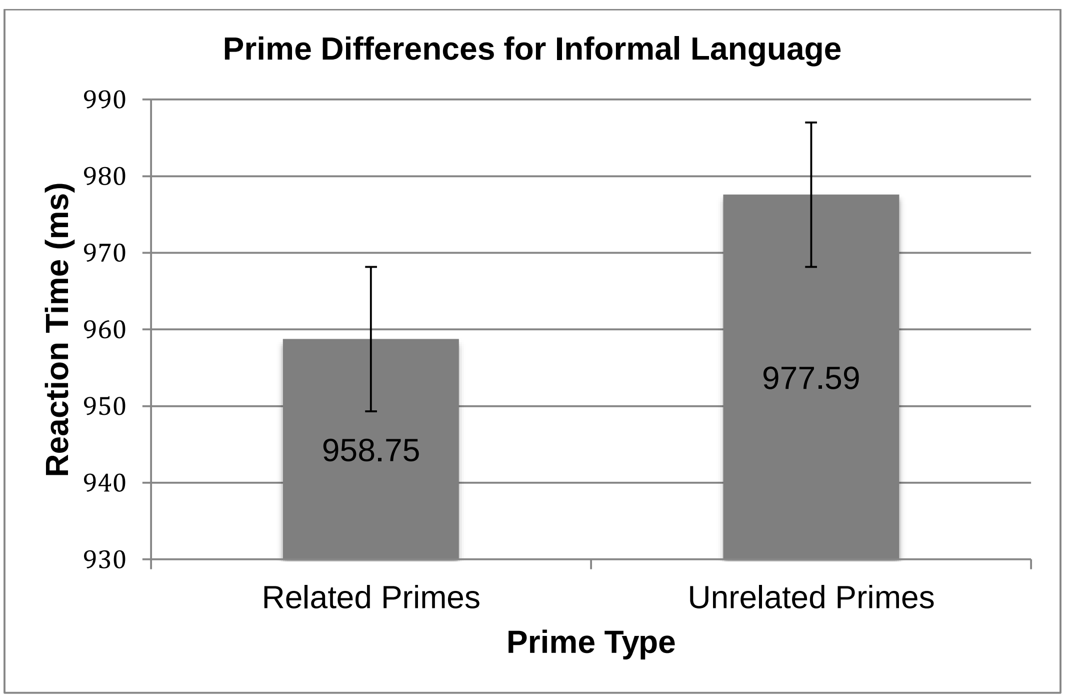

Figure 8. Prime differences for informal language. Error bars represent standard error.

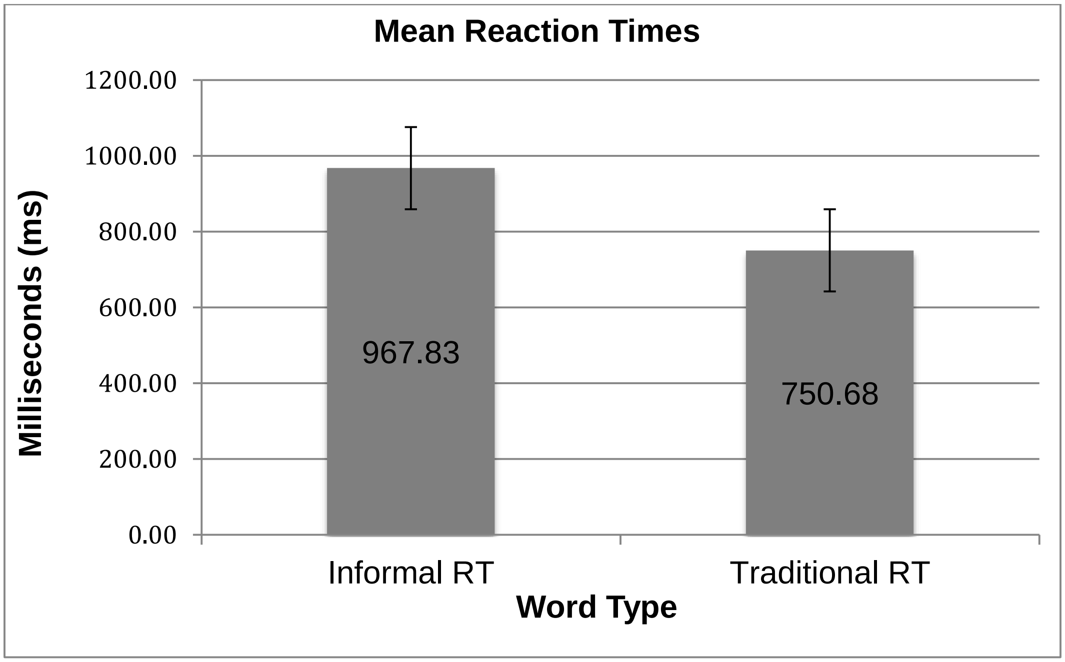

Figure 9. Behavioral reaction time results. Informal words elicited greater reaction times than traditional words. Error bars represent standard error.

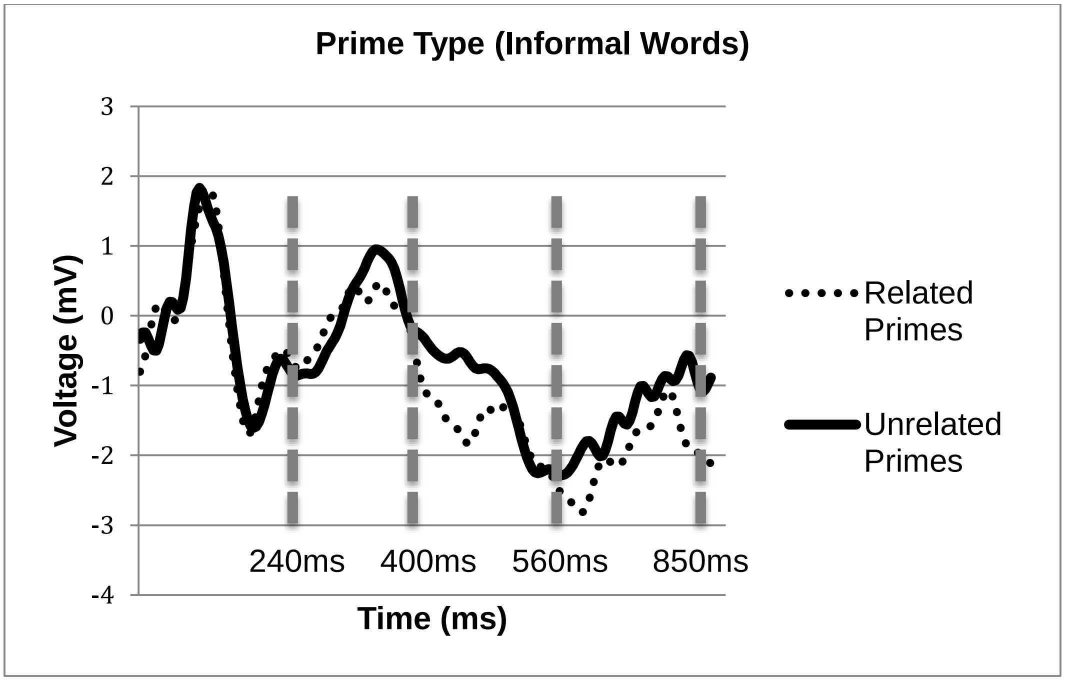

Figure 10. Depiction of grand average waveform differences between related and unrelated primes on informal language. Negative voltages are plotted downwards and positive voltages are plotted upwards.

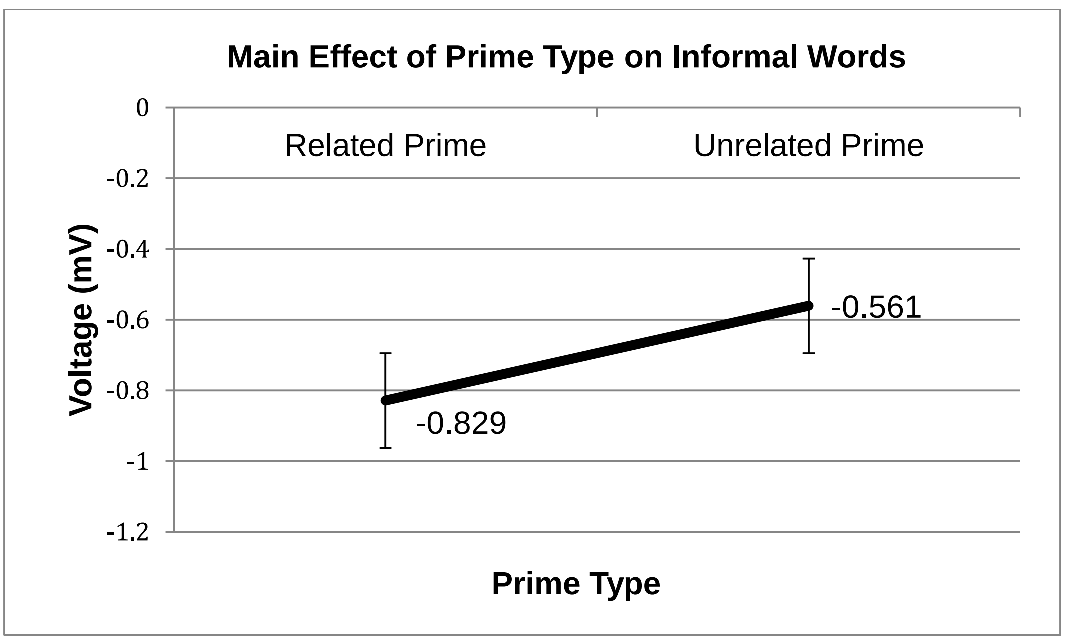

Figure 11. Main effect of prime type on informal language across the entire waveform. Error bars represent standard error.

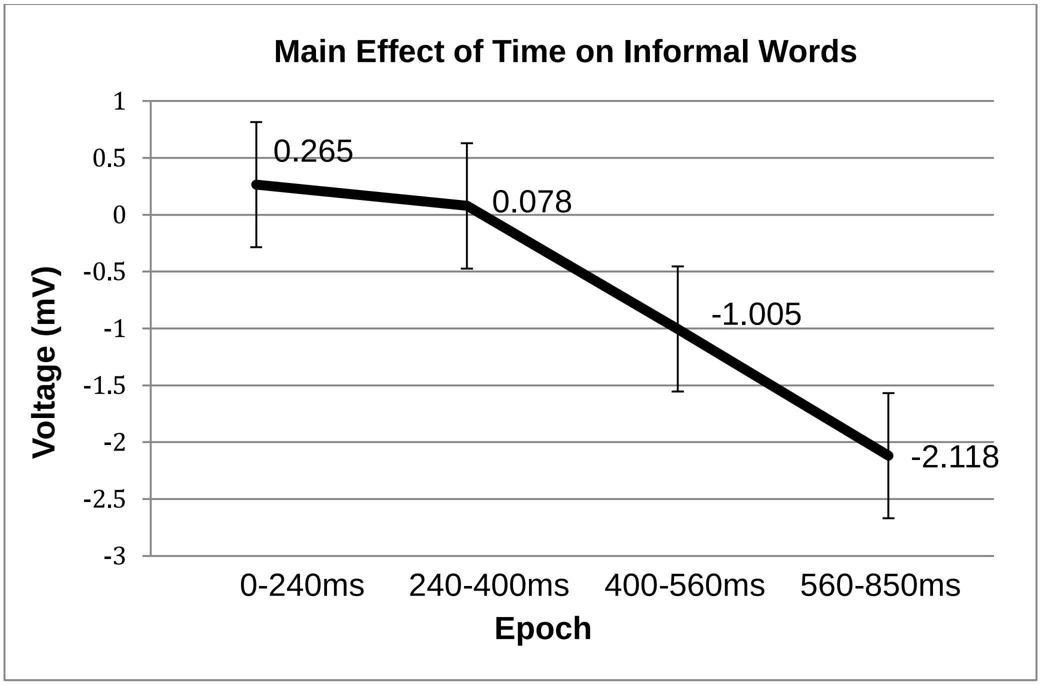

Figure 12. Main effect of time on informal language across the entire waveform. Error bars represent standard error.

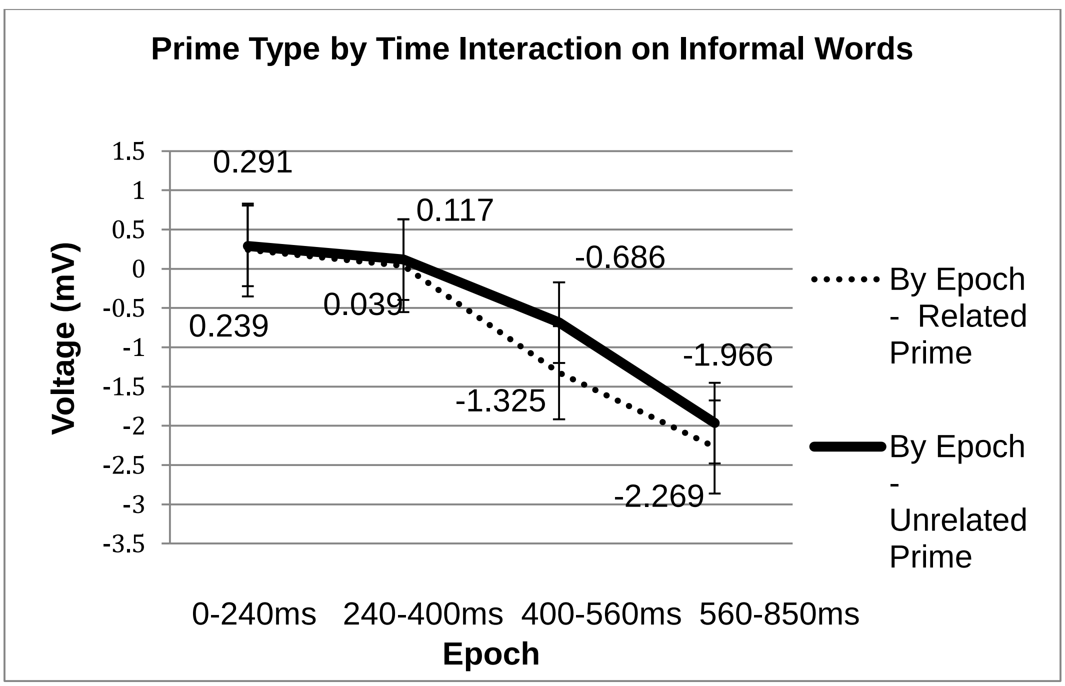

Figure 13. Prime by time interaction for informal language across the entire waveform. Error bars represent standard error.

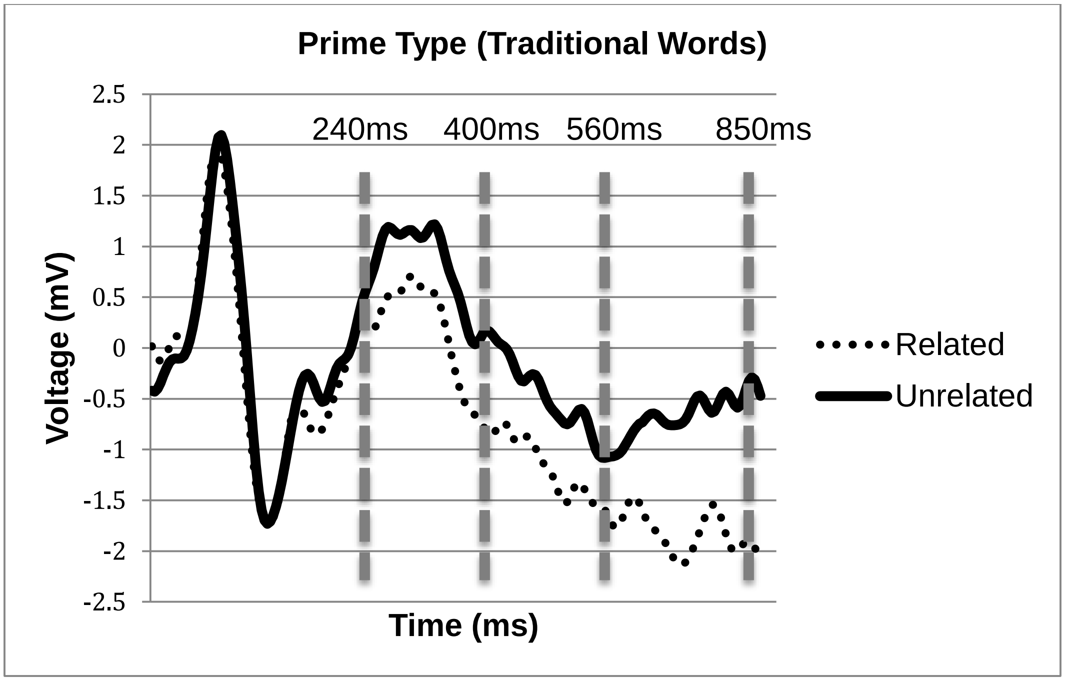

Figure 14. Depiction of grand average waveform differences between related and unrelated primes on traditional language. Negative voltages are plotted downwards and positive voltages are plotted upwards.

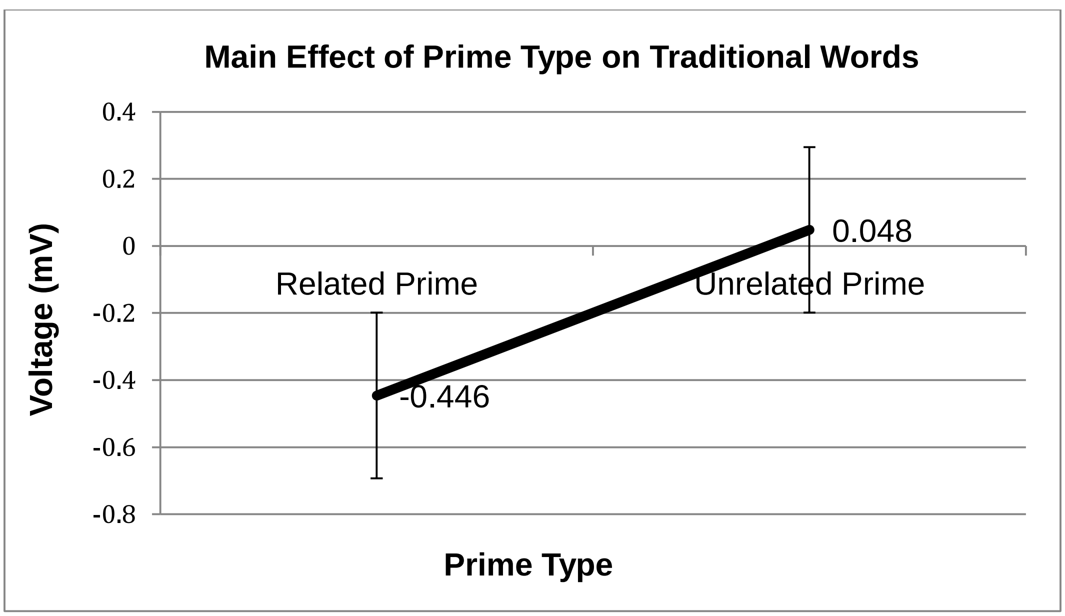

Figure 15. Main effect of prime on traditional language across the entire waveform. Error bars represent standard error.

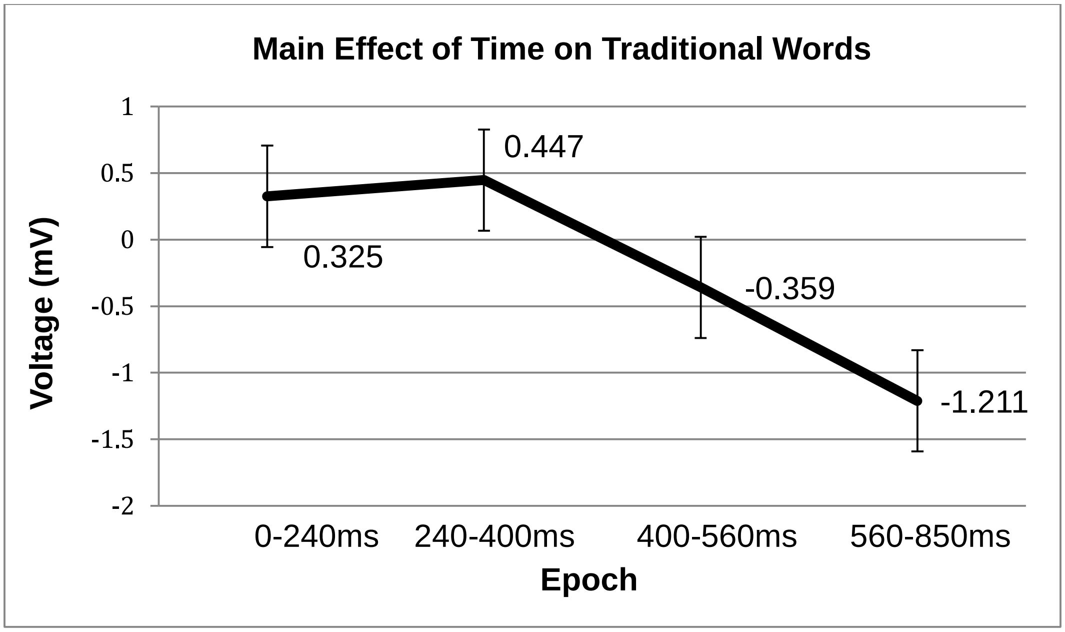

Figure 16. Main effect of time on traditional language across the entire waveform. Error bars represent standard error.

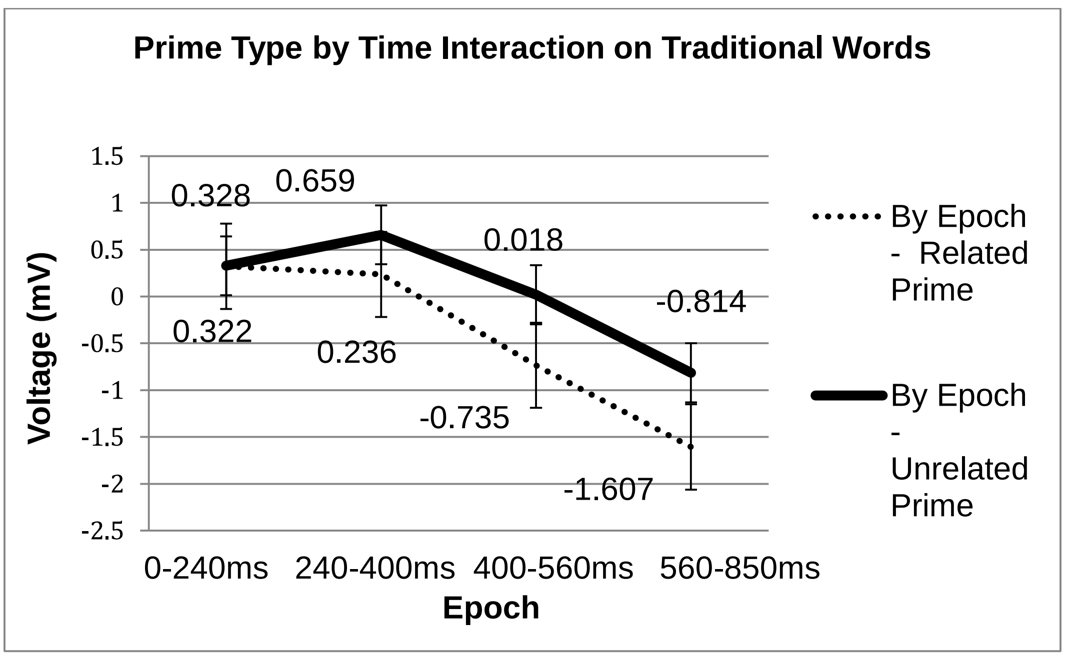

Figure 17. Prime by time interaction for traditional language across the entire waveform. Error bars represent standard error.

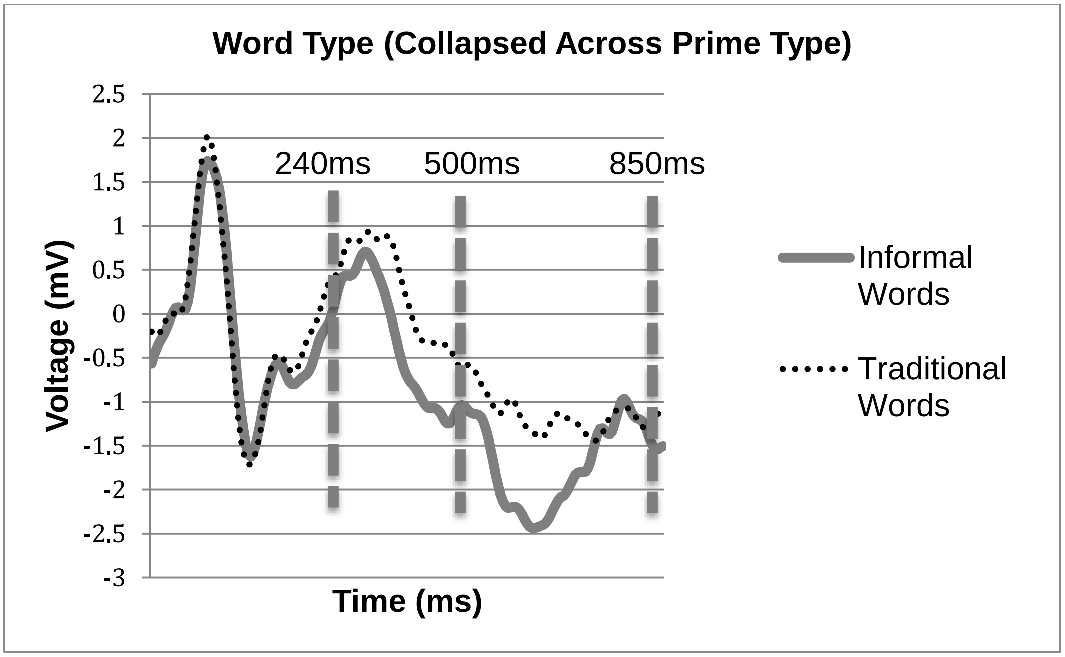

Figure 18. Depiction of grand average waveform differences between informal and traditional words collapsed across prime types. Negative voltages are plotted downwards and positive voltages are plotted upwards.

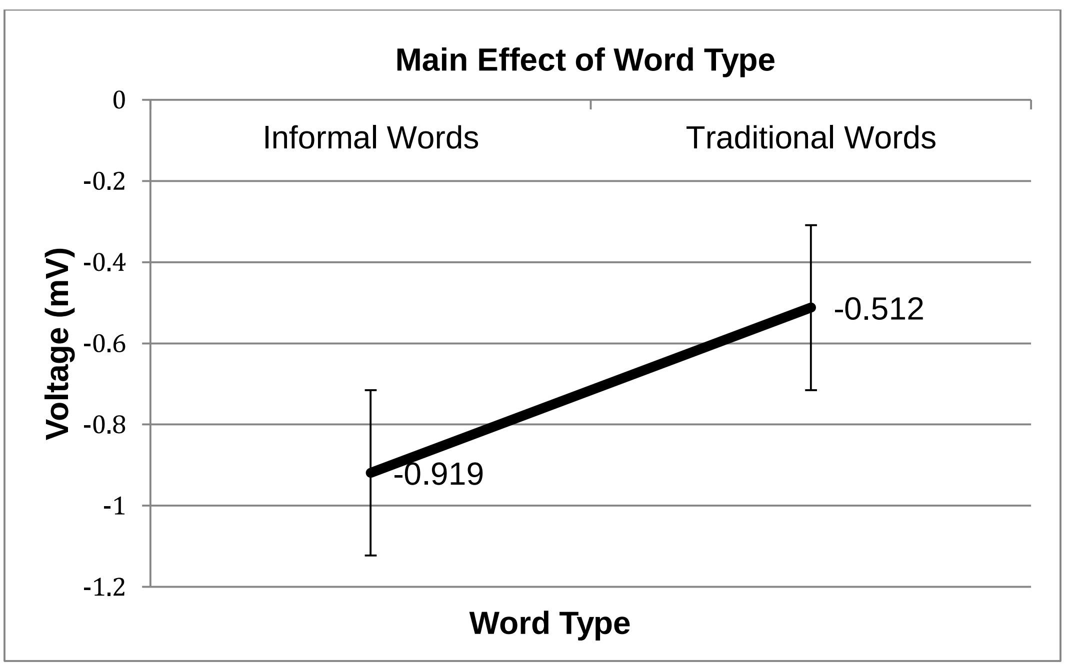

Figure 19. Main effect of word type across the entire waveform. Error bars represent standard error.

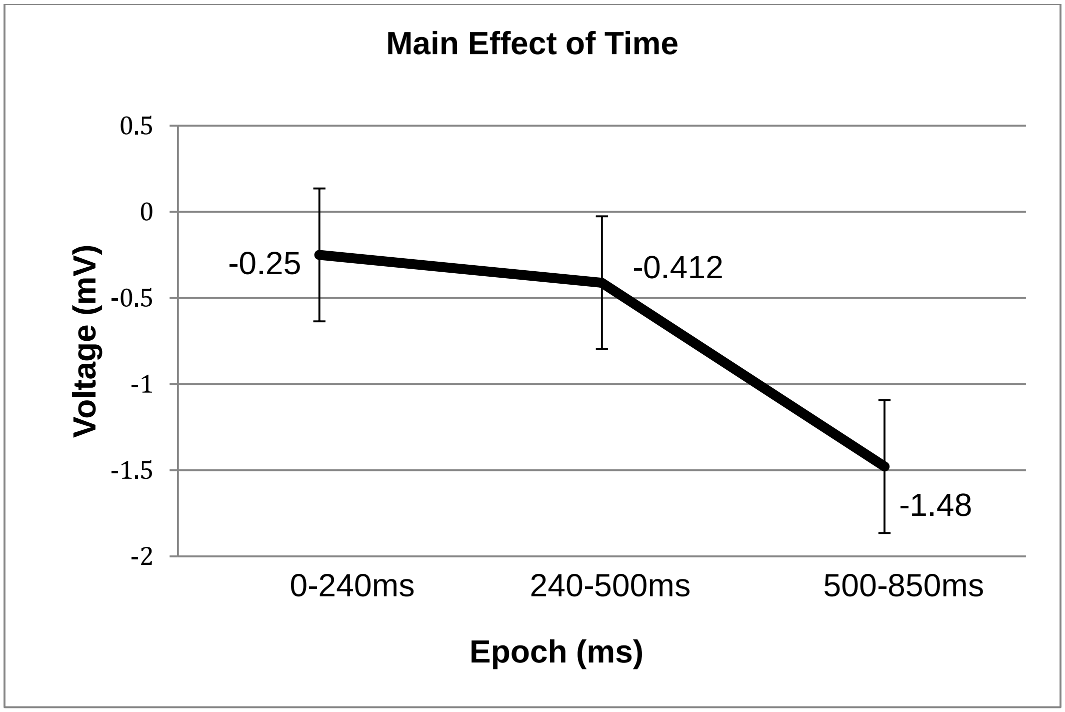

Figure 20. Main effect of time on word type across the entire waveform. Error bars represent standard error.

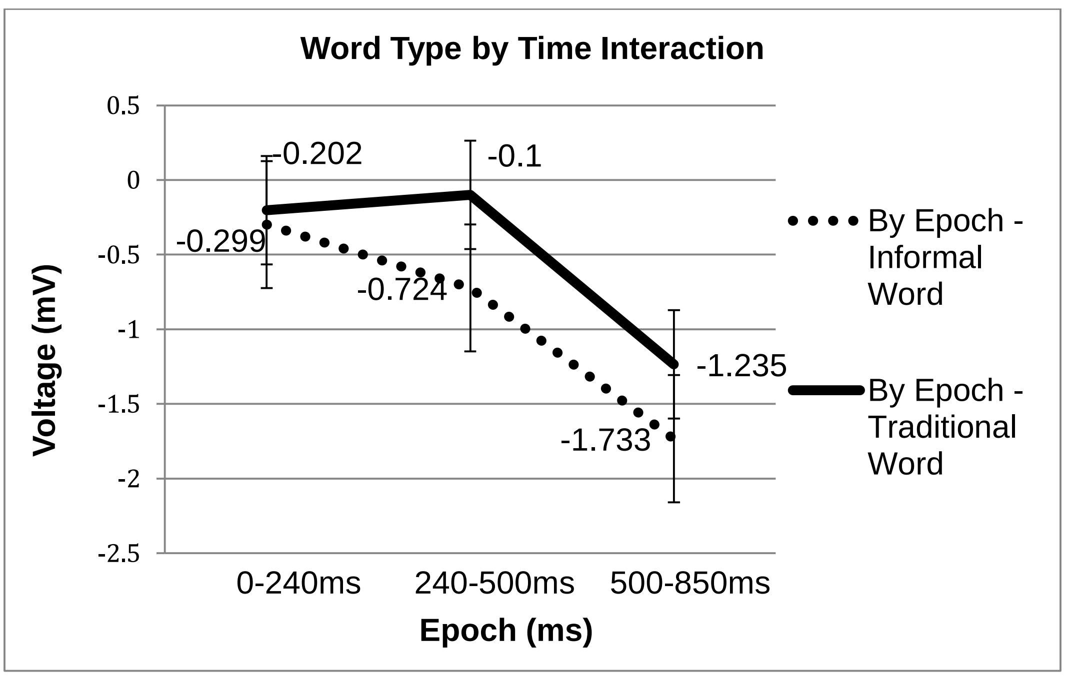

Figure 21. Word type by time interaction across the entire waveform. Error bars represent standard error.

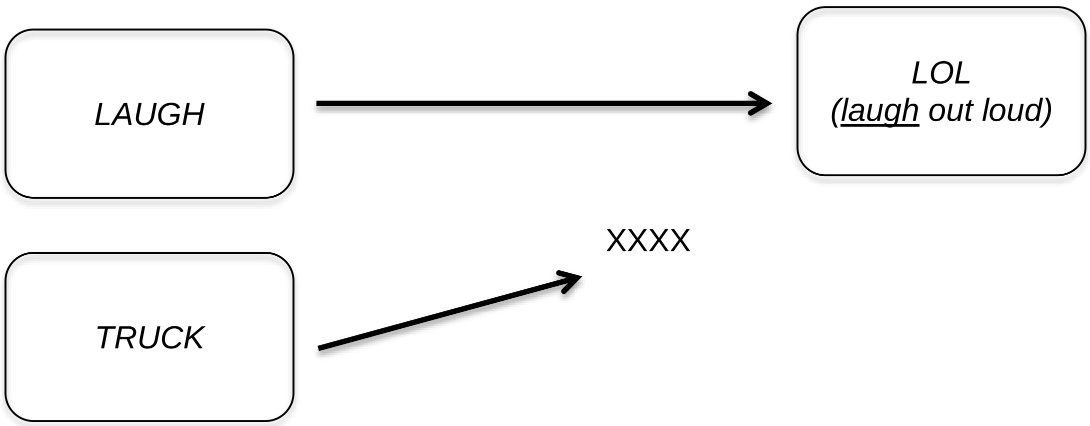

Figure 22. Primes found within acronyms facilitated significantly faster recognition than unrelated primes. Unrelated primes do not share a semantic connection, therefore elicit much greater reaction times.

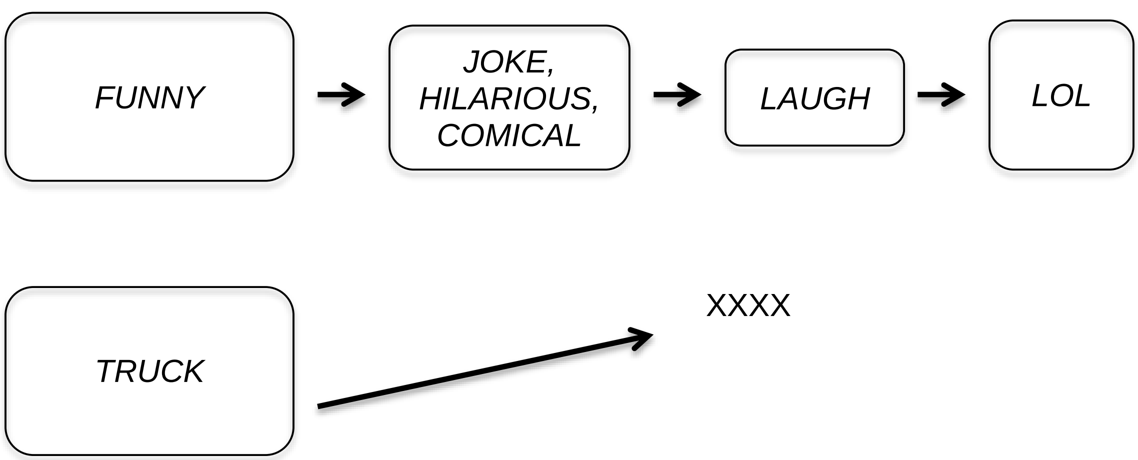

Figure 23. Related primes not found within the acronym must travel through a greater semantic network before activating the target, eliciting longer overall processing times. Unrelated primes do not share a semantic connection, therefore reaction times are much greater.

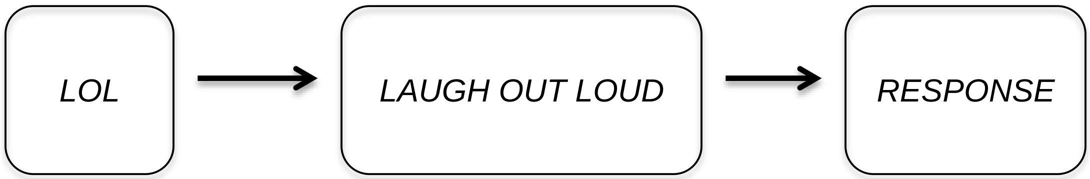

Figure 24. Example of one-to-one mapping.

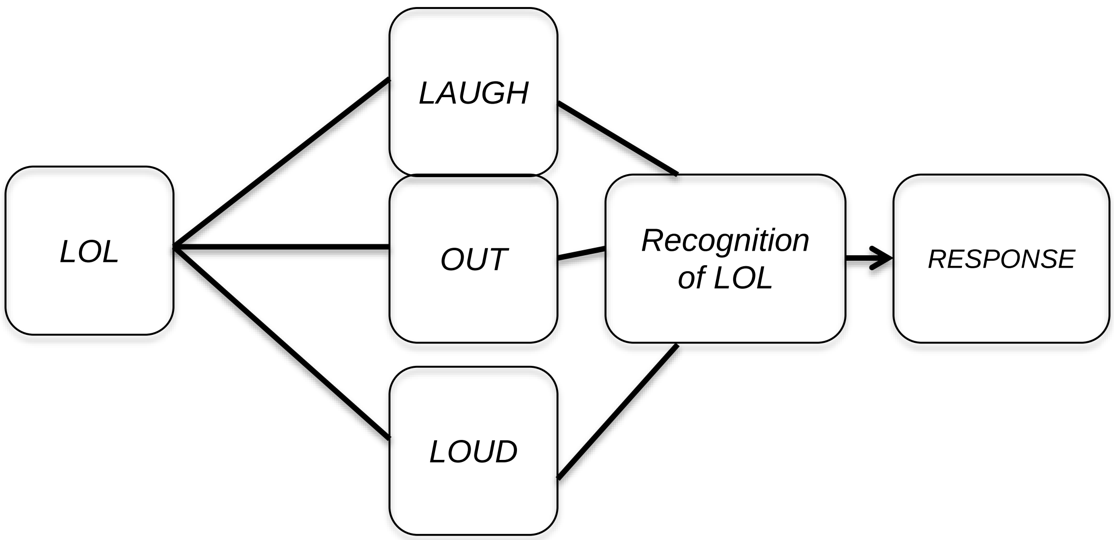

Figure 25. Example of one-to-*n* mapping for acronyms.

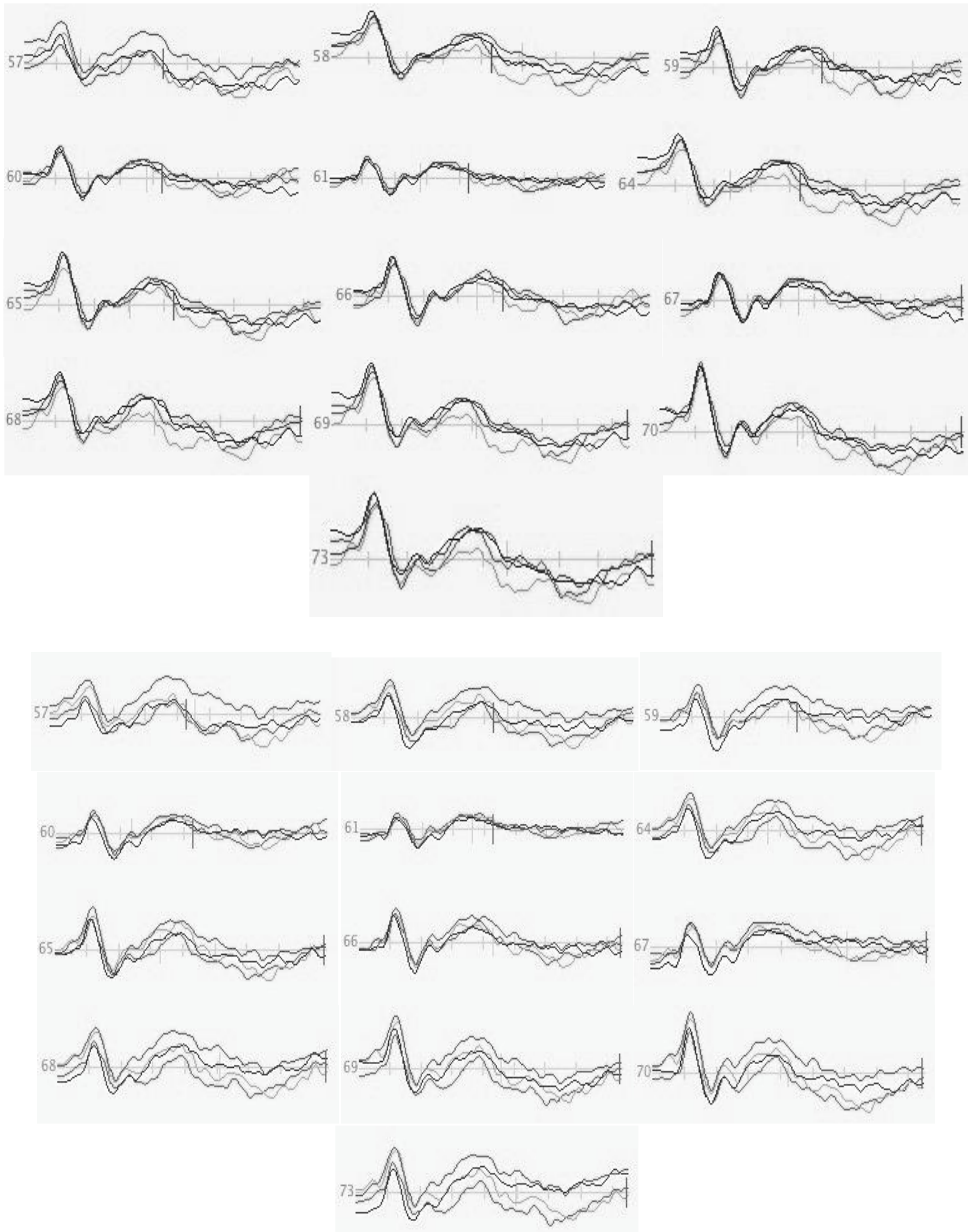

Figure 26. Visual comparison of the waveform trends viewed at an amplitude scale of 0.4mv. The top EEG data are filtered at 0.3Hz - 30Hz, and the bottom EEG data are filtered at .01Hz – 30Hz. Positive is plotted upward and negative is downward.

Appendix C

List of Stimuli (Targets and Primes)

Target	Related Prime	Unrelated Prime
aka	alternate	acquiring
asap	quickly	develop
bff	friendship	absolutely
bogo	free	week
brb	returning	candidate
btw	within	because
fyi	aware	development
gtfo	leave	value
hmu	communicate	approximation
icymi	avoid	afford
idc	thoughtless	abstracting
idk	unsure	abound
ily	adore	aback
kcco	relax	brand
lmao	chuckle	concepts
lmbo	giggle	delaware
lol	funny	pointing
nbd	nothing	general
nsfw	inappropriate	unsympathetic
omg	shock	grain
omw	coming	beyond
smh	disappointed	contributing
stfu	quiet	favor
tbt	memory	reduction
tgif	weekend	sharing
wcw	feelings	contract
wtf	shocked	airport
yolo	reckless	abundant
aint	isnt	books
appt	meeting	england
awk	uncomfortable	refrigeration
aye	hello	adage
bae	girlfriend	department
bish	vixen	yeast
boi	male	atom
cray	insane	absorb
dawg	friend	merely
fam	relatives	telegraph
gorg	beautiful	operation
gotcha	understood	confidence

Target	Related Prime	Unrelated Prime
ham	tough	japan
iight	alright	abysmal
nvm	nevermind	aboriginal
obvi	clearly	numbers
peeps	person	should
perf	ideal	bible
plz	gratify	abelson
ppl	person	school
rly	truly	alive
preciate	grateful	attached
prego	expecting	violation
preshh	valuable	allowing
prob	likelihood	adjusting
prof	teacher	germany
prolly	likely	nation
selfie	picture	central
srsly	severely	encourage
sry	apology	admirer
swag	cool	vast
thot	hoe	several
thx	appreciation	capabilities
totes	completely	democratic
tryna	attempt	project
turnt	intoxicated	abbreviated
tweeps	followers	synthesis
ace	expert	allied
ache	pain	gray
bed	cot	ale
bass	low	red
bar	pole	acre
bin	container	abolition
fat	plump	image
gold	medal	wedge
hug	embrace	alcohol
image	picture	defense
ice	frozen	albert
ink	black	party
inn	hotel	horse
king	crown	bench
lady	woman	front
lake	pond	rank
leg	limb	mass
nap	sleep	study
nude	naked	blame

Target	Related Prime	Unrelated Prime
oar	paddle	abated
odd	strange	captain
sky	atmosphere	expression
scar	blemish	zooming
toy	plaything	yellowing
thug	gangster	ablation
wet	damp	cone
win	victory	artists
yard	lawn	bees
arch	curve	angry
army	military	evidence
axe	hatchet	accents
ash	embers	abound
box	carton	zombie
boss	director	symptoms
big	large	young
cage	enclosure	amusement
debt	bills	adapt
fly	soar	ajar
grin	smile	birds
greasy	oily	toss
hay	straw	radio
idiot	fool	atom
nun	sister	walnut
odor	smell	bride
pilot	captain	classes
pool	puddle	abound
pan	skillet	abysmal
pen	write	mouth
rip	tear	bolt
puzzling	confusing	zoologist
panic	alarm	attic
pepper	season	attack
plot	story	alter
portal	doorway	bathing
school	academy	authors
sun	light	least
slit	cut	art
tune	song	wage
tub	bath	wars
track	path	seed
torso	chest	phone
trash	garbage	aerosol
thread	fiber	drill

Appendix D

Map of expected negative voltage in posterior temporal region. (Note: this is not an exact representation of the equipment that used).