Electrophysiological Evidence of Different Loci for Case Mixing and Word Frequency Effects in Visual Word Recognition

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Abstract

Do word frequency and case mixing affect different processing stages in visual word recognition? Some studies of on line reading suggests that word frequency affects an earlier perceptual, encoding stage and case mixing affects a later central, decision stage (e.g., Reingold, Yang, & Rayner, 2010). Others have suggested otherwise (e.g., Allen, Smith, Lien, Grabbe, & Murphy, 2005; Besner & McCann, 1987). To determine the locus of word frequency and case mixing effects, we manipulated word frequency (high vs. low) and case type (consistent lowercase vs. mixing case in a lexical-decision paradigm. We measured two event-related potential components: the N170 (an early peak occurring 140-240 ms after stimulus onset, related to structural encoding) and the P3 (a late peak occurring 400-600 ms after stimulus onset, related to stimulus categorization). The critical finding is that the N170 amplitude was sensitive to case mixing, but the P3 amplitude was sensitive to word frequency and lexicality. These results suggest that case mixing affects an earlier processing stage than word frequency, at least with respect to lexical-decision processes.

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The question of how we process words during reading has generated a large literature, probably because reading is such a frequent activity. One fruitful approach to studying reading and word recognition is to examine how characteristics of the word affect recognition using a lexical-decision task (LDT; determining whether a letter string forms a word or nonword). Two of the commonly used manipulations of words are case mixing (e.g., mixed case [TeNnIs] vs. consistent lower case [tennis]) and word frequency (frequency with which a word occurs in the language). Studies with a case mixing manipulation have consistently revealed shorter response times (RTs) for consistent lower case than mixed case words (the *case mixing effect*). Studies with a word frequency manipulation have found shorter RTs for high than low frequency words (the *word frequency effect*). Researchers generally agree that these two variables affect different processing stages but disagree about exactly which stages they are (Allen, Smith, Lien, Grabbe, & Murphy, 2005; Besner & McCann, 1987; Reingold, Yang, & Rayner, 2010). The present study aims to shed light on this debate using electrophysiological measures.

Case Mixing vs. Word Frequency

Most word recognition models assume multiple processing stages involved in a single, visual word identification (e.g., from orthographic encoding, lexical identification, to response decision; Monsell, Doyle, & Haggard, 1989). Case mixing has been assumed to affect the early encoding of visual features (Besner & McCann, 1987). In contrast, the word frequency effect has been attributed to a later stage than encoding, such as stimulus categorization or decision (Allen et al., 2005; McCann, Remington, & Van Selst, 2000)[1]. For instance, McCann et al. examined the locus of the word frequency effect using a dual-task paradigm where the time interval between the tone Task 1 and the lexical decision Task 2 (stimulus onset asynchrony [SOA]) was varied. A typical finding with this dual-task paradigm is that Task-2 RT increases as SOA decreases, which has been attributed to a central bottleneck – an inability to perform central operations (e.g., decision making) for the two tasks simultaneously. McCann et al. found that the word frequency effect on the lexical decision Task 2 was similar at all SOAs, suggesting that word frequency affects processing stages that are subject to postponement (i.e., located at or after central operations).

Distinct loci for case mixing and word frequency were also confirmed by Reingold et al. (2010) but with a critical difference in the conclusion. Instead of arguing for an early locus of case mixing and a late locus of word frequency, Reingold et al. asserted the opposite view. They recorded participants' eye movements during reading. The critical measure was the first fixation duration (when the eyes first moved from the fixated word) with multiple first-pass fixations (trials where the word was immediately refixated). They assumed that the initial saccade to the subsequent word depends on the completion of lexical access to the currently fixated word. The multiple first-pass fixations would, therefore, indicate incomplete lexical processing. By examining what factors influence the first fixation in multiple first-pass fixations, one could determine what variables influence early lexical encoding. They found additivity of word frequency and case mixing effects on fixation times, consistent with the claim that these factors influence different processing stages. However, word frequency, but not case mixing, affected the first fixation duration in trials with multiple first-pass fixations (the word frequency effect was 14.8 ms whereas the case mixing effect was only 3 ms). In contrast to earlier studies, Reingold et al. concluded that word frequency influences early lexical encoding and case mixing influences later attentional, post-lexical processing.

Although Reingold et al.'s (2010) finding raises a question regarding the exact loci for case mixing and word frequency, their conclusion was primarily based on sentence reading rather than single-word identification, as in the LDT employed in most previous studies. Sentence reading involves not only word identification but also other processes such as syntactical formation, semantic extraction, and sentence comprehension. It has been argued that these processes have a relatively weak influence on reading, especially for skilled readers (e.g., Besner & Humphreys, 1991; Humphreys, 1985). Oftentimes we skip words when we read or are unaware of misspelled, additional, or missing words. Accordingly, the sentence-reading paradigm may not be sensitive enough to determine the loci for case mixing and word frequency or possibly produce different loci. Likewise, the other studies using LDT were based on indirect behavioral measures of the time course of word recognition and the additive factor method.

An Electrophysiological Measure of Word Processing

The present study therefore used online measures of event-related potentials (ERPs) to examine word frequency and case mixing effects in LDT. The ERPs can provide continuous measures of a single-word processing and often reveal evidence of deeper processing than is apparent in behavioral data (see Vogel, Luck, & Shapiro, 1998, for an excellent example of ERPs elicited by semantic activation even when participants could not report the targets in the attentional blink task). By examining the ERP components associated with word processing, it is possible to determine which word processing stages are affected by word frequency and case mixing.

We used the N170 and P3 components. The N170 is a negative ERP that peaks 140-240 ms after stimulus onset. This component occurs strongly at occipito-temporal area and relates to structural encoding that is specialized for faces and words (Rossion et al., 2000; Simon, Petit, Bernard, & Rebaï, 2007). With respect to words, the N170 amplitude was larger for orthographic (e.g., words) than nonorthographic stimuli (e.g., symbols) in the left hemisphere (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999). These findings suggest that the N170 indexes orthographic encoding, an early process of object recognition.

The P3 component is a positive ERP that peaks 400-600 ms after stimulus onset and is larger over parietal midline sites[2]. The P3 is often taken as a measure of context updating and is sensitive to the relative frequency of stimuli (Donchin, Ritter, & McCallum, 1978; Nasman & Rosenfeld, 1990). It reflects the time required to complete stimulus classification for response selection (Luck, 1998). With respect to word recognition, Polich and Donchin (1988) found larger P3 amplitudes for high than low frequency words (see also Lien, Ruthruff, Cornett, Goodin, & Allen, 2008). Acosta and Nasman (1992) also found that the P3 amplitude was modulated by within-experiment repetition of words in discrimination tasks, but not in detection tasks. These results suggest that the P3 indexes stimulus categorization, a later process of object recognition that leads to decision making.

The Present Study

While earlier studies have shown word frequency effects on the P3, the exact locus of the case mixing effect has not yet been determined. We used N170 and P3 to examine the processing loci of word frequency and case mixing within the same LDT experiment. Word frequency and case type were varied within blocks. Because we were interested in these two effects without contamination from stimulus-repetition-based increased familiarity, we presented each word and nonword only once for each participant.

Our main interest was for the word trials only. If mixing case disrupts early logographic encoding, then we expect case mixing effects on N170. If it affects later stimulus categorization, then we expect case mixing effects on P3. Likewise, if word frequency affects early encoding, then we expect word frequency effects on N170. However, if it affects later stimulus categorization, then we expect word frequency effects on P3.

Method

Participants. Twenty-eight undergraduates (native English speakers) at Oregon State University participated in this experiment. Data from 4 of these participants were excluded due to excessive eye movement artifacts in the electroencephalographic (EEG) data (see below).

Apparatus, Stimuli, and Procedure. The stimulus was a string of letters (0.83° × 0.63° for each letter) printed in white, against a black background, in the center of the screen. Letters were presented entirely in lower case or in alternating case (mixed case). The stimuli were taken from the Kučera and Francis (1967) norms. Low frequency words ranged from 10 to 30 occurrences (mean orthographic neighborhood [ON] size = 5.10; Balota et al., 2007) and high frequency words from 151 to 1,016 occurrences (ON = 5.35). Nonwords were formed by changing one of the letters of a word. Each word and nonword appeared only once for each participant.

Each trial started with a fixation cross for 500 ms and then was replaced with the stimulus until a response was made. Next, auditory feedback (a tone on error trials, silence on correct trials) was presented for 200 ms. The fixation cross for the next trial appeared 300 ms later.

Participants performed one practice block of 36 trials, followed by 16 experimental blocks of 72 trials each. They pressed the leftmost response-box button if the letter string was a word and the rightmost button if it was a non-word. Speed and accuracy were emphasized.

EEG Recording and Analyses. The EEG activity was recorded from electrodes F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, O1, Oz, O2, P5, P6, PO5, PO6, T7, T8, TP7, and TP8. These sites and the right mastoid were recorded in relation to a reference electrode at the left mastoid. The

EEGs were then re-referenced offline to the average of the left and right mastoids. The horizontal electrooculogram (HEOG) was recorded bipolarly from electrodes at the outer canthi of both eyes, and vertical electrooculogram (VEOG) was recorded from electrodes above and below the midpoint of the left eye. Electrode impedance was kept below 5 kΩ. EEG, HEOG, and VEOG were amplified using Synamps2 (Neuroscan) with a gain of 2,000, a bandpass of 0.1-50 Hz, and digitized at 250 Hz.

Trials with possible ocular and movement artifacts were identified using a threshold of ± 75µV for a 1,000 ms epoch beginning 200 ms before stimulus onset to 800 ms after stimulus onset. Each of these artifact trials were then inspected manually. This procedure led to the rejection of 5% of the trials, with no more than 22% rejected for any individual.

Averaged ERPs were time-locked to the stimulus onset. We conducted two different analyses on the ERPs. The first analysis was on N170, focusing on the occipital-parietal (electrodes O1, O2, PO5, and PO6) and temporal-parietal (electrodes T7, T8, TP7, and TP8) sites (see e.g., Simon et al., 2007). We measured the mean amplitude of N170 from 140-240 ms after stimulus onset relative to the 200-ms baseline period before stimulus onset. The second analysis was on P3, using electrodes Cz and Pz (e.g., Lien et al., 2008; Luck, 1998). The mean amplitude of P3 was measured from 400-600 ms after stimulus onset relative to the 200-ms baseline period before stimulus onset.

Analysis of variance (ANOVA) was used for all statistical analyses. Because word frequency and lexicality are not orthogonal (i.e., nonwords do not possess word frequency categories), we conducted ANOVAs on words including word frequency and separate ANOVAs that examined the lexicality effect (words vs. nonwords) but excluded word frequency.

<u>Results</u>

In addition to trials with ocular artifacts, trials were excluded from the analyses of behavioral data (RT and proportion of errors [PE]) and ERP data if RT was less than 100 ms or greater than 3,000 ms (0.05% of trials exceeded these cutoff values). Incorrect response trials were also excluded from RT and ERP analyses.

Behavioral Data Analyses. The primary ANOVA (words only) was conducted as a function of word frequency (high vs. low) and case type (lower case vs. mixed case). There was a word frequency effect on RT (67 ms), $F(1, 23) = 151.53$, $p < .0001$, $\eta_p^2 = .87$, and PE (.097), $F(1, 23) = 91.83$, $p < .0001$, $\eta_p^2 = .78$. There was also a case mixing effect on RT (50 ms), $F(1, 23) = 73.02$, $p < .0001$, $\eta_p^2 = .76$, and PE (.040), $F(1, 23) = 24.46$, $p < .0001$, $\eta_p^2 = .52$. The interaction between word frequency and case type was significant on PE, $F(1, 23) = 9.27$, $p < .01$, $\eta_p^2 = .29$, and it approached significance on RT, $F(1, 23) = 3.69$, $p = .0673$, $\eta_p^2 = .14$ (lower-case frequency effect: 74 ms and .087; mixed case: 60 ms and .107; see Table 1).

The secondary ANOVA (excluding word frequency) was conducted as a function of lexicality (word vs. nonword) and case type (lower case vs. mixed case). We were primarily interested in the lexicality effect; thus, only the effects involving lexicality were reported. Analyses revealed a lexicality effect on RT (63 ms), $F(1, 23) = 51.86$, $p < .0001$, $\eta_p^2 = .69$, and PE (-.018), $F(1, 23) = 4.66$, $p < .05$, $\eta_p^2 = .17$. The lexicality effect was significantly larger for lowercase than mixed case on RT (76 ms vs. 50 ms, respectively), $F(1, 23) = 16.83$, $p < .001$, $\eta_p^2 = .42$, and PE, $F(1, 23) = 11.96$, $p < .01$, $\eta_p^2 = .34$ (.004 vs. -.040).

ERP Analyses – N170. For the primary ANOVA (words only), N170 amplitudes were analyzed as a function of word frequency (high vs. low), case type (lower case vs. mixed case), electrode site (occipital-parietal vs. temporal-parietal), and electrode location (left vs. right hemisphere)[3]. Figure 1 shows the N170 amplitudes for these electrodes.

No main effect or interactions involved word frequency, *F*s ≤ 2.54, *p*s ≥ .1248. The N170 amplitude was larger for lowercase (-1.188 μV) than mixed case (-0.720 μV), $F(1, 23) = 2.95$, $p = .09$, $\eta_p^2 = .11$ (i.e., the case mixing effect). The case mixing effect was larger for the temporal-parietal site than for the occipital-parietal site, $F(1, 23) = 4.83$, $p < .05$, $\eta_p^2 = .17$. Further simple main effect analyses revealed that the case mixing effect approached significance for the temporal-parietal site, $F(1, 23) = 3.71$, $p = .06$, $\eta_p^2 = .14$ (-1.241 μV and -0.662 μV for lower and mixed cases, respectively), but not for the occipital-parietal site, $F(1, 23) = 2.03$, $p = .17$, $\eta_p^2 = .08$ (-1.136 μV and -0.778 μV for lower and mixed cases).

To examine the effect of lexicality, a second ANOVA was conducted. By necessity, we excluded the word frequency variable. N170 amplitudes were analyzed as a function of lexicality (word vs. nonword), case type (lower case vs. mixed case), electrode site (occipital-parietal vs. temporal-parietal), and electrode location (left vs. right hemisphere). Figure 2 depicts the N170 amplitudes for these electrodes. Only effects involving lexicality were reported.

No main effect of lexicality was found, $F < 1.0$. Although the lexicality effect on N170 was significantly larger for the temporal-parietal site (0.162 μV) than the occipital-parietal site (0.022 μV), $F(1, 23) = 4.71$, $p < .05$, $\eta_p^2 = .17$, further simple effects analyses failed to show a significant lexicality effect for the temporal-parietal site, $F(1, 23) = 2.75$, $p = .11$, $\eta_p^2 = .11$.

<u>ERP Analyses – P3.</u> For the primary ANOVA (words only), the P3 amplitudes were analyzed as a function of word frequency, case type, and electrode site (Cz vs. Pz). Figure 3 shows the P3 amplitudes for these electrodes. Only the main effect of word frequency was significant, $F(1, 23) = 24.33$, $p < .0001$, $\eta_p^2 = .51$ (6.612 μV and 4.679 μV for high and low frequency words, respectively).

The secondary ANOVA on P3 (excluding the word frequency variable) was conducted as a function of lexicality, case type, and electrode site. Figure 4 shows the P3 amplitudes for these electrodes. Analyses revealed a significant lexicality effect, $F(1, 23) = 57.76$, $p < .0001$, $\eta_p^2 = .72$ (5.645 μV for words and 2.420 μV for nonwords). The lexicality effect was larger for the electrode Cz (3.421 μV) than the electrode Pz (3.029 μV), $F(1, 23) = 7.52$, $p < .05$, $\eta_p^2 = .25$.

Discussion

The present study was designed to determine the processing loci for case mixing and word frequency effects. Earlier studies addressing this issue used behavioral measures on LDT (Allen et al., 2005) or eye movements in sentence reading (Reingold et al., 2010). They reached opposite conclusions. We addressed this issue by employing ERP measures in a LDT that manipulated word frequency and case mixing using specific “time stamps”: the relatively early N170 (an index of structural encoding) and the relatively late P3 (an index of stimulus categorization). It should be noted that although some studies have utilized the ERP approach (e.g., Donchin et al., 1978; Nasman & Rosenfeld, 1990; Lien et al., 2008; Polich & Donchin, 1988), they focused primarily on word frequency but not its interaction with case mixing, as in the present study.

Consistent with earlier reports, RT data revealed word frequency (67 ms) and case mixing (50 ms) effects. Furthermore, these effects were additive in the response latencies (lower-case frequency effect: 74 ms; mixed case: 60 ms), indicating that word frequency and case mixing primarily influenced different processing stages in lexical decision.

With regard to the time course of case mixing and word frequency effects, the ERP data revealed two notable results that help answer this question. First, case type influenced the N170 amplitude but not the P3 amplitude. While there was a trend for larger N170 for lower case than mixed case (the case mixing effect), the N170 modulation by case type was stronger for the temporal-parietal site than the occipital-parietal site. Consistent with this finding, neuroimaging evidence generally supports the idea that the temporal-parietal area (e.g., left fusiform gyrus) is associated with word recognition (Carreiras, Mechelli, Estévez, & Price, 2007).

The second notable finding was that word frequency in LDT affected the P3 amplitude but not the N170 amplitude. The modulation of the P3 amplitude by word frequency replicates Polich and Donchin (1988) and Lien et al. (2008). These findings suggest that, when words are presented only once, the word frequency effect emerges at a later stimulus categorization stage. Simon et al. (2007) also found no word frequency effect on the N170 when words were presented only twice for each participant. Because they did not examine the P3 component, it is difficult to evaluate whether their word frequency effect would occur later in processing. Simon et al., however, did observe a word frequency effect on the N170 when words were repeated 100 times. Thus, it is possible that the N170 is sensitive to familiarity, which could exaggerate the word frequency effect when words were repeated massively.

The present results were based on the examination of single-word identification using a LDT. Although the present conclusion is in contrast to the interpretation of Reingold et al.'s (2010) eye-tracking study of sentence reading, their findings rely on fundamentally different assumptions. As we indicated above, sentence reading is a complex process involving multiple levels of processing in addition to word identification. Thus, in sentence reading it may be difficult to isolate word-level effects of case mixing and word frequency. The presentation of a single word in the LDT, however, provides a precise description of the time course on how a single word is processed. Furthermore, Rheingold et al.'s examination of how fixation was modulated by word frequency and case mixing may have been confounded by the possible decoupling of fixation and attention (e.g., Yantis, 2000).

We suspect that there exists a more parsimonious interpretation of the Reingold et al. (2010) data (effects of word frequency and case type for four eye-tracking dependent variables, but only a word frequency effect for first fixation gaze duration for multiple-fixated words). Namely, the data can be explained by the two-stage model proposed by Allen, Wallace, and Weber (1995) and Yap and Balota (2007). The first stage involves stimulus normalization that assesses familiarity-based information (e.g., orthographic similarity of a letter string to a word). The second stage involves stimulus categorization/lexical access. This model can account for the Rheingold et al. data, as well as lexical decision, and word naming/pronunciation involving stimulus quality/case mixing and word frequency manipulations (see Yap & Balota, 2007).

The present finding provides some insight to whether case mixing and word frequency exhibit cascaded, interactive processing as suggested by the cascaded model (e.g., McClelland, 1979; Plaut & Booth, 2000) or a serial discrete model discussed above (e.g., Allen et al., 1995; Besner & McCann, 1987; Yap & Balota, 2007). While the additivity between case mixing and word frequency in the behavioral RT data can also be accounted by the cascaded model, the independence of case mixing and word frequency affecting different ERP components posts challenges for this model. The observed distinct temporal effects in the present study favor of the serial, discrete stage model of visual word recognition.

In conclusion, the present behavioral and ERP data indicate different loci for case mixing and word frequency effects in LDT. In particular, the ERP data suggest an early locus of case mixing (structural encoding as indexed by the N170 modulation) and a later locus of word frequency (stimulus categorization as indexed by the P3 modulation). In addition, lexicality also modulates the P3, which is consistent with an effect on later stimulus categorization (Monsell et al., 1989). The present study provides the first ERP demonstration of the time course for the case mixing and word frequency effects within the same LDT. We argue that case mixing affects an earlier processing stage than word frequency, at least with respect to lexical-decision processes.

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Footnotes

1. There is a debate regarding how word frequency affects decision processing. Some researchers argue that the word frequency effect is an early decision effect, triggered by stimulus categorization (e.g., Allen et al., 2005). Others assert that the effect is a late decision effect, triggered by the post-lexical decision (Balota & Chumbley, 1984). The present study is not intended to differentiate these two claims.
2. Although there is some disagreement regarding what this component actually reflects, there is general consensus that the latency of P3 indexes the time participants require to categorize a stimulus for response selection (Donchin, Ritter, & McCallum, 1978; Luck, 1998). In the present study, the P3 was large during the time window 400-600 ms as in Lien et al.'s (2008; Experiment 5) LDT study.
3. For the occipital-parietal site, the electrodes O1 and PO5 are located in the left hemisphere and the electrodes O2 and PO6 are in the right hemisphere. The N170 amplitude was averaged across O1 and PO5. The same method was used for the electrodes O2 and PO6. A similar method was applied to the temporal-parietal site.

Table 1.

Mean Response Time (RT; in Milliseconds) and Proportions of Errors (PE) as a Function of Lexicality (Word vs. Nonword), Word Frequency (High vs. Low), and Case Type (Lower vs. Mixed).

	Case Type	
	Lower Case	Mixed Case
	RT	
High Frequency Word	577 (15)	634 (19)
Low Frequency Word	651 (19)	694 (21)
Nonword	690 (21)	714 (25)
	PE	
High Frequency Word	.029 (.005)	.059 (.009)
Low Frequency Word	.115 (.014)	.166 (.016)
Nonword	.076 (.008)	.072 (.007)

Note: The standard error of the mean is shown in parentheses.

Figure Captions

Figure 1. Grand average event-related brain potentials for N170 as a function of word frequency (high vs. low) and case type (lower case vs. mixed case) for the left hemisphere electrodes (O1/PO5 and T7/TP7) and the right hemisphere electrodes (O2/PO6 and T8/TP8). The unfilled rectangular boxes indicate the time window used to assess N170 (140-240 ms after stimulus onset). Negative is plotted upward and time zero represents stimulus onset. The baseline period was the 200 ms prior to stimulus onset.

Figure 2. Grand average event-related brain potentials for N170 as a function of lexicality (word vs. nonword) and case type (lower case vs. mixed case) for the left hemisphere electrodes (O1/PO5 and T7/TP7) and the right hemisphere electrodes (O2/PO6 and T8/TP8). The unfilled rectangular boxes indicate the time window used to assess N170 (140-240 ms after stimulus onset). Negative is plotted upward and time zero represents stimulus onset. The baseline period was the 200 ms prior to stimulus onset.

Figure 3. Grand average event-related brain potentials for P3 as a function of word frequency (high vs. low) and case type (lower case vs. mixed case) for the electrodes Cz and Pz. The unfilled rectangular boxes indicate the time window used to assess P3 (400-600 ms after stimulus onset). Negative is plotted upward and time zero represents stimulus onset. The baseline period was the 200 ms prior to stimulus onset.

Figure 4. Grand average event-related brain potentials for P3 as a function of lexicality (word vs. nonword) and case type (lower case vs. mixed case) for the electrodes Cz and Pz. The unfilled rectangular boxes indicate the time window used to assess P3 (400-600 ms after stimulus onset). Negative is plotted upward and time zero represents stimulus onset. The baseline period was the 200 ms prior to stimulus onset.

Figure 1

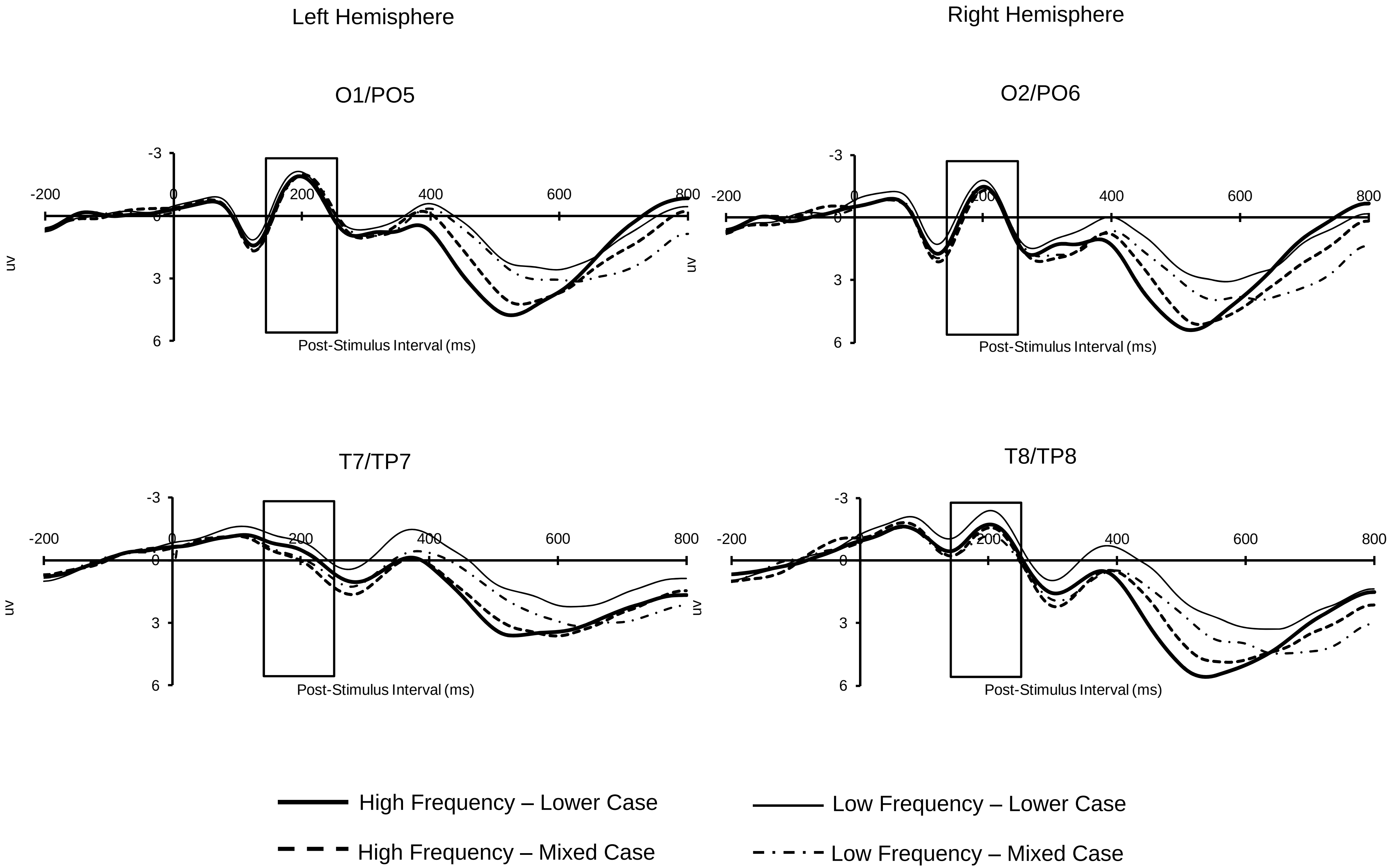

Left Hemisphere
Right Hemisphere
O1/PO5
O2/PO6
T7/TP7
T8/TP8
uv
Post-Stimulus Interval (ms)
High Frequency – Lower Case
Low Frequency – Lower Case
High Frequency – Mixed Case
Low Frequency – Mixed Case

Figure 2

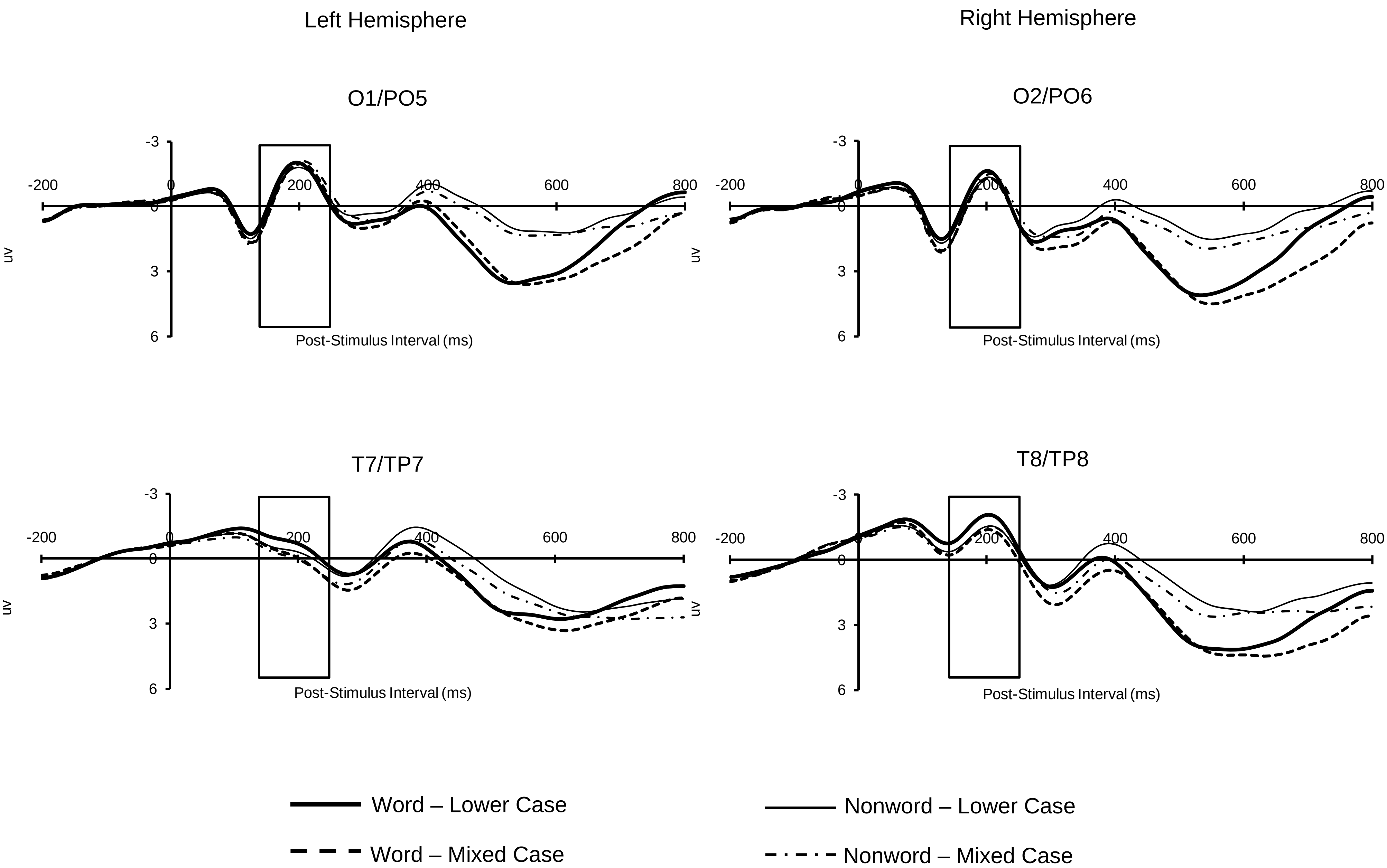
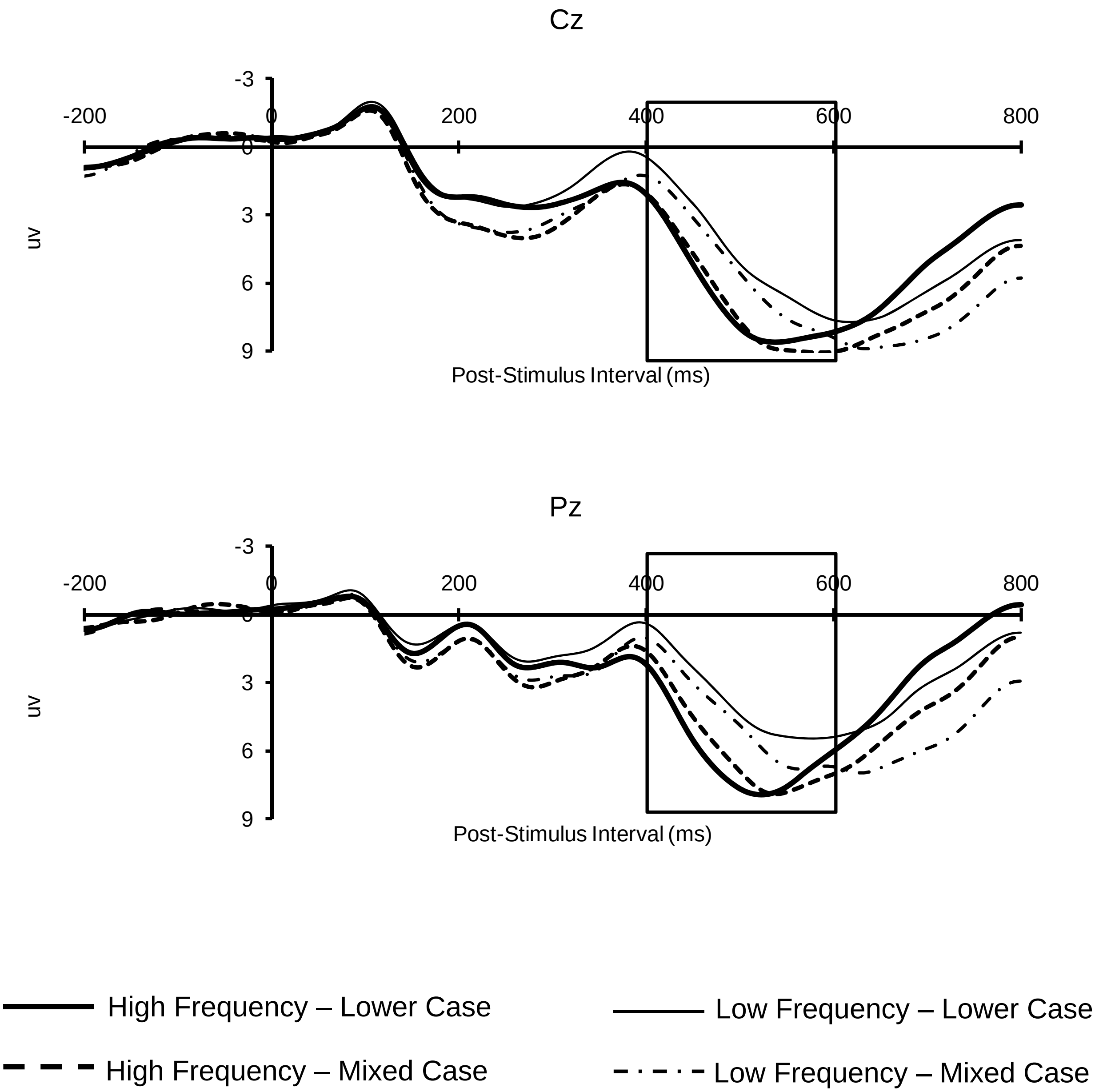
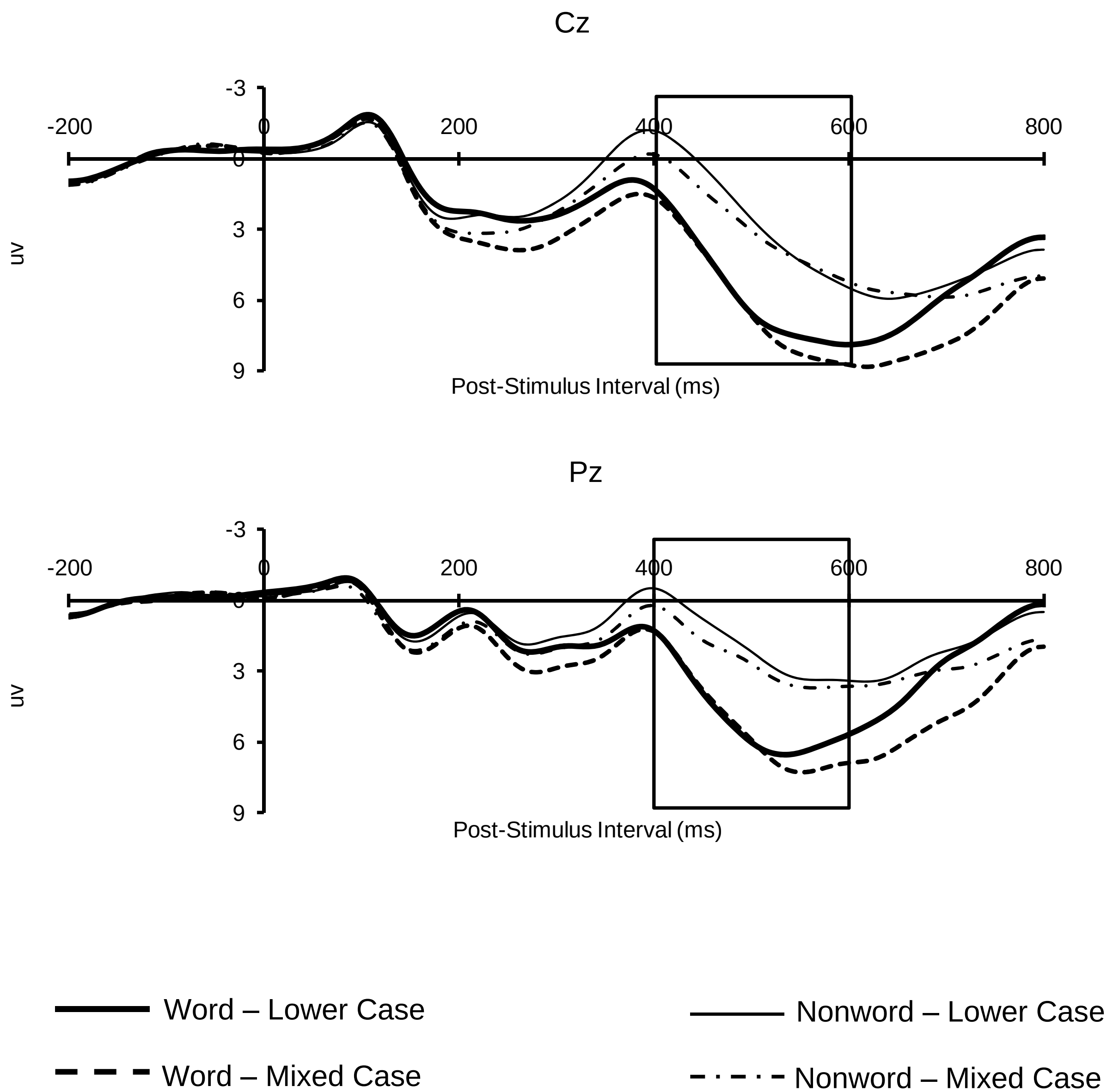

Left Hemisphere
Right Hemisphere
O1/PO5
O2/PO6
T7/TP7
T8/TP8
-3
0
3
6
-200
0
200
400
600
800
uv
Post-Stimulus Interval (ms)
Word – Lower Case
Word – Mixed Case
Nonword – Lower Case
Nonword – Mixed Case

Figure 3



Cz
-3
-200
0
200
400
600
800
0
3
6
9
uv
Post-Stimulus Interval (ms)
Pz
-3
-200
0
200
400
600
800
0
3
6
9
uv
Post-Stimulus Interval (ms)
High Frequency – Lower Case
Low Frequency – Lower Case
High Frequency – Mixed Case
Low Frequency – Mixed Case

Figure 4


Cz
-3
-200
0
200
400
600
800
3
6
9
uv
Post-Stimulus Interval (ms)
Pz
-3
-200
0
200
400
600
800
3
6
9
uv
Post-Stimulus Interval (ms)
Word – Lower Case
Word – Mixed Case
Nonword – Lower Case
Nonword – Mixed Case