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Effects of lexical status and morphological complexity in masked priming: An ERP study

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Two masked priming experiments examined behavioural and event-related potential responses to simplex target words (e.g., flex) preceded by briefly presented, masked, derived word primes (flexible-flex), complex nonword primes formed by an illegal combination of the target word and a real suffix (flexify-flex), and simplex nonword primes formed by adding a nonsuffix word ending to the target (flexint-flex). Subjects performed a lexical decision task. Behavioural results showed that all prime types significantly facilitated target recognition. Priming effects were reflected in the electrophysiological data by reduced N250 and N400 amplitudes, and these priming effects were statistically equivalent for the three types of prime. The strong priming effects found with simplex primes in the present study, compared with prior research, are thought to be due to the combination of targets always being completely embedded in prime stimuli plus the reduced lexical inhibition that arises with nonword primes. In line with prior behavioural research, however, there was evidence for differential priming effects as a function of prime type in the N400 ERP component in Experiment 2, with greater priming effects for derived and pseudocomplex primes relative to simplex primes at lateral posterior electrode sites.

Keywords: Evoked potentials; Morphology (language); Priming; Word recognition.

A number of findings suggest that the morphological structure of complex words plays a role in the way in which they are represented in the mental lexicon and accessed in language production and comprehension. Taft and Forster (1975) were among the first to propose that all morphologically

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complex words are subject to decomposition prior to lexical access during reading comprehension. According to this approach, morphological relations between words determine the nature of form representations that intervene between initial prelexical processing and access to whole-word form representations and meaning. Morphological relations between words could also determine the nature of semantic representations and their connectivity with whole-word form representations (e.g., Giraudo & Grainger, 2000, 2001).

The presence of a superficial morphological structure in certain morphologically simple words (e.g., "corner", which can be incorrectly decomposed into CORN + ER) has been exploited in recent years in order to investigate the role played by form-based and meaning-based morphology. Such pseudocomplex words can be contrasted with semantically transparent complex words of similar structure (e.g., farmer), and with simplex words that have an embedded pseudoroot but no morphological structure (e.g., scandal, with the embedded word "scan" followed by a nonmorphological ending "-dal").[1] A typical priming manipulation would involve first presenting the complex (or pseudocomplex, or orthographic control) prime stimulus followed by the stem target. Target recognition in these three types of related prime condition is then compared with performance when primes are unrelated to targets, providing a measure of priming. In this way, differences in the magnitude of priming effects across the three types of prime stimulus can reveal the relative influence of form and meaning-based morphology.

One key experimental finding is that semantically opaque primes produce significant priming whereas orthographic control primes generally do not (Diependaele, Sandra, & Grainger, 2005, 2009; Gold & Rastle, 2007; Lavric, Clapp, & Rastle, 2007; Longtin, Segui, & Halle, 2003; McCormick, Rastle, & Davis, 2008; Rastle, Davis, Marslen-Wilson, & Tyler, 2000; Rastle, Davis, & New, 2004). Furthermore, these opaque priming effects are only present with short prime durations (Dominguez, Segui, & Cuetos, 2002; Rastle et al., 2000, 2004). This is clear evidence for a form of automatic morpho-orthographic decomposition operating during the early phases of visual word recognition that is sensitive to the superficial morphological structure of strings, but blind to the semantic consequences of the decomposition. This process of prelexical morpho-orthographic decomposition is illustrated in Figure 1, which describes a hybrid approach to the representation and processing of complex words (see Diependaele et al., 2009). Figure 1 illustrates how such morpho-orthographic decomposition might influence

[1] Note that in psycholinguistic research, pseudocomplex words (e.g., corner) are typically put in the same category as semantically opaque morphologically complex words (e.g., department) as both lack a transparent semantic relationship between the stem and the whole-word.

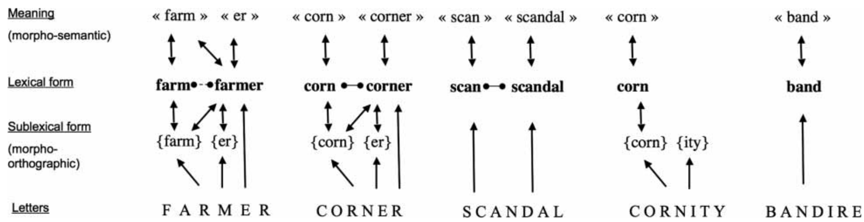

Figure 1. A model of morphological processing showing how semantically transparent complex words (farmer), pseudocomplex words (corner), simple words (scandal), complex nonwords (cornity), and simplex nonwords (cornires) are represented at the letter, sub-lexical form, lexical form, and meaning levels in the lexicon. Excitatory connections are represented by arrows and inhibitory connections by circles. The dashed inhibitory connection between "farmer" and "farm" represents the modulation of lateral inhibition by semantic transparency.

the processing of various types of complex stimuli (e.g., *farmer, corner, cornity*) relative to the processing of simplex stimuli (e.g., *scandal, cornire*).

One key prediction of this general approach is that prelexical morpho-orthographic decomposition should operate irrespective of the lexical status of prime stimulus. In other words, complex nonword primes (e.g., CORNITY, composed of the legal stem CORN and the legal suffix ITY) should prime their embedded stems (CORN) as much as complex real word primes (e.g., CORNER) whereas simplex nonword primes (e.g., CORNIRE) should not. This prediction was tested by Longtin and Meunier (2005) with nonword primes and their results were in line with the prediction. In French, the language used by Longtin and Meunier, complex nonword primes facilitated recognition of the embedded stem, whereas simplex nonword primes did not. Within the theoretical framework shown in Figure 1, the priming effect for complex nonwords ("cornity" as an example in English) arises from the automatic prelexical decomposition of the prime stimulus into its component morphemes ("corn", "ity").

One key feature of the model depicted in Figure 1, is the modulation of lateral inhibitory connections between whole-word form representations as a function of their semantic compatibility. This is hypothesised to be one source of semantic transparency effects in masked morphological priming (Morris, Holcomb, & Grainger, 2008).[2] More precisely, it is hypothesised that there is reduced competition between words that have both a morphological and a semantically transparent relation, as indicated by the dashed inhibitory connection between "farmer" and "farm" in Figure 1, compared with the solid inhibitory connections between "corner" and

[2] Another possible source, not shown in Figure 1, would be inhibitory connections between whole-word representations and semantics (i.e., between the semantic representation of "corner" and the whole-word representation of "corn".

"corn" and "scandal" and "scan". According to this general account, nonword primes (e.g., cornity-corn, cornire-corn) will not be subject to the same inhibitory influences, and should therefore produce even stronger facilitatory priming effects than real word primes. Evidence for such differences in priming effects from nonword and real word primes has been shown previously in behavioural research (Davis & Lupker, 2006; Segui & Grainger, 1990), and with ERPs (Massol, Grainger, Dufau, & Holcomb, 2010). Primes that are real word orthographic neighbours tend to inhibit target word recognition compared with unrelated primes, whereas nonword orthographic neighbour primes tend to produce the opposite effect.

ERPS AND MASKED MORPHOLOGICAL PRIMING

In recent years, researchers using behavioural data to test hypotheses about the representation and processing of words have begun to supplement these data with those of other methodologies such as scalp recorded event-related potentials (ERPs). Grainger and Holcomb (2009) have proposed a mapping of the ERP components observed in their masked repetition priming experiments onto component processes in a functional architecture for word recognition. A series of ERP components, whose amplitudes are modulated by priming, appear to reflect processing that proceeds from visual features to orthographic representations and finally to meaning (Grainger & Holcomb, 2009; Holcomb & Grainger, 2006, 2007; Massol et al., 2010). The interpretative framework developed by Holcomb and Grainger is shown in Figure 2.

Figure 2 illustrates a tentative mapping of ERP components obtained with the masked priming procedure onto the component processes of a generic interactive–activation model of word recognition (the bi-modal interactive–activation model; Diependaele, Ziegler, & Grainger, in press; Grainger & Holcomb, 2009; Grainger & Ziegler, 2007; Holcomb & Grainger, 2007). On presentation of a printed word, visual features are mapped onto prelexical orthographic representations (letters and letter clusters: O-units), which are subsequently mapped onto whole-word orthographic representations (O-words) and at the same time onto prelexical phonological representations via the central interface between orthography and phonology (O⇔P). Whole-word form representations then send activation onto semantic representations (S-units).

Focusing on the ERP components of interest for the present study, the N250 is hypothesised to reflect the mapping of prelexical orthographic representations onto whole-word orthographic representation. Within the general framework of interactive–activation, this mapping process involves the transfer of activation (feed-forward and feed-back) from letter and

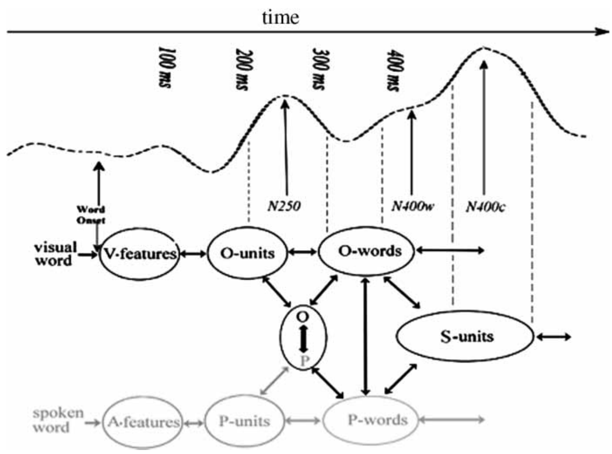

Figure 2. ERP masked priming effects mapped onto a bi-modal interactive–activation model, highlighting the two components of interest in the present study—the N250 and N400. The model has been turned on its side to better accommodate the temporal correspondence with ERP effects, and the auditory pathway has been dimmed. See main text for a description of the model, and Grainger and Holcomb (2009) for a more detailed analysis.

letter cluster representations to whole-word representations, and therefore indexes the initial build-up of activation at the lexical level and the stabilisation of activation at the sublexical level. The N400 (at least in its early phase, N400w) is hypothesised to reflect the mapping of lexical form onto meaning (later effects could reflect integration across semantic representations—labeled as N400c in Figure 2). Again, translated into the mechanics of interactive–activation, this mapping process reflects the transfer of activation from whole-word representations to semantic representations and therefore indexes the initial phase of activation of semantic representations and the stabilisation of activation at the level of whole-word units.

How does the latency and amplitude of these ERP components reflect changes in the underlying processes? Our initial attempts at bridging the gap between model and data suggest that the amplitude of the ERP components obtained in the masked priming paradigm at least partly reflect ease of target processing (see Grainger & Holcomb, 2009, for a recent review). For the two negative-going components of interest in the present study (N250 and N400), unrelated prime stimuli have systematically been found to generate more negative-going waveforms than related prime stimuli (Chauncey, Holcomb, & Grainger, 2008; Dufau, Grainger, & Holcomb, 2008; Grainger, Kiyonaga, & Holcomb, 2006; Holcomb & Grainger, 2006, 2007; Kiyonaga, Grainger, Midgley, & Holcomb, 2007). We would therefore tentatively associate greater negativity of these components with increased difficulty of target processing.[3]

The apparent sensitivity of the N250 to prelexical processing (Holcomb & Grainger, 2006) suggest that it can be productively used to investigate the early morpho-orthographic segmentation of morphologically complex stimuli. Several recent studies combining masked priming with ERP recordings have demonstrated the sensitivity of the paradigm to morphological structure (Lavric, Clapp, & Rastle, 2007; Morris, Frank, Grainger, & Holcomb, 2007, Morris et al., 2008; Rastle et al., 2004). Most relevant for the present study are the findings of Morris et al. (2008), i.e., a widespread priming effect in the early phase of the N250 for both morphologically related semantically transparent and semantically opaque morphological primes, but a dissociation between semantic and opaque primes in the late phase of the N250. These data support the hypothesis that early in visual word recognition there is a process of morpho-orthographic segmentation that operates independently of the semantic relatedness of the embedded root and the whole-word form. Semantic transparency started to have an influence in the later phase of the N250 in this study, in line with the model depicted in Figure 1 and the interpretative framework shown in Figure 2, where the earliest effects of semantic transparency occur at the level of whole-word representations via the modulation of lateral inhibitory influences. Also in line with this account is the evidence for semantic transparency effects in the N400 ERP component (Morris et al., 2007) and in behavioural studies (Diependaele et al., 2005, 2009; Feldman, O'Connor, Del Prado Martín, 2009), since semantically transparent primes activate meaning representations that are compatible with the prime, whereas opaque primes do not.

THE PRESENT STUDY

In the present study we provide a further investigation of priming effects from morphologically complex nonword primes, building on prior

[3] The tentative mapping of ERP components onto component processes in word recognition, illustrated in Figure 2, would appear to stand in contradiction with reports of early influences of lexical (i.e., word frequency) and semantic variables on ERPs (e.g., Dell'Acqua, Pesciarelli, Jolicoeur, Eimer, & Peressotti, 2007; Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006; Hauk & Pulvermüller, 2004). There are two possible reasons for this apparent discrepancy. One is that the masked priming procedure, used in our studies, produces an overall slowing down of target word processing (a general interference from prime and masking stimuli against which prime relatedness effects emerge). Therefore, our timing estimates will be longer compared with studies using unprimed word recognition. The other possible reason is that major ERP components, such as the widely distributed N250 and N400, may reflect the bulk of processing at a given level of representation (or perhaps resonant activity across two adjacent levels), and not the fastest feedforward processes.

behavioural research on this topic (Longtin & Meunier, 2005) as well our prior research combining masked priming and ERP recordings. We compare priming effects from semantically transparent derived prime words (e.g., farmer-farm) with priming effects from morphologically complex nonword primes (e.g., cornity-corn) and simplex nonwords with an embedded word at their beginnings (e.g., *cornire*-*corn*). We expect the complex nonwords to generate priming effects at least as strong as the complex real word primes, and both of these conditions should generate stronger priming than the simplex nonwords. The time-course of these different priming effects will be investigated by measuring their impact in the two major ERP components seen in our prior masked priming research (N250, N400) thought to reflect the gradual transition from prelexical form representations to semantics via whole-word representations (Grainger & Holcomb, 2009; Holcomb & Grainger, 2006).

EXPERIMENT 1

In the study reported here, we examined the effects produced by the short masked presentation of existing derived words, complex nonwords, and simplex nonwords on the recognition of their roots or pseudoroots. Given the results of prior behavioural and ERP research, we expect to see effects of lexical status and morphological complexity in the N250 component. The morpho-orthographic decomposition hypothesis predicts that the effects of complex nonword primes should be equivalent to the effects of true derived word primes on the one hand, and differ from those of simplex nonword primes on the other. Within the specific framework described in Figures 1 and 2, if semantic transparency effects are mostly driven by lateral inhibitory interactions between whole-word representations, then there should be little difference between pseudocomplex (*cornity*) and true derived primes (*farmer*) in any ERP components. Differences with respect to the orthographic control condition (i.e., simplex nonword primes: *cornire*) will depend on the extent to which prelexical morpho-orthographic decomposition has an influence in the absence of lateral inhibitory effects.

Method

Participants

The participants for this study were 33 adults (20 women). The electrophysiological and behavioural data from eight participants were excluded from analysis, four because of excessive eye movement artifact and four for error rates greater than 30%. All participants were recruited from the Tufts University community and paid for their participation. The participants ranged in age from 18 to 26 years (mean 20.5 years). All were right-handed native English speakers with normal or corrected-to-normal vision, and none reported any linguistic or neurological impairment.

Stimuli

The stimuli for this study consisted of 1,200 prime-target pairs in which the target was a simple root (e.g., flex) and the prime was either a morphologically related complex word (e.g., flexible), a morphologically related complex nonword (e.g., flexity), an orthographically related nonword (e.g., flexire), or an unrelated complex word (e.g., painter). We created the stimuli by selecting 300 roots and 17 bound suffixes from the CELEX English database (Baayen, Piepenbrock, & Gulikers, 1995; see Appendix 1). We then combined each root with either a permissible suffix to form an existing derived word (e.g., "good" + "-ness" ⇨ "goodness") or with an impermissible suffix to form a morphologically complex nonword (e.g., "cool" + "-age" ⇨ "coolage"). We also selected 17 existing nonmorphemic word ending—matched in length with the suffixes—which were combined with the roots to form nonmorphological nonwords (e.g., "corn" + "-ire" ⇨ "cornire"). Average frequencies per million for roots and derived words were 13.3 and 71.7, respectively. The mean suffix type frequency was 541.9, and the mean suffix token frequency, i.e., the summed frequency of all words with that ending, was 831,19.1. The mean type frequency of the nonsuffix endings was 72.1, and the mean token frequency was 46,385.8. We also measured the productivity of the suffixes and nonsuffix endings by counting the number of words with that ending having a frequency of one (Baayen, 1994). For suffixes, the mean productivity score was 44.6, while for nonsuffixes the mean productivity score was four. Suffixes and nonsuffixes differed in type frequency, $F(1,\ 32) = 7.8$, $p < .01$, and productivity, $F(1,\ 32) = 4.6$, $p < .05$, but did not differ not in token frequency, $F(1,\ 32) = 0.00$, $p > .3$. The mean length in number of letters for targets and primes were 4.8 and 7.5, respectively.

We constructed five lists consisting of 240 prime-target pairs. In each list there were 60 roots preceded by related complex words, 60 roots preceded by related morphologically complex nonwords, 60 roots preceded by related nonmorphological nonwords and 60 roots preceded by unrelated complex words. Each participant saw each item in only one condition, but each item appeared in all four conditions within a group of five participants. This reduced the possibility of item specific confounds.

Of the 240 experimental prime-target pairs, 180 were related pairs and 60 were unrelated. Therefore, as fillers, we added 120 unrelated pairs with word targets to equate the number of related and unrelated pairs. As the task was lexical decision, we also added 360 pairs with nonword targets. All nonword targets were created by changing one or two letters of an existing word, ensuring that the nonword created in this fashion adhered to the phonotactic rules of English. Of these 360 pairs with nonword targets, 60 were related derived word/nonword pairs, 60 were related pseudocomplex word/nonword pairs, 60 were orthographically related word/nonword pairs, and 180 were unrelated word/nonword pairs. Thus each list consisted of a total of 720 prime-target pairs with equal numbers of word and nonword targets and equal numbers of related and unrelated pairs.

Procedure

Participants were seated in a comfortable chair is a darkened room at a distance of 140 cm from the computer monitor. Each testing session began with a short practice block, followed by the experimental block. Participants were told that they would see a string of letters appear on the screen and they were instructed to decide whether the stimulus was a valid English word or not and respond as quickly and as accurately as possible by pressing one of two response keys, with either the right or left hand. The keys were counter balanced across participants. Visual stimuli were presented on a 19-inch monitor, with a diagonal viewable screen size of 18 inches, and a width of approximately 14.5 inches, set to a refresh rate of 100 Hz (which allows 10 ms resolution of stimulus control). Stimuli were displayed at high contrast as white letters (Verdana font) on a black background. Each letter was 40 pixels tall by 20 pixels wide. The screen resolution was 800 by 600 pixels, and the visual angle subtended by stimuli (3–9 characters) ranged from 1.1 to 3.25 degrees. Primes were presented in lower case letters for 50 ms preceded by a 500 ms random consonant mask. The mask shared no letters in common with the target or with the prime. The target was presented immediately after the prime in upper case letters for 300 ms followed by a 900 ms ISI.

Recording procedure

The electroencephalogram (EEG) was recorded from 29 active tin electrodes held in place on the scalp by an elastic cap (Electrode-Cap International). In addition to the 29 scalp sites, additional electrodes were attached to below the left eye (to monitor for vertical eye movement/blinks), to the right of the right eye (to monitor for horizontal eye movements), over the left mastoid bone (reference) and over the right mastoid bone (recorded actively to monitor for differential mastoid activity). All EEG electrode impedances were maintained below 5 kω (impedance for eye electrodes was less than 10 kω). The EEG was amplified by an SA Bioamplifier with a bandpass of 0.01 and 40 Hz and the EEG was continuously sampled at a rate of 200 Hz throughout the experiment.

Data analysis

We calculated the mean voltage in each of 3 two windows (225–325 ms, and 375–475 ms after target onset), relative to a 100 ms preprime baseline. These time epochs were chosen by visual inspection of the ERP waveforms, and because they correspond roughly to the latency ranges that have been found for the N250, and the N400 in prior research using masked priming albeit shifted later in time about 25 ms, although the reasons for this shift are unclear. In addition, based on previous research showing a division of the N250 into early and late components, we also measured mean voltage amplitudes in two equal intervals corresponding to an early (225–275 ms) and a late (275–325 ms) phase. Critical trials to which participants had responded incorrectly were discarded, as were trials characterised by excessive EOG artifact, and those with response times greater than 1,200 ms. This resulted in 12.3% of trials being discarded, a percentage that did not vary significantly across experimental conditions, $F(3, 72) = 1.1$, $p > .3$.

We analysed the electrophysiological data with four separate repeated measures ANOVAs (see Figure 3). The first "midline" ANOVA included a single anterior/posterior ELECTRODE SITE factor with five levels (FPz vs. Fz vs. Cz vs. Pz vs. Oz); the three other analyses included sites located at three bilateral columns running along the rostral–caudal axis. These three analyses involved an anterior/posterior ELECTRODE SITE factor with either three (Lateral Column 1-FC1/FC2 vs.C3/C4 vs. PC1/PC2), four

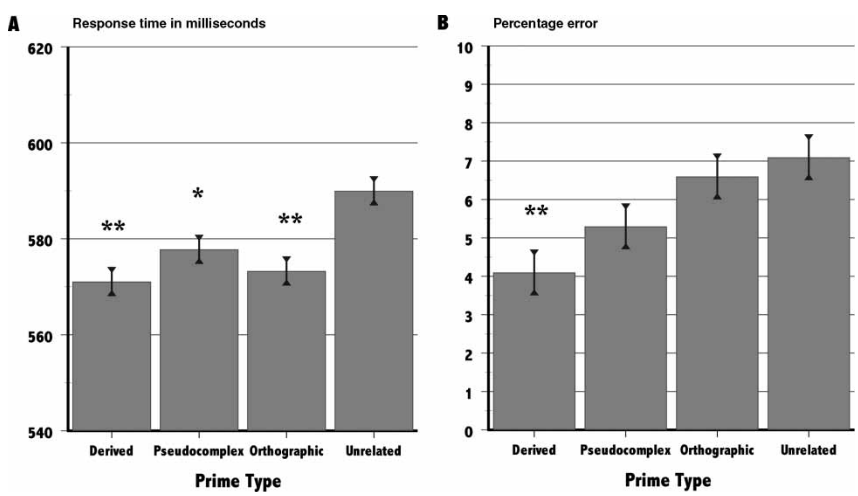

Figure 3. Mean response time in milliseconds (panel A) and mean percentage correct (panel B) for targets preceded by derived, pseudocomplex, orthographic, and unrelated primes. *Difference from the unrelated condition significant at $p = .05$; **Difference from the unrelated condition was significant at $p = .01$.

(Lateral Column 2-F3/F4 vs. FC5/FC6 vs. CP5/CP6 vs. P3/P4) or five levels (Lateral Column 3-FP1/FP2 vs. F7/F8 vs. T3/T4 vs. T5/T6 vs. O1/O2), as well as a HEMISPHERE factor (Left vs. Right). All four ANOVAs included the factor PRIMETYPE with four levels—Derived, Pseudocomplex, Orthographic, and Unrelated. LIST was included as a dummy variable. We only report results concerning the main effects of the experimentally manipulated factor PRIMETYPE, and the interaction of this factor with the topographic factors ELECTRODE SITE and HEMISPHERE. The alpha level was set at 0.05.

We analysed the reaction time and error rate data with a repeated measure ANOVA including the factor PRIMETYPE with four levels, Derived, Pseudocomplex, Orthographic, and Unrelated. As with the analysis of the electrophysiological data, LIST was included as a dummy variable. Any responses that were longer than 1,200 ms were excluded from analyses.

For both the electrophysiological and the behavioural data, the Geisser–Greenhouse correction was applied when evaluating effects with more than one degree of freedom.

Results

Behavioural data

The reaction time data showed that all related prime types primed their targets (see Table 1). There was a main effect of PRIMETYPE in both the subjects and items analyses, $F_{subj}(3, 60) = 10.1$, $p < .001$; $F_{itm}(3, 897) = 39.82$, $p < .001$. Follow-up analyses showed that the main effect of PRIMETYPE was due to response times to targets preceded by derived, $t(1, 24) = 5.3$, $p = .001$, pseudocomplex, $t(1, 24) = 2.7$, $p = .013$,[4] and orthographic, $t(1, 24) = 3.7$, $p = .001$, primes being all significantly faster than response times to targets preceded by unrelated primes.

The error data also showed a main effect of PRIMETYPE, $F_{subj}(3, 60) = 8.8$, $p < .001$; $F_{itm}(3, 897) = 5.099$, $p = .002$. Follow-up analyses showed that there were fewer errors to targets preceded by derived and pseudocomplex primes than to targets preceded by unrelated primes. This effect was significant for the derived primes, $t(1, 24) = 3.5$, $p = .002$, but only marginally so for the pseudocomplex primes, $t(1, 24) = 1.9$, $p = .065$. Errors to targets preceded by orthographic primes did not differ from those to targets preceded by unrelated primes ($p > .4$). Errors to target preceded by derived primes also differed from those to targets preceded by pseudocomplex, $t(24) = 3.1$, $p = .005$, and orthographic, $t(24) = 4.1$, $p < .001$, primes.

[4] Not significant when corrected for multiple comparisons.

TABLE 1
Mean response times in milliseconds and mean percentage error rates for responses to targets in Experiment 1

PRIMETYPE	*Mean response time (ms)*	*Std. Error*	*Mean response time (ms)*	*Std. Error*	*Priming effect*
Derived	571.05	14.21	4.07	0.96	19.95
Pseudomorphemic	577.75	13.43	5.33	0.97	12.25
Orthographic	573.32	12.89	6.60	1.23	16.68
Unrelated	590.00	13.41	7.13	1.38	–

Electrophysiological data

N250 time window. Between 225 and 325 ms after target onset, across all four analysis columns, we found a significant main effect of PRIMETYPE [Midline: $F(3, 60) = 6.0$, $p = .002$; Lateral Column 1: $F(3, 60) = 6.9$, $p = .001$; Lateral Column 2: $F(3, 60) = 4.9$, $p = .005$; Lateral Column 3: $F(3, 60) = 4.2$, $p = .01$] as well as a significant PRIMETYPE by ELECTRODE SITE interaction at midline sites, $F(12, 240) = 2.6$, $p = .04$. There were no other significant interactions involving the factor PRIMETYPE (all ps $> .05$).

Follow-up analyses conducted to clarify the source of the main effect of PRIMETYPE revealed that responses to targets preceded by unrelated primes were more negative in this epoch than those to targets preceded by either derived [Midline: $F(1, 24) = 9.2$, $p = .006$; Lateral Column 1: $F(1, 24) = 8.8$, $p = .007$; Lateral Column 2: $F(1, 24) = 6.5$, $p = .017$; Lateral Column 3: $F(1, 24) = 6.6$, $p = .017$], pseudocomplex [Midline:$F(1, 24) = 10.5$, $p = .003$; Lateral Column 1: $F(1, 24) = 13.3$, $p = .001$; Lateral Column 2: $F(1, 24) = 8.3$, $p = .008$; Lateral Column 3: $F(1, 24) = 7.2$, $p = .013$] or orthographic [Midline: $F(1, 24) = 20.8$, $p < .001$; Lateral Column 1: $F(1, 24) = 22.5$, $p < .001$; Lateral Column 2: $F(1, 24) = 15.6$, $p = .001$; Lateral Column 3: $F(1, 24) = 9.4$, $p = .005$] primes. Derived, pseudocomplex and orthographic primes did not differ significantly from each other (all ps $> .1$).

Visual inspection of the waveforms suggested, and planned comparisons confirmed, that the PRIMETYPE by ELECTRODE SITE interaction that we found in the analysis of midline sites resulted from the presence of a priming effect for derived primes at all sites [unrelated vs. derived: $t_{FPz}(1, 24) = 2.4$, $p = .026$; $t_{Fz}(1, 24) = 2.2$, $p = .036$; $t_{Cz}(1, 24) = 2.8$, $p = .010$; $t_{Pz}(1, 24) = 3.1$, $p = .004$; $t_{Oz}(1, 24) = 2.9$, $p = .009$], for orthographic primes at all but the most anterior site, FPz [unrelated vs. orthographic: $t_{Fz}(1, 24) = 2.5$, $p = .020$; $t_{Cz}(1, 24) = 4.9$, $p < .001$; $t_{Pz}(1, 24) = 6.1$, $p < .001$; $t_{Oz}(1, 24) = 4.0$, $p = .001$], and for pseudocomplex primes at all but the most posterior site, Oz [unrelated vs. pseudocomplex: $t_{FPz}(1, 24) = 2.4$, $p = .024$; $t_{Fz}(1, 24) = 3.0$, $p = .006$; $t_{Cz}(1, 24) = 4.2$, $p = .001$; $t_{Pz}(1, 24) = 2.3$, $p = .029$].

Visual inspection of the N250 epoch suggested that effects might differ in the earlier and later portions of the epoch and recent studies have found distinct patterns of priming effects in a division of the N250 into early and late sub-components. Therefore we divided this epoch into two equal intervals corresponding to an early (225–275 ms) and a late (275–325 ms) phase. The pattern of effects seen in both the early and late N250 time windows mirrored that of the overall N250 analysis, and there were no notable differences in these two time windows.

N400 time window. Between 375 and 525 ms after target onset, across all four analysis columns, we found a significant main effect of PRIMETYPE [Midline: $F(3, 60) = 10.7$ $p < .001$; Lateral Column 1: $F(3, 60) = 12.0$, $p < .001$; Lateral Column 2: $F(3, 60) = 11.2$, $p < .001$; Lateral Column 3: $F(3, 60) = 4.3$, $p = .015$] as well as a significant PRIMETYPE by ELECTRODE SITE interaction [Midline: $F(12, 240) = 11.3$, $p < .001$; Lateral Column 1: $F(6, 120) = 5.9$, $p = .001$; Lateral Column 2: $F(9, 180) = 8.6$, $p < .001$; Lateral Column 3: $F(12, 240) = 9.4$, $p < .001$]. There were no other significant interactions involving the factor PRIMETYPE (all ps $> .05$).

Follow-up analyses conducted to clarify the source of the main effect of PRIMETYPE revealed that responses to targets preceded by unrelated primes were more negative in this epoch than those to targets preceded by either derived [Midline: $F(1, 24) = 19.4$, $p < .001$; Lateral Column 1: $F(1, 24) = 40.5$, $p < .001$; Lateral Column 2: $F(1, 24) = 22.6$, $p < .001$; Lateral Column 3: $F(1, 24) = 9.0$, $p = .006$], pseudocomplex [Midline: $F(1, 24) = 12.6$, $p = .002$; Lateral Column 1: $F(1, 24) = 21.0$, $p < .001$; Lateral Column 2: $F(1, 24) = 14.0$, $p = .001$; Lateral Column 3: $F(1, 24) = 7.1$, $p = .01$] or orthographic [Midline: $F(1, 24) = 29.4$, $p < .001$; Lateral Column 1: $F(1, 24) = 50.3$, $p < .001$; Lateral Column 2: $F(1, 24) = 37.3$, $p < .001$; Lateral Column 3: $F(1, 24) = 15.2$, $p = .001$] primes. Derived, pseudocomplex and orthographic primes did not differ significantly from each other (all ps $> .05$), although the difference between the derived and orthographic conditions was marginally significant at midline sites, $F(1, 24) = 4.2$, $p = .051$. The PRIMETYPE by ELECTRODE SITE interaction was due to the centro-parietal distribution of the effect, with greater differences between responses to unrelated and related targets at centro-posterior sites compared with anterior sites (Figure 4 and 5).

Summary of results

The electrophysiological data showed an N250 and an N400 effect for all related primes. In both the N250 and N400 epochs, responses to

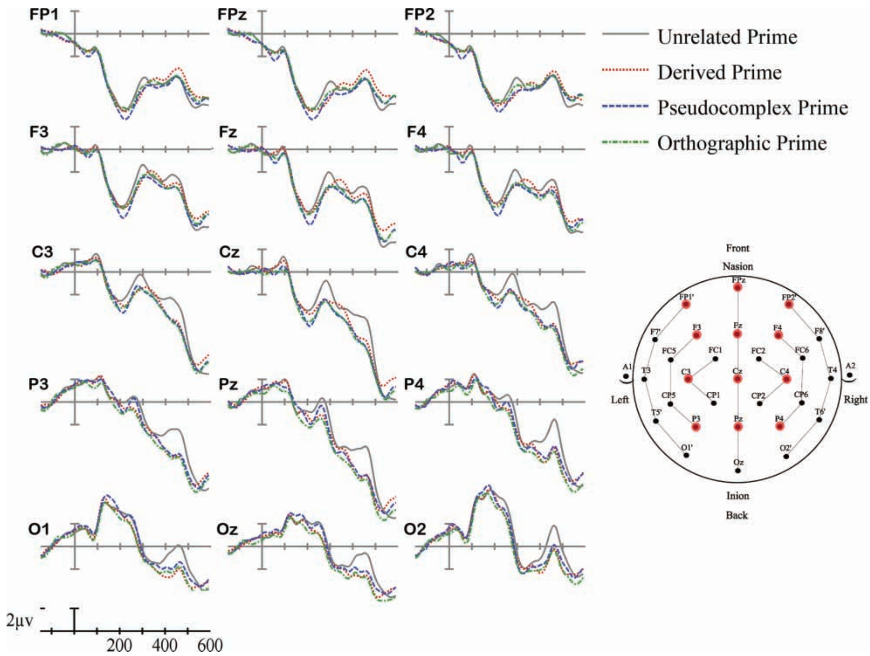

Figure 4. ERP waveforms at 12 selected electrode sites showing the responses to targets following derived (red dotted line), pseudocomplex (blue dashed line), orthographic (green dotted/dashed line), and unrelated (grey solid line) primes in Experiment 1. At the bottom right of the figure is shown the electrode montage. The four analysis columns used for ANOVAs are illustrated with solid lines. The 15 electrode sites plotted in the figure are shown highlighted with red circles. Negative voltages are plotted upward. Target onset is marked by the vertical calibrating bar, and each tick mark on the *x*-axis represents 100 ms.

targets preceded by unrelated primes were more negative than those to targets preceded by derived, pseudocomplex or orthographic primes. Behavioural data showed the same pattern, with all related primes generating shorter RTs than the unrelated primes. However, there was some evidence for an advantage for complex and pseudocomplex primes in the error data.

Visual inspection of the N250 epoch suggested that effects might differ in the earlier and later portions of the epoch and recent studies have found distinct patterns of priming effects in a division of the N250 into early and late sub-components. Therefore we divided this epoch into two equal intervals corresponding to an early (225–275 ms) and a late (275–325 ms) phase. However, we found no differences; in both the early and late phases of the N250, unrelated targets were more negative than targets preceded by either derived, pseudocomplex or orthographic primes.

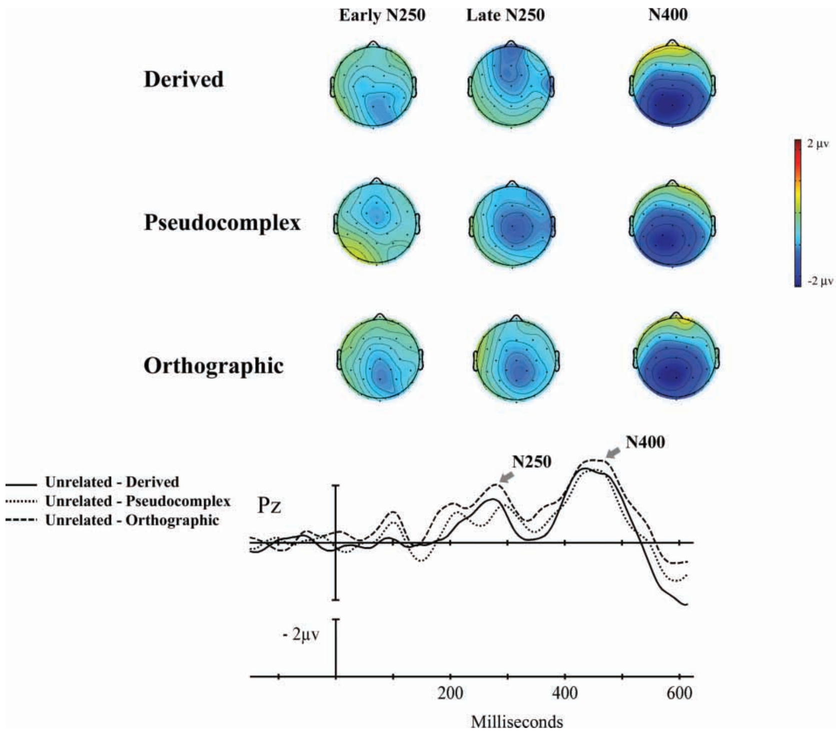

Figure 5. The spatial distribution of the priming effects found in the N250 and N400 time windows at the scalp surface for the derived (top), pseudocomplex (middle), and orthographic (bottom) conditions in Experiment 1. These maps were formed from difference waves calculated by subtracting each related condition from the unrelated condition. At the bottom of the figure is depicted the difference waveforms for unrelated minus related targets for the derived (dashed line), pseudocomplex (dotted line), and orthographic (solid line) conditions at electrode site Pz.

EXPERIMENT 2

In Experiment 1, although related primes were of three types—derived, complex nonword (pseudocomplex), or simplex nonword (orthographic), unrelated primes were always real derived words. Therefore we conducted another study in which the unrelated primes, like the related primes, were also derived real words, complex nonwords or simplex nonwords. This design resulted in a better match of related and unrelated primes and allowed us to ensure that the findings in Experiment 1 were not an artifact of differences in word type across related and unrelated primes. Moreover, the design in which all unrelated primes in one list were used as related primes in another list ensured that any differences between related and unrelated items—for any prime type—could not be due to individual items differences.

Methods

Subjects

As in Experiment 1, participants in Experiment 2 were recruited from the Tufts University community and were paid for their participation. All subjects had normal or corrected to normal vision, did not report any linguistic or neurological condition, and were right handed, native English speakers. Experiment 2 had 30 participants (17 females) who ranged in age from 17 to 26 (mean of 19.7). We excluded the data of three subjects, two for excessive eye movement artifacts and one for an error rate greater than 30%.

Stimuli

The experimental stimuli for Experiment 2 were 2,160 prime-target pairs. Sixty roots and six suffixes from the CELEX database (Baayen et al., 1995) and six nonmorphemic existing word endings, matched in length to the suffixes, were added to those from Experiment 1 to give 360 roots, 23 bound suffixes and 23 nonsuffix word endings (see Appendix 2). The primes were formed in the same way as in Experiment 1, by combining the roots with each of one of the three types of endings; real suffixes to give real derived words, real suffixes to give complex nonwords, and nonsuffix endings to give the simplex nonwords. In Experiment 2, the unrelated primes were of the same three types as the related words, that is, real derived words (Derived), complex nonwords (pseudocomplex), and simplex nonwords (orthographic).

Average frequencies per million taken from the CELEX database were 72.3 for the roots and 12.0 for derived words. The mean type frequency of the suffixes was 477.1 and the mean token frequency was 66,823.7. The mean type frequency of the nonsuffix endings was 60.6 and the token frequency was 37,089.0. The mean productivity of the suffixes was 36.6 and that of the nonsuffixes was 3.1. The suffixes and nonsuffixes differed in type frequency, $F(1, 44) = 10.6$, $p < .01$, and productivity, $F(1, 44) = 5.5$, $p < .05$, but not in token frequency, $F(1, 44) = 1.1$, $p > .2$. The mean length of targets was 4.8 letters and that of primes was 7.6 letters.

Nine stimulus lists were constructed so that each target appeared in each condition once among the nine lists, no list contained any repeated primes or targets, and all unrelated primes in one list were used as related primes in another list so that across participants the same items appeared as primes in the related and unrelated conditions.

Each list contained 240 experimental items, 120 related items, and 120 unrelated items, all with real word targets. To these items, 240 word pairs were added with nonwords targets. As in Experiment 1, nonword targets were created by changing one or two letters of existing words. Each nonword prime was preceded by a related or unrelated prime that was derived, pseudocomplex or orthographic with 40 prime-target pairs in each condition, just as for real word targets.

Procedure

The behavioural data collection and electrophysiological recording procedures were identical to those of Experiment 1.

Data analysis

We calculated the mean voltage in each of two time windows (200–300 ms and 350–450 ms after target onset), relative to a 100 ms preprime baseline. These time epochs were chosen both by visual inspection of the ERP waveforms, and because they correspond to the latency ranges that have been found for the N250, and the N400 in prior research using masked priming. They also correspond to the latencies of ERP peaks prominent in the waves seen at many sites. Unlike in Experiment 1, these were not shifted in time. In addition, as in Experiment 1, we also measured mean voltage amplitudes in two equal intervals corresponding to an early (200–250 ms) and a late (250–300 ms) phase. Critical trials to which participants had responded incorrectly were discarded, as were trials with response times greater than 1,200 ms, and those characterised by excessive EOG artifact. The percentage of trials that were discarded because of excessive EOG artifact (6.96%) did not vary significantly across experimental conditions, $F(5, 156) = 0.27$, $p > .9$.

As in Experiment 1, we analysed the electrophysiological data with four separate repeated measures ANOVAs, the first including the midline sites and the three other analyses including sites located at three bilateral columns running along the rostral–caudal axis (see Figure 6). In the current analyses, we also had two nontopographic variables, RELATEDNESS (related, unrelated), and PRIME TYPE (derived, pseudocomplex, and orthographic).

All four ANOVAs included an ELECTRODE SITE factor identical to that of Experiment 1, as well as the two-level factor RELATEDNESS (related vs. unrelated) and the three-level factor PRIMETYPE (derived vs. pseudocomplex, vs. orthographic). As in Experiment 1, all three lateral column ANOVAs included the factor of HEMISPHERE (left vs. right). LIST was included as a dummy variable. We only report results concerning the experimentally manipulated factors PRIMETYPE and RELATEDNESS and the interaction of these factors with the topographic factors ELECTRODE SITE and HEMISPHERE.

We analysed the reaction time and error rate data with a repeated measure ANOVA including the factors PRIMETYPE with three levels, derived, pseudocomplex, and orthographic and RELATEDNESS with two levels, Related and Unrelated. As with the analysis of the electrophysiological data, LIST was included as a dummy variable and responses longer than 1,200 ms

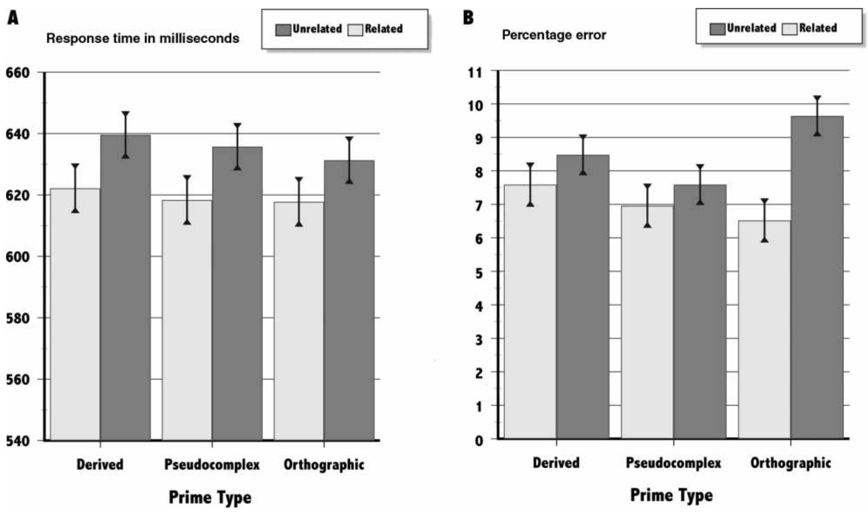

Figure 6. Mean Response time in milliseconds (panel A) and mean percentage correct (panel B) for targets preceded by related (light bars) and unrelated (dark bars) derived, pseudocomplex, orthographic and unrelated primes.

were excluded from the analysis. For both the electrophysiological and behavioural data, the Greenhouse–Geisser correction was applied when evaluating effects with more than one degree of freedom.

Results

Behavioural data

The behavioural data showed an effect of RELATEDNESS in both the reaction times and error rates (see Tables 2 and 3). There was a main effect of RELATEDNESS for reaction times in both the subjects and items analyses, $F_{subj}(1, 18) = 16.7$, $p = .001$; $F_{itm}(1, 347) = 20.38$, $p < .001$, with reaction times to targets in the related condition being faster than those in the unrelated condition. There was also a main effect of RELATEDNESS on the error data, $F_{subj}(1, 18) = 9.3$, $p = .007$; $F_{itm}(1, 359) = 6.98$, $p = .009$, with a higher error rate to targets in the unrelated condition than in the related condition. There was no effect of PRIMETYPE ($p > .05$) and no interaction between PRIMETYPE and RELATEDNESS ($p > .3$) in either the reaction time or the error data analyses, indicating the priming effect—the difference between related and unrelated items—did not differ across conditions. The lack of a main effect of PRIMETYPE confirms that the design—in which all unrelated primes in one list were used as related primes in another list—was an effective counterbalancing measure.

TABLE 2
Mean response times in milliseconds for responses to targets in Experiment 2

PRIMETYPE	*Mean response time (ms) related*	*Std. Error*	*Mean response time (ms) unrelated*	*Std. Error*	*Priming effect*
Derived	622.18	17.07	639.57	14.38	17.39
Pseudocomplex	618.38	15.76	635.73	15.01	17.34
Orthographic	617.76	15.78	631.31	16.97	13.55

Electrophysiological data

N250 time window. The N250 was analysed between 200 and 300 ms after target onset. We found a main effect of RELATEDNESS [Midline: $F(1, 18) = 11.9$, $p = .003$; Lateral Column 1: $F(1, 18) = 13.2$, $p = .002$; Lateral Column 2: $F(1, 18) = 9.2$, $p = .007$; Lateral Column 3: $F(1, 18) = 7.2$, $p = .015$] with responses to targets in the unrelated condition being more negative than those in the related condition. We also found a significant RELATEDNESS by ELECTRODE SITE interaction at Lateral Column 2, $F(3, 54) = 4.05$, $p = .048$. The interaction was marginally significant at the midline, $F(4, 72) = 3.6$, $p = .065$, and at lateral column 1, $F(2, 36) = 3.4$, $p = .069$. This interaction was due to a greater N250 effect at posterior compared to anterior sites [Midline: $p_{FPz} = .22$, $p_{Fz} = .076$, $p_{Cz} = .001$, $p_{Pz} < .001$, $p_{Oz} = .001$; Lateral Column 1: $p_{FC1/FC2} = .014$, $p_{C3/C4} = .002$, $p_{CP1/CP2} < .001$; Lateral Column 2: $p_{F3/F4} = .089$, $p_{FC5/FC6} = .061$, $p_{CP5/CP6} = .003$, $p_{P3/P4} < .001$]. A significant RELATEDNESS by HEMISPHERE interaction was found for Lateral Column 3, $F(1, 18) = 4.9$, $p = .039$, with a larger N250 effect seen in the right hemisphere, $p_{right} = .008$, $p_{left} = .06$. Finally, a significant RELATEDNESS by HEMISPHERE by ELECTRODE SITE interaction was found at Lateral Columns 2 and 3 [Lateral Column 2: $F(3, 54) = 5.13$, $p = .009$; Lateral Column 3: $F(4, 72) = 6.2$, $p = .004$], with the N250 effect being greater at right posterior sites [Lateral Column 2: $p_{F3} =$

TABLE 3
Mean percentage error rate for responses to targets in Experiment 2

PRIMETYPE	*Mean percentage error related*	*Std. Error*	*Mean percentage error unrelated*	*Std. Error*	*Priming effect*
Derived	7.59	1.34	8.48	1.29	0.89
Pseudocomplex	6.96	1.42	7.59	1.11	0.63
Orthographic	6.52	1.22	9.64	1.38	3.13

.062, $p_{FC5} = .065$, $p_{CP5} = .03$, $p_{P3} = .003$, $p_{F4} = .129$, $p_{FC6} = .08$, $p_{CP6} = .001$, $p_{P4} < .001$; Lateral Column 3: $p_{FP1} = .137$, $p_{F7} = .18$, $p_{T3} = .309$, $p_{T5} = .184$, $p_{O1} = .033$, $p_{FP2} = .4$, $p_{F8} = .097$, $p_{T4} = .024$, $p_{T6} = .001$, $p_{O2} < .001$]. There were no other significant interactions involving the factor PRIMETYPE or RELATEDNESS (all ps > .05).

Separate analyses performed on the early and late N250 time windows revealed exactly the same pattern of effects as in the main analysis.

N400 time window. The N400 was analysed between 350 and 500 ms after target onset. A significant main effect of RELATEDNESS was found in the analysis of sites at Lateral column 1, $F(1, 18) = 4.8$, $p = .04$, with responses to targets preceded by unrelated primes being more negative than those preceded by related primes. There was also a significant RELATEDNESS by ELECTRODE SITE interaction in all analyses [Midline: $F(4, 72) = 13.6$, $p < .001$; Lateral Column 1: $F(2, 36) = 20.2$, $p < .001$; Lateral Column 2: $F(3, 54) = 21.2$, $p < .001$; Lateral Column 3: $F(4, 72) = 14.9$, $p < .001$] with larger N400 effects seen at posterior sites and a marginally significant reversal of the effect at the frontal pole [Midline: $p_{FPz} = .12$, $p_{Fz} = .75$, $p_{Cz} = .023$, $p_{Pz} < .002$, $p_{Oz} < .006$; Lateral Column 1: $p_{FC1/FC2} = .38$, $p_{C3/C4} = .039$, $p_{CP1/CP2} = .004$; Lateral Column 2: $p_{F3/F4} = .73$, $p_{FC5/FC6} = .96$, $p_{CP5/CP6} = .013$, $p_{P3/P4} = .002$; Lateral Column 3: $p_{FP1/FP2} = .065$, $p_{F7/F8} = .26$, $p_{T3/T4} = .49$, $p_{T5/T6} = .007$, $p_{O1/O2} = .006$].

Only in the analyses of sites at Lateral Column 2 was there a RELATEDNESS by PRIMETYPE by ELECTRODE SITE interaction, $F(6, 108) = 3.6$, $p = .03$, due to a significant effect for targets preceded by derived and pseudocomplex primes at posterior sites [Derived: $p_{CP5/CP6} = .04$; $p_{P3/P4} = .005$; Pseudocomplex: $p_{P3/P4} = .007$] but not for orthographic primes. There were no other significant interactions involving the factors PRIMETYPE or RELATEDNESS (all ps > .05; Figure 7 and 8).

Summary of results

As in Experiment 1, we found significant priming effects in both the N250 and N400 time windows, with responses to targets following unrelated primes being more negative than those following all related primes (derived, pseudocomplex, and orthographic). This is in line with the behavioural data that also showed significant priming effects for all prime types with faster response times and lower error rates for all related targets compared to their unrelated controls. However, in this experiment, with more appropriate control conditions, there was also evidence for greater priming effects for targets preceded by derived and pseudocomplex primes relative to orthographic primes in the N400 epoch at lateral posterior electrode sites.

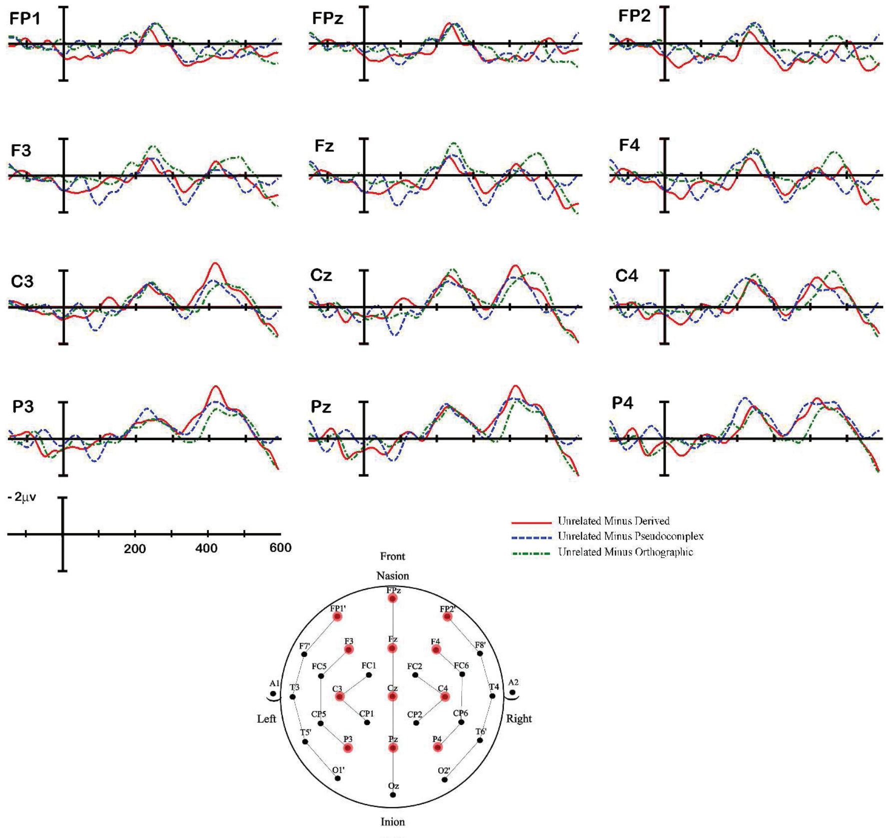

Figure 7. ERP waveforms at 12 selected electrode sites showing the showing responses to targets following related and unrelated derived (panel A), pseudocomplex (panel B), and orthographic (panel C) primes in Experiment 2. At the top centre of the figure is shown the electrode montage. The four analysis columns used for ANOVAs are illustrated with solid lines. The 15 electrode sites plotted in the figure are shown highlighted with red circles. Negative voltages are plotted upward.

GENERAL DISCUSSION

Previous findings of robust morphological priming effects for semantically opaque and pseudoderived words in a masked priming paradigm suggest that there is a form of morphological decomposition that is based on orthographic rather than semantic information (Gold & Rastle, 2007; Lavric, Clapp, & Rastle, 2007; Longtin, Segui, & Halle, 2003; McCormick et al., 2008; Rastle et al., 2000, 2004). Furthermore, there is a growing consensus that such morpho-orthographic decomposition occurs prelexically, prior to contact with whole-word orthographic representations during the recognition of

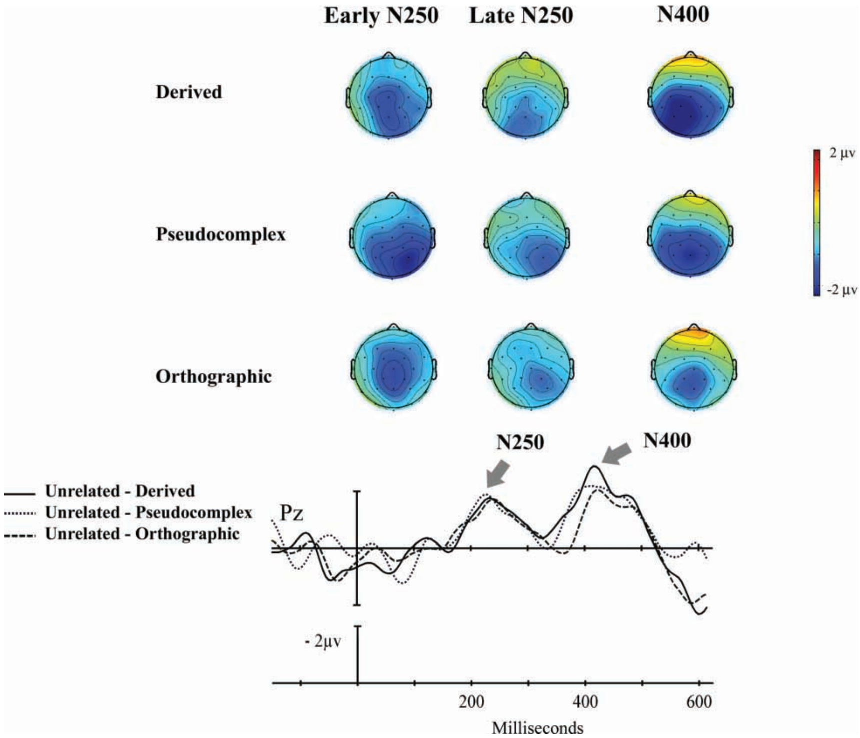

Figure 8. The spatial distribution of the priming effects found in the N250 and N400 time windows at the scalp surface for the derived (top), pseudocomplex (middle), and orthographic (bottom) conditions in Experiment 2. These maps were formed from difference waves calculated by subtracting each related condition from the corresponding unrelated condition. At the bottom of the figure is depicted the difference waveforms for unrelated minus related targets for the derived (solid line), pseudocomplex (dotted line), and orthographic (dashed line) conditions at electrode site Pz.

morphologically complex words. Perhaps the clearest evidence in support of this was provided by Longtin and Meunier (2005), who demonstrated that in French, complex nonwords (e.g., rapidifier) primed their embedded stems (e.g., rapide) as effectively as true derived words (e.g., rapidement). Furthermore, nonwords consisting of an embedded word and a nonsuffix ending (e.g., rapiduit) did not facilitate recognition of the embedded word as a target.

The present study provided a further exploration of the key findings reported by Longtin and Meunier (2005) using the increased sensitivity of ERP recordings. Contrary to Longtin and Meunier, however, in the two experiments reported here we found statistically equivalent behavioural priming for derived word primes (flexible-flex), complex nonword primes (flexify-flex) and simplex nonword primes (flexint-flex). The key divergence with respect to Longtin and Meunier's results is our finding of priming with simplex nonwords, a condition that generated no priming in their experiments. Furthermore, the ERP results were basically in line with the pattern of behavioural priming effects in the present study; there were robust priming effects that did not differ as a function of the priming manipulation. However, in Experiment 2, there was some evidence for the pattern of priming effects reported by Longtin and Meunier (2005) in the N400 time window, with priming effects only being significant for complex primes (derived and pseudocomplex), and not simplex primes (orthographic), at lateral posterior electrode sites.

Concerning the behavioural data of the present study, there are two key divergences with respect to prior behavioural results that need explaining. The first concerns our failure to replicate the behavioural results of Longtin and Meunier (2005). One explanation for this discrepancy may lie in the nature of the stimuli used in the two studies. In our stimulus set the target was always fully contained in the prime (e.g., flexify-FLEX). However, in the stimulus set used by Longtin et al., the orthographic overlap between primes and targets was not always complete (e.g., chambrage-CHAMBRE). The two studies taken together suggest that complex nonword primes with incomplete overlap prime their targets (chambrage-CHAMBRE), while simplex nonword primes with incomplete overlap do not (chambrour-CHAMBRE). On the other hand, simplex nonword primes with complete overlap (e.g., cornire-CORN) prime their embedded targets as much as do complex nonword primes with complete overlap (e.g., cornity-corn). For simplex primes, therefore, it appears that complete overlap is required to activate the embedded target string.

In line with this reasoning, in a recent study McCormick, Rastle, & Davis (2008) showed that the morphological decomposition process can handle the regular orthographic alterations found in complex words, such as a missing final "e" as in "adorable", a shared final "e" as in "baker" or final consonant doubling as in "runner". The data of Longtin and Meunier (2005) suggest that this process also works with morphologically complex nonwords. However, for simplex nonword primes and partially overlapping embedded targets, the target is not recognised as a stem, and therefore the process that allows the recognition of underspecified stems is not triggered, and there is no priming. In contrast, for simplex nonword primes with complete stem overlap (cornire-CORN), the presence of all the letters of the target embedded in the prime is enough to activate the whole-word representation of the embedded target.

The second discrepancy with respect to prior behavioural research concerns the fact that in prior research there was no hint of priming from simplex primes when the prime was a real word (e.g., scandal-SCAN). This influence of the lexical status of prime stimuli is predicted by the model presented in Figure 1. It is the lateral inhibitory connections between whole-word representations that cancel the bottom-up facilitation from prime words such as "scandal" when processing the embedded target word, such as "scan" in "scandal". Such inhibition is not present (or present to a lesser extent) when prime stimuli are nonwords, hence allowing bottom-up facilitatory processes to influence behaviour.

In line with the model presented in Figure 1, in the present study priming effects from complex nonwords were practically the same as the effects found with real derived words, in the behavioural data and both the N250 and N400 ERP components. Within this theoretical framework, this result suggests that any advantage in segmenting true derived words compared with complex nonwords, due to prior experience with such stimuli, for example, is offset by the lateral inhibition between whole-word representations for the stem and the derived word. However, given that there was no evidence in the N250 component for an early advantage for the derived word primes in the present study, the simplest interpretation for this pattern of effects is that prelexical segmentation operates irrespective of lexical status, and therefore that there is little or no lateral inhibition between the whole-word representations of the derived word and its stem.

Although the model presented in Figure 1 predicts priming by simplex nonword primes, just as we found, it also predicts that complex nonword primes should be more effective than simplex nonword primes, given the presence of prelexical morpho-orthographic segmentation for the former but not the latter. Simplex nonwords should only be able to prime their stems through shared representations at the orthographic or letter level, whereas complex word and nonword primes should also be able to do so via the shared representations at the morpho-orthographic level, leading to a differential priming effect for morphologically simplex vs. complex primes. Although we did not find evidence for differences due to morphological structure in the N250 ERP component, we did find some evidence for differential priming effects at lateral posterior electrode sites in the N400 component, where both derived and pseudocomplex—but not the simplex—primes generated a significant priming effect. Within the interpretative framework provided in Figure 2, this particular result suggests that although prelexical morpho-orthographic segmentation may have little influence on the efficiency of prelexical processing per se, it can have a significant influence on the subsequent mapping of word form representations onto meaning.

The pattern of priming effects seen in the N250 component in the present study is in line with the model outlined in Figure 1, in that feed-forward prelexical morpho-orthographic segmentation processes operate independently of lexical status and semantic transparency. The N250 is thought to reflect the mapping of prelexical representations onto whole-word representations (Grainger & Holcomb, 2009; Holcomb & Grainger, 2006, 2007), and therefore should be sensitive to the relative difficulty of morpho-orthographic segmentation. The results of the present study also suggest that fully embedded words in simplex nonword primes generate activation in the corresponding whole-word representation with the same level of efficiency as when morpho-orthographic decomposition has occurred. In other words, the fact that there is an additional process of morpho-orthographic segmentation for complex compared with simplex primes does not necessarily affect the ease with which prelexical orthographic representations are mapped onto the whole-word representation of the embedded stem. Our results suggest that this occurs just as efficiently for simplex as for complex nonwords. Our prior research, however, has shown that the N250 component is sensitive to processing differences between transparent derived word primes (e.g., farmer-FARM) and opaque primes (corner-CORN). According to the model presented in Figure 1, this would be due to the greater amount of lateral inhibition operating in the case of opaque word primes. Lateral inhibition between whole-word orthographic representations (e.g., between "corner" and "corn") would affect the efficiency of mapping of prelexical orthographic representations onto whole-word representations.

In a similar vein, it is the presence of lateral inhibitory connections between whole-word orthographic representations that enables our model to accommodate prior evidence for semantic transparency effects on the N400 component (Morris et al., 2007). This does not arise in the present study (i.e., no observable difference between the true complex primes and the pseudocomplex primes) because nonword prime stimuli are not subject to the effects of lateral inhibition to the same extent as real word primes. In other words, activation of the whole-word representation of *corner*, following presentation of this prime word, will interfere in the mapping of form to meaning when processing the target word *corn*, whereas there is no such interference when the prime is a nonword (*cornity)*.

SUMMARY

In the two experiments of the present study, the overall pattern of effects seen in the behavioural results and both major negative-going ERP components (N250, N400) revealed statistically equivalent priming for true derived word primes (farmer-FARM), complex nonword primes (cornity-CORN), and simplex nonword primes (cornire-CORN). The only evidence for differential priming as a function of morphological structure was found in the lexical decision error rates of Experiment 1 and the ERP data at lateral posterior electrode sites in Experiment 2. The unusually strong priming effects found with the simplex nonword primes in the present study, as opposed to the findings of prior research using simplex nonwords and words, can be attributed to the fact that all our targets were completely embedded in the prime stimuli as well as the reduced lexical inhibition that arises with nonword as opposed to real word primes. The fact that there was some evidence for greater priming with complex as opposed to simplex primes in the N400 ERP component and not the N250 component, suggests that efficiency of prelexical processing per se is not influenced by morphological complexity, but rather the efficiency of mapping form representations onto meaning.

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APPENDIX 1

List	Stem	Derived	Pseudocomplex	Orthographic
1	betray	betrayal	betrayic	betrayne
1	front	frontal	fronter	frontire
1	herb	herbal	herbness	herbmane
1	norm	normal	normer	normir
1	optic	optical	opticer	opticint
1	fiction	fictional	fictionor	fictionel
1	bank	banker	bankor	bankmane
1	buy	buyer	buyness	buyne
1	buzz	buzzer	buzzous	buzznore
1	desert	deserter	desertage	desertir
1	design	designer	designal	designel
1	fish	fisher	fishity	fishnore
1	found	founder	foundant	foundir
1	kick	kicker	kickal	kickel
1	kill	killer	killous	killmane
1	own	owner	ownal	ownint
1	feed	feeder	feedity	feedel
1	ring	ringer	ringance	ringave
1	roll	roller	rollor	rollact
1	teach	teacher	teachor	teachnore
1	test	tester	testity	testel
1	wash	washer	washous	washire
1	wear	wearer	wearness	wearne
1	organ	organic	organer	organire
1	prophet	prophetic	propheter	prophetir
1	direct	director	directant	directel
1	edit	editor	editous	editis
1	sculpt	sculptor	sculptous	sculptel
1	solicit	solicitor	solicital	solicitel
1	lever	leverage	leverer	leverne
1	link	linkage	linkous	linknore
1	wreck	wreckage	wreckment	wreckire
1	assail	assailant	assaility	assailel
1	expect	expectant	expecter	expectel
1	inform	informant	informery	informire
1	mock	mockery	mockant	mockact
1	trick	trickery	trickal	trickact
1	fluid	fluidity	fluider	fluidire
1	formal	formality	formaler	formalir
1	moral	morality	moraler	moralnore
1	mortal	mortality	mortaler	mortalel
1	solid	solidity	solidage	solidave
1	stupid	stupidity	stupidal	stupidir
1	cavern	cavernous	caverner	cavernel

APPENDIX 1 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
1	cancer	cancerous	cancerant	cancerne
1	peril	perilous	periler	perilave
1	poison	poisonous	poisonary	poisonact
1	pay	payable	payity	payne
1	port	portable	portage	portasse
1	vigil	vigilance	vigiler	vigilmane
1	defer	deference	deferage	deferne
1	annul	annulment	annulness	annulasse
1	endow	endowment	endowness	endowir
1	apt	aptness	aptal	aptint
1	aware	awareness	awarement	awarenth
1	fair	fairness	fairic	fairne
1	firm	firmness	firmity	firmis
1	new	newness	newity	newapse
1	open	openness	openment	openel
1	sweet	sweetness	sweetible	sweetel
2	cleric	clerical	clericer	clericire
2	form	formal	formence	formel
2	intern	internal	interner	internire
2	nation	national	nationer	nationire
2	orient	oriental	orientic	orientel
2	verb	verbal	verber	verbir
2	beat	beater	beatness	beatnore
2	burn	burner	burnity	burnapse
2	call	caller	callal	callasse
2	deal	dealer	dealness	dealnore
2	dream	dreamer	dreamity	dreamel
2	fight	fighter	fightity	fightave
2	golf	golfer	golfness	golfnore
2	keep	keeper	keepment	keepapse
2	kiss	kisser	kissage	kissel
2	mix	mixer	mixor	mixave
2	paint	painter	paintity	paintave
2	print	printer	printage	printel
2	sell	seller	sellment	sellave
2	talk	talker	talkage	talkel
2	think	thinker	thinkage	thinkease
2	warm	warmer	warmage	warmave
2	work	worker	workness	workote
2	idyll	idyllic	idyller	idyllel
2	rhythm	rhythmic	rhythmer	rhythmel
2	conquer	conqueror	conqueral	conquerel
2	govern	governor	governic	governir
2	sail	sailor	saility	sailire
2	visit	visitor	visitness	visitir
2	leak	leakage	leakal	leaknore
2	orphan	orphanage	orphanor	orphanire

APPENDIX 1 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
2	volt	voltage	volter	voltire
2	assist	assistant	assistal	assistel
2	exult	exultant	exultity	exultel
2	malign	malignant	malignity	malignel
2	green	greenery	greenment	greenel
2	class	classify	classor	classel
2	final	finality	finaler	finalire
2	frugal	frugality	frugalous	frugalir
2	minor	minority	minorer	minorel
2	normal	normality	normaler	normalel
2	solemn	solemnity	solemner	solemnire
2	timid	timidity	timidence	timidnore
2	bulb	bulbous	bulbity	bulbnore
2	danger	dangerous	dangerer	dangerel
2	murder	murderous	murderal	murderne
2	rigor	rigorous	rigorer	rigorne
2	favor	favorable	favorness	favornore
2	read	readable	readal	readint
2	clear	clearance	clearous	clearave
2	exist	existence	exister	existint
2	amuse	amusement	amuseness	amusenth
2	enjoy	enjoyment	enjoyic	enjoyapse
2	alert	alertness	alertity	alertnore
2	black	blackness	blackity	blackact
2	eager	eagerness	eagerer	eagerel
2	fit	fitness	fitment	fitact
2	mad	madness	madable	madint
2	raw	rawness	rawor	rawne
2	stiff	stiffness	stiffment	stiffint
3	clinic	clinical	clinicer	clinicel
3	fanatic	fanatical	fanaticer	fanaticis
3	ironic	ironical	ironicer	ironicel
3	music	musical	musicer	musicapse
3	origin	original	originer	originel
3	tropic	tropical	tropicer	tropicave
3	blow	blower	blowity	blowis
3	build	builder	buildness	buildis
3	camp	camper	campous	campire
3	count	counter	countal	countir
3	dress	dresser	dressant	dressire
3	farm	farmer	farmant	farmnore
3	grow	grower	growal	growact
3	hunt	hunter	huntal	huntmane
3	labor	laborer	laborery	laborel
3	mark	marker	markness	marknore
3	peel	peeler	peelant	peelave
3	preach	preacher	preachage	preachel

APPENDIX 1 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
3	sing	singer	singity	singel
3	surf	surfer	surfness	surfact
3	trail	trailer	trailal	trailire
3	walk	walker	walkal	walknore
3	acid	acidic	acidable	acidire
3	hero	heroic	heroer	herone
3	system	systemic	systemal	systemel
3	conduct	conductor	conductic	conductir
3	inspect	inspector	inspectal	inspectel
3	react	reactor	reactal	reactel
3	acre	acreage	acreable	acremane
3	drain	drainage	drainery	drainact
3	pack	package	packous	packel
3	vicar	vicarage	vicarer	vicarne
3	attend	attendant	attendal	attendave
3	depend	dependant	depender	dependel
3	resist	resistant	resistic	resistel
3	bind	bindery	bindify	bindnore
3	null	nullify	nullable	nullire
3	equal	equality	equaler	equalnore
3	human	humanity	humaner	humannore
3	mental	mentality	mentaler	mentalire
3	odd	oddity	oddant	oddease
3	rigid	rigidity	rigider	rigidel
3	total	totality	totaler	totalel
3	analog	analogous	analoger	analogel
3	decor	decorous	decorer	decorote
3	moment	momentous	momenter	momentact
3	ruin	ruinous	ruinance	ruinease
3	bear	bearable	bearness	bearne
3	renew	renewable	renewic	renewint
3	avoid	avoidance	avoidage	avoidel
3	refer	reference	referery	referne
3	amaze	amazement	amazeance	amazenth
3	equip	equipment	equipor	equipel
3	treat	treatment	treatity	treatire
3	blind	blindness	blindment	blindmane
3	deaf	deafness	deafable	deafnore
3	flat	flatness	flator	flatint
3	ill	illness	iller	illire
3	rich	richness	richable	richnore
3	soft	softness	softor	softire
4	comic	comical	comicer	comicnore
4	digit	digital	digiter	digitel
4	logic	logical	logicer	logicnore
4	medic	medical	medicer	medicel
4	person	personal	personer	personis

APPENDIX 1 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
4	tactic	tactical	tacticer	tacticis
4	boil	boiler	boilness	boilint
4	breed	breeder	breedous	breedmane
4	clean	cleaner	cleanness	cleanel
4	cool	cooler	coolage	coolnore
4	drink	drinker	drinkant	drinkir
4	eat	eater	eatness	eatince
4	heal	healer	healness	healave
4	hold	holder	holdness	holdel
4	lead	leader	leadage	leadost
4	lock	locker	lockness	lockapse
4	pick	picker	pickant	pickint
4	point	pointer	pointage	pointel
4	sleep	sleeper	sleepary	sleepel
4	steam	steamer	steamness	steamnore
4	train	trainer	trainal	trainire
4	wait	waiter	waitable	waitire
4	angel	angelic	angelity	angelire
4	graph	graphic	graphness	graphel
4	titan	titanic	titanity	titannore
4	collect	collector	collectic	collectel
4	invent	inventor	inventity	inventel
4	protect	protector	protectal	protectel
4	band	bandage	bandness	bandire
4	cover	coverage	coverness	covernore
4	patron	patronage	patroner	patronave
4	short	shortage	shortic	shortel
4	buoy	buoyant	buoyer	buoyne
4	defend	defendant	defendage	defendel
4	result	resultant	resulter	resultir
4	honor	honorary	honorer	honorne
4	absurd	absurdity	absurdal	absurdel
4	brutal	brutality	brutaler	brutalel
4	humid	humidity	humider	humidis
4	major	majority	majorer	majorint
4	prior	priority	priorer	priorne
4	real	reality	realous	realire
4	valid	validity	validment	validel
4	vulgar	vulgarity	vulgarer	vulgarne
4	glamor	glamorous	glamorer	glamorel
4	joy	joyous	joyer	joyne
4	vigor	vigorous	vigorer	vigorne
4	avail	available	availous	availel
4	suit	suitable	suitity	suitmane
4	annoy	annoyance	annoyor	annoyne
4	flex	flexible	flexage	flexint
4	align	alignment	alignant	alignel

APPENDIX 1 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
4	move	movement	moveance	movene
4	state	statement	stateance	stateire
4	bold	boldness	boldment	boldact
4	dark	darkness	darkor	darkave
4	fresh	freshness	freshable	freshmane
4	idle	idleness	idleant	idleapse
4	rude	rudeness	rudeable	rudenth
4	sick	sickness	sickous	sickmane
5	critic	critical	criticer	criticir
5	cynic	cynical	cynicer	cynicire
5	magic	magical	magicer	magicint
5	margin	marginal	marginer	marginir
5	option	optional	optionity	optionost
5	sign	signal	signity	signmane
5	bomb	bomber	bombness	bombnore
5	box	boxer	boxal	boxapse
5	climb	climber	climbor	climbasse
5	cook	cooker	cookal	cooknore
5	dust	duster	dustment	dustnore
5	earn	earner	earnous	earnel
5	heat	heater	heatment	heatire
5	help	helper	helpness	helpnore
5	learn	learner	learnor	learnel
5	light	lighter	lightant	lightint
5	play	player	playous	playne
5	plumb	plumber	plumbor	plumbmane
5	speak	speaker	speakal	speakint
5	start	starter	startness	startire
5	turn	turner	turnor	turnel
5	view	viewer	viewity	viewne
5	artist	artistic	artistor	artistire
5	demon	demonic	demoner	demonint
5	act	actor	actness	actapse
5	arm	armor	armic	armasse
5	invest	investor	investal	investel
5	profess	professor	professic	professis
5	break	breakage	breakness	breakel
5	coin	coinage	coinity	coinis
5	peer	peerage	peerous	peerne
5	post	postage	postary	postel
5	claim	claimant	claimence	claimel
5	combat	combatant	combatage	combatact
5	bound	boundary	boundity	boundire
5	diet	dietary	dietify	dietost
5	actual	actuality	actualer	actualir
5	author	authority	authorer	authorel
5	local	locality	localer	localel

APPENDIX 1 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
5	lucid	lucidity	lucider	lucidel
5	public	publicity	publicer	publicave
5	rapid	rapidity	rapidable	rapidapse
5	virgin	virginity	virginer	virginel
5	vital	vitality	vitaler	vitalint
5	hazard	hazardous	hazarder	hazardel
5	humor	humorous	humorer	humorne
5	zeal	zealous	zealer	zealel
5	adapt	adaptable	adaptment	adaptave
5	tax	taxable	taxity	taxact
5	allow	allowance	allowness	allowis
5	agree	agreement	agreeant	agreene
5	ail	ailment	ailer	ailne
5	place	placement	placeal	placeis
5	ship	shipment	shipity	shipel
5	close	closeness	closeage	closenore
5	cold	coldness	coldity	coldave
5	good	goodness	gooder	goodmane
5	harsh	harshness	harshity	harshel
5	sad	sadness	sadity	sadact
5	shy	shyness	shyous	shyne

APPENDIX 2

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
1	betray	betrayal	betrayic	betrayne
1	music	musical	musicer	musicapse
1	nation	national	nationer	nationire
1	tactic	tactical	tacticize	tacticis
1	kiss	kisser	kissage	kissel
1	desert	deserter	desertage	desertir
1	dress	dresser	dressant	dressire
1	hold	holder	holdness	holdel
1	sleep	sleeper	sleepary	sleepel
1	mark	marker	markness	marknore
1	teach	teacher	teachor	teachnore
1	warm	warmer	warmage	warmave
1	wash	washer	washous	washire
1	collect	collector	collectic	collectel
1	conduct	conductor	conductic	conductir
1	protect	protector	protectal	protectel
1	patron	patronage	patroner	patronave
1	attend	attendant	attendal	attendave
1	buoy	buoyant	buoyer	buoyne
1	trick	trickery	trickal	trickact
1	class	classify	classor	classel
1	formal	formality	formaler	formalir
1	rigid	rigidity	rigider	rigidel
1	vulgar	vulgarity	vulgarer	vulgarne
1	analog	analogous	analoger	analogel
1	zeal	zealous	zealer	zealel
1	adapt	adaptable	adaptment	adaptave
1	tax	taxable	taxity	taxige
1	enjoy	enjoyment	enjoyic	enjoyapse
1	aware	awareness	awarement	awarenth
1	black	blackness	blackity	blackact
1	mad	madness	madable	madint
1	new	newness	newity	newapse
1	stiff	stiffness	stiffment	stiffint
1	union	unionize	unionish	unionean
1	self	selfish	selfize	selfige
1	sheep	sheepish	sheepize	sheepige
1	modern	modernist	modernate	modernalt
1	sex	sexist	sexern	sexalt
1	lecher	lecherous	lecherish	lecheralt
2	cleric	clerical	clericer	clericire
2	medic	medical	medicer	medicel
2	optic	optical	opticize	opticint
2	tropic	tropical	tropicize	tropicave
2	call	caller	callal	callasse
2	deal	dealer	dealness	dealnore

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
2	drink	drinker	drinkant	drinkir
2	help	helper	helpness	helpnore
2	hunt	hunter	huntal	huntmane
2	mix	mixer	mixor	mixave
2	surf	surfer	surfness	surfact
2	walk	walker	walkal	walknore
2	wear	wearer	wearness	wearne
2	arm	armor	armic	armasse
2	conquer	conqueror	conqueral	conquerel
2	react	reactor	reactal	reactel
2	pack	package	packous	packel
2	assist	assistant	assistal	assistel
2	claim	claimant	claimence	claimel
2	mock	mockery	mockant	mockact
2	null	nullify	nullable	nullire
2	frugal	frugality	frugalous	frugalir
2	real	reality	realous	realire
2	vital	vitality	vitaler	vitalint
2	bulb	bulbous	bulbity	bulbnore
2	vigor	vigorous	vigorer	vigorne
2	avail	available	availous	availel
2	allow	allowance	allowness	allowis
2	endow	endowment	endowness	endowir
2	apt	aptness	aptal	aptint
2	blind	blindness	blindment	blindmane
2	ill	illness	iller	illire
2	open	openness	openment	openel
2	sweet	sweetness	sweetible	sweetel
2	terror	terrorize	terrorish	terrorean
2	child	childish	childize	childige
2	freak	freakish	freakize	freakige
2	medal	medalist	medality	medalint
2	drunk	drunkary	drunkary	drunkale
2	rancor	rancorous	rancorish	rancorint
3	clinic	clinical	clinicage	clinicel
3	margin	marginal	marginer	marginir
3	design	designer	designal	designel
3	verb	verbal	verber	verbir
3	buzz	buzzer	buzzous	buzznore
3	count	counter	countal	countir
3	dust	duster	dustment	dustnore
3	heat	heater	heatment	heatire
3	keep	keeper	keepment	keepapse
3	own	owner	ownal	ownint
3	steam	steamer	steamness	steamnore
3	wait	waiter	waitable	waitire
3	work	worker	workness	workote

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
3	act	actor	actness	actapse
3	direct	director	directant	directel
3	sail	sailor	saility	sailire
3	orphan	orphanage	orphanor	orphanire
3	assail	assailant	assaility	assailel
3	combat	combatant	combater	combatact
3	green	greenery	greenment	greenel
3	absurd	absurdity	absurdal	absurdel
3	human	humanity	humaner	humannore
3	rapid	rapidity	rapidable	rapidapse
3	virgin	virginity	virginer	virginel
3	cavern	cavernous	caverner	cavernel
3	ruin	ruinous	ruinance	ruinease
3	bear	bearable	bearness	bearne
3	annoy	annoyance	annoyor	annoyne
3	annul	annulment	annulness	annulasse
3	alert	alertness	alertity	alertnore
3	bold	boldness	boldment	boldact
3	idle	idleness	idleant	idleapse
3	raw	rawness	rawor	rawne
3	canon	canonize	canonard	canonire
3	tender	tenderize	tenderist	tenderean
3	book	bookish	bookize	bookige
3	colt	coltish	coltern	coltige
3	lyric	lyricist	lyricish	lyricalt
3	dull	dullery	dullery	dullale
3	sulfer	sulferous	sulferist	sulferint
4	comic	comical	comicage	comicnore
4	magic	magical	magicate	magicint
4	orient	oriental	orientic	orientel
4	fiction	fictional	fictionor	fictionel
4	kick	kicker	kickal	kickel
4	cool	cooler	coolage	coolnore
4	earn	earner	earnous	earnel
4	heal	healer	healness	healave
4	kill	killer	killous	killmane
4	feed	feeder	feedity	feedel
4	start	starter	startness	startire
4	view	viewer	viewity	viewne
4	acid	acidic	acidable	acidire
4	titan	titanic	titaner	titannore
4	edit	editor	editous	editis
4	sculpt	sculptor	sculptous	sculptel
4	link	linkage	linkous	linknore
4	wreck	wreckage	wreckment	wreckire
4	defend	defendant	defendage	defendel
4	bind	bindery	bindify	bindnore

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
4	actual	actuality	actualer	actualir
4	humid	humidity	humider	humidis
4	public	publicity	publicer	publicave
4	valid	validity	validment	validel
4	cancer	cancerous	cancerant	canceme
4	rigor	rigorous	rigorer	rigorne
4	favor	favorable	favorness	favornore
4	avoid	avoidance	avoider	avoidel
4	amuse	amusement	amuseness	amusenth
4	treat	treatment	treatity	treatire
4	close	closeness	closeage	closenore
4	harsh	harshness	harshity	harshel
4	rich	richness	richable	richnore
4	civil	civilize	civilard	civilean
4	symbol	symbolize	symbolish	symbolean
4	fever	feverish	feverize	feverige
4	boy	boyish	boyist	boyige
4	loyal	loyalist	loyalize	loyalint
4	west	western	westify	westege
4	riot	riotous	riotish	riotint
5	critic	critical	criticer	criticir
5	logic	logical	logicer	logicnore
5	origin	original	originer	originel
5	bank	banker	bankor	bankmane
5	buy	buyer	buyness	buyne
5	cook	cooker	cookal	cooknore
5	eat	eater	eatness	eatince
5	grow	grower	growal	growact
5	lead	leader	leadage	leadost
5	paint	painter	paintity	paintave
5	speak	speaker	speakal	speakint
5	turn	turner	turnor	turnel
5	angel	angelic	angelity	angelire
5	system	systemic	systemal	systemel
5	govern	governor	governic	governir
5	solicit	solicitor	solicital	solicitel
5	lever	leverage	leverer	leverost
5	volt	voltage	volter	voltire
5	depend	dependant	depender	dependel
5	honor	honorary	honorer	honorne
5	author	authority	authorer	authorel
5	local	locality	localer	localel
5	prior	priority	priorer	priorne
5	total	totality	totaler	totalel
5	danger	dangerous	dangerer	dangerel
5	poison	poisonous	poisonary	poisonact
5	pay	payable	payity	payne

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
5	clear	clearance	clearous	clearave
5	amaze	amazement	amazeance	amazenth
5	state	statement	stateance	stateire
5	cold	coldness	coldity	coldave
5	good	goodness	gooder	goodmane
5	rude	rudeness	rudeable	rudenth
5	factor	factorize	factorer	factorean
5	polar	polarize	polarous	polarean
5	girl	girlish	girler	girlige
5	doctor	doctorate	doctorize	doctorain
5	left	leftist	leftize	leftalt
5	north	northern	northist	northege
5	just	justify	justish	justote
6	cynic	cynical	cynicer	cynicire
6	ironic	ironical	ironicer	ironicel
6	dream	dreamer	dreamity	dreamel
6	beat	beater	beatness	beatnore
6	burn	burner	burnity	burnapse
6	climb	climber	climbor	climbasse
6	farm	farmer	farmant	farmnore
6	golf	golfer	golfness	golfnore
6	learn	learner	learnor	learnel
6	peel	peeler	peelant	peelave
6	sing	singer	singity	singel
6	train	trainer	trainal	trainire
6	artist	artistic	artistor	artistire
6	rhythm	rhythmic	rhythmer	rhythmel
6	inspect	inspector	inspectal	inspectel
6	visit	visitor	visitness	visitir
6	leak	leakage	leakal	leaknore
6	vicar	vicarage	vicarer	vicarne
6	exult	exultant	exultity	exultel
6	diet	dietary	dietify	dietost
6	brutal	brutality	brutaler	brutalel
6	lucid	lucidity	lucider	lucidel
6	odd	oddity	oddant	oddease
6	timid	timidity	timidence	timidnore
6	decor	decorous	decorer	decorote
6	peril	perilous	periler	perilave
6	port	portable	portage	portasse
6	vigil	vigilance	vigiler	vigilmane
6	align	alignment	alignant	alignel
6	ship	shipment	shipity	shipel
6	dark	darkness	darkor	darkave
6	fresh	freshness	freshable	freshmane
6	sad	sadness	sadity	sadact
6	fossil	fossilize	fossilern	fossilean

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
6	penal	penalize	penalous	penalean
6	hell	hellish	hellity	hellean
6	emir	emirate	emirer	emirain
6	fatal	fatalist	fatalize	fatalint
6	south	southern	southist	southege
6	planet	planetary	planetist	planetost
7	digit	digital	digiter	digitel
7	intern	internal	interner	internire
7	person	personal	personer	personis
7	blow	blower	blowity	blowis
7	build	builder	buildness	buildis
7	clean	cleaner	cleanness	cleanel
7	fight	fighter	fightity	fightave
7	print	printer	printage	printel
7	talk	talker	talkage	talkel
7	pick	picker	pickant	pickint
7	sell	seller	sellment	sellave
7	trail	trailer	trailal	trailire
7	demon	demonic	demoner	demonint
7	prophet	prophetic	propheter	prophetir
7	invent	inventor	inventity	inventel
7	acre	acreage	acreable	acremane
7	drain	drainage	drainery	drainact
7	short	shortage	shortic	shortel
7	expect	expectant	expecter	expectel
7	bound	boundary	boundity	boundire
7	equal	equality	equaler	equalnore
7	major	majority	majorer	majorint
7	normal	normality	normaler	normalel
7	stupid	stupidity	stupidal	stupidir
7	glamor	glamorous	glamorer	glamorel
7	murder	murderous	murderal	murderne
7	read	readable	readal	readint
7	defer	deference	deferage	deferne
7	ail	ailment	ailer	ailne
7	place	placement	placeal	placeis
7	deaf	deafness	deafable	deafnore
7	flat	flatness	flator	flatint
7	shy	shyness	shyous	shyne
7	ideal	idealize	idealate	idealean
7	motor	motorize	motorous	motorean
7	vocal	vocalize	vocalery	vocalean
7	fix	fixate	fixize	fixain
7	arson	arsonist	arsonize	arsonalt
7	east	eastern	eastist	eastege
7	second	secondary	secondate	secondir
8	fanatic	fanatical	fanaticer	fanaticis

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
8	herb	herbal	herbness	herbmane
8	option	optional	optionity	optionost
8	boil	boiler	boilness	boilint
8	breed	breeder	breedous	breedmane
8	labor	laborer	laborery	laborel
8	point	pointer	pointage	pointel
8	found	founder	foundant	foundir
8	light	lighter	lightant	lightint
8	play	player	playous	playne
8	roll	roller	rollor	rollact
8	think	thinker	thinkage	thinkease
8	graph	graphic	graphness	graphel
8	organ	organic	organer	organire
8	invest	investor	investal	investel
8	band	bandage	bandness	bandire
8	cover	coverage	coverness	covernore
8	post	postage	postary	postel
8	inform	informant	informery	informire
8	result	resultant	resulter	resultir
8	final	finality	finaler	finalire
8	mental	mentality	mentaler	mentalire
8	mortal	mortality	mortaler	mortalel
8	solid	solidity	solidage	solidave
8	hazard	hazardous	hazarder	hazardel
8	moment	momentous	momenter	momentact
8	renew	renewable	renewic	renewint
8	exist	existence	exister	existint
8	agree	agreement	agreeant	agreene
8	move	movement	moveance	movene
8	eager	eagerness	eagerer	eagerel
8	fit	fitness	fitment	fitact
8	sick	sickness	sickous	sickmane
8	item	itemize	itemer	itemean
8	maxim	maximize	maximous	maximean
8	victim	victimize	victimist	victimean
8	oxygen	oxygenate	oxygenize	oxygenain
8	alarm	alarmist	alarmize	alarmalt
8	odor	odorous	odorist	odoralt
8	brew	brewery	brewish	brewalt
9	form	formal	formence	formel
9	front	frontal	fronter	frontire
9	sign	signal	signity	signmane
9	bomb	bomber	bombness	bombnore
9	box	boxer	boxary	boxapse
9	camp	camper	campous	campire
9	fish	fisher	fishity	fishnore
9	preach	preacher	preachage	preachel

APPENDIX 2 (*Continued*)

List	*Stem*	*Derived*	*Pseudocomplex*	*Orthographic*
9	lock	locker	lockness	lockapse
9	plumb	plumber	plumbor	plumbmane
9	ring	ringer	ringance	ringave
9	test	tester	testity	testel
9	hero	heroic	heroer	herone
9	idyll	idyllic	idyller	idyllel
9	profess	professor	professic	professis
9	break	breakage	breakness	breakel
9	coin	coinage	coinity	coinis
9	peer	peerage	peerous	peerne
9	malign	malignant	malignity	malignel
9	resist	resistant	resistic	resistel
9	fluid	fluidity	fluider	fluidire
9	minor	minority	minorer	minorel
9	moral	morality	moraler	moralnore
9	solemn	solemnity	solemner	solemnire
9	humor	humorous	humorer	humorne
9	joy	joyous	joyer	joyne
9	suit	suitable	suitity	suitmane
9	refer	reference	referate	referne
9	flex	flexible	flexage	flexint
9	equip	equipment	equipor	Equipel
9	fair	fairness	fairic	Fairne
9	firm	firmness	firmity	Firmis
9	soft	softness	softor	Softire
9	lion	lionize	lionous	Lionean
9	legal	legalize	legalous	Legalean
9	vandal	vandalize	vandalern	Vandalean
9	ulcer	ulcerate	ulcerize	Ulcerain
9	solo	soloist	soloize	Solonth
9	clamor	clamorous	clamorish	Clamoralt
9	placid	placidity	placidist	Placidact