Masked priming by misspellings: Word frequency moderates the effects of SOA and prime–target similarity

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Abstract University students made lexical decisions to eight- or nine-letter words preceded by masked primes that were the target, an unrelated word, or a typical misspelling of the target. At a stimulus onset asynchrony (SOA) of 47 ms, primes that were misspellings of the target produced a priming benefit for low-, medium-, and high-frequency words, even when the misspelled primes were changed to differ phonologically from their targets. At a longer SOA of 80 ms, misspelled primes facilitated lexical decisions only to medium- and low-frequency targets, and a phonological change attenuated the benefit for medium-frequency targets. The results indicate that orthographic similarity can be preserved over changes in letter position and word length, and that the priming effect of misspelled words at the shorter SOA is orthographically based. Orthographic-priming effects depend on the quality of the orthographic learning of the target word.

Keywords Lexical processing · Word recognition · Reading · Psycholinguistics

The effects of brief pattern-masked primes in lexical tasks are revealing about the knowledge and processes involved in visual word identification. Limited awareness of the prime reduces strategic effects, and short-duration primes can tap early lexical processes. Much attention has been devoted to orthographically similar primes in the lexical decision task (LDT), with a view to illuminating the nature of the orthographic component of the internal lexical representation, as well as

how a word (say, *batter*) is not misidentified as a similar, higher-frequency word (*better*). In initial studies, such priming effects involved nonword primes differing from their targets in one letter and were usually facilitatory (Forster, Davis, Schoknecht, & Carter, 1987). Subsequently it was observed that short words with many or high-frequency orthographic neighbors may show null effects from orthographically similar nonword primes (e.g., *nare*–CARE; Forster & Taft, 1994), and may show costs with word primes (e.g., *case*–CARE; C. J. Davis & Lupker, 2006; Segui & Grainger, 1990). The lack of facilitation in these cases is usually considered to reflect the effects of activated competitor words for the target (C. J. Davis, 2003). The present experiments used long words, which have few orthographic neighbors. For such items, facilitation by nonword primes is the norm (Burt & Tate, 2002; Forster et al., 1987; Holmes & Davis, 2002). The basis of facilitation is likely to be activation by the prime of the lexical representation of the target, by virtue of their shared letters in position. Typically the target is the word that is orthographically most similar to the prime, and there is no highly similar competitor word to be activated by the prime.

The effects on word identification of letter strings sharing all but one letter in position are readily interpretable in the interactive-activation models (Colombo, 1986; C. J. Davis, 2003; Mathey, Robert, & Zagar, 2004; Rumelhart & McClelland, 1982; Segui & Grainger, 1990) and in other models that represent a word's letters in position-specific slots. However, recently interest has increased in the importance of letter order in word reading and the role of letter order in coding schemes for orthography. There is clear evidence that with nonword primes (Dunabeitia, Perea, & Carreiras, 2009), priming facilitation occurs when a transposition of two adjacent or nonadjacent letters in the target is used to create the primes (Perea & Lupker, 2003, 2004). There is some evidence that orthographic neighbor primes created by adding or

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deleting a letter affect a target word's identification, suggesting some flexibility about word length in the coding of orthography (C. J. Davis, Perea, & Acha, 2009).

The present experiments were designed to examine the ability of misspellings to prime lexical decisions to relatively long targets (eight to nine letters). As was noted by Holmes and C. W. Davis (2002), misspellings presumably capture aspects of the internal orthographic representation of the target word. The misspelled primes used here mainly involved a one-letter change to the target, involving a letter replacement in the target or the addition or deletion of a letter. A smaller number had two-letter changes, including transpositions of adjacent and nonadjacent letters. These changes largely preserved the phonology of the target and were designed to reflect typical misspellings. If these primes uniformly produced facilitatory priming, this would add to recent evidence challenging the idea that word length and letter position constitute inviolable constraints in lexical processing.

The primary question motivating the experiments was whether the magnitude of priming by misspellings varies over target frequencies. Varying the frequency of a target is a simple way to directly influence the time taken to identify it. Manipulations of target processing time have the potential to illuminate orthographic (and phonological) effects of nonword orthographic primes and their time courses. Furthermore, a word's frequency indexes how much has been learned about a printed word. As a result of many exposures, high-frequency words have high-quality representations, reflected in their accurate spelling and rapid identification. According to Perfetti and Hart (2002), the quality of lexical representations is based on the precision and interconnectedness of the constituents' phonology, orthography, and meaning.

If typical misspellings were to provide a better match than traditional one-letter-different primes with individuals' orthographic representations, then the effect of misspelled primes may vary substantially as a function of the adequacy of orthographic learning for a word. Thus, word frequency effects on priming may be more evident with misspelled primes. For poorly learned words, the orthographic representation may be incomplete or inaccurate, and hence may make a sufficiently good match with a misspelled prime to support priming facilitation. On the other hand, well-learned words are more likely to have complete and accurate orthographic representations that would fail to make a strong match with a misspelled prime.

The idea above was tested by Holmes and Davis (2002) by examining priming effects separately for words that participants could versus could not spell. The researchers found that naming was facilitated more by misspelled primes when the targets were those that participants could not spell correctly. In a similar vein, Burt and Tate (2002) evaluated the effects of masked identity and one-letter-different primes separately for

words that participants spelled correctly and incorrectly. In contrast to Holmes and Davis, they found that one-letter-different (and identity) priming effects were similar for words that participants could and could not spell. This result is consistent with the idea that misspellings have privileged overlap with the internal orthographic representation. The discrepancy between the two studies may reflect the fact that most of the words were of very low frequency in the Burt and Tate experiments. Thus, the range of learning strength and the difference between correct and incorrectly spelled words may have been less than in the Holmes and Davis study. In the present experiments, large variations in target frequency were introduced.

Until recently, there has been little investigation of target frequency effects in orthographic-priming studies with nonword primes differing by one letter from their targets. In one study with words of six to ten letters, the effects of one-letter-different nonword primes (relative to unrelated word primes) were equal for high- and low-frequency targets (Forster et al., 1987). However, those low-frequency words were of higher frequency than those used in the present study. Sereno (1991) used the LDT with high- and low-frequency targets four to six letters long to examine the effects of identity primes, together with primes consisting of one-letter-different nonwords, asterisks, and unrelated words and nonwords. Frequency did not significantly modulate the differences among the five priming conditions, but the orthographic-priming effects tended to be larger for low-frequency targets. A sensitive assessment of the moderating effect of frequency was provided by a recent megastudy of priming that included 420 six-letter targets and data collected from 14 laboratories (Adelman et al., 2014). The results were that one of their three frequency measures, log SUBTLEX frequency (Balota et al., 2007), made a consistent but small prediction of priming effects, with high-frequency targets being less susceptible to orthographic priming.

A potentially important characteristic of misspelled primes is that they usually are more phonologically similar to their targets than one-letter-different primes. Indeed, misspellings normally reflect an attempt to represent the phonology of the target. When nonword orthographic primes are pronounceable, prime phonology can be produced via sublexical spelling–sound knowledge, and thus has the potential to affect response times to the target. In studies that have directly examined phonological priming, masked nonword primes that have the same pronunciation as the target (pseudohomophones) have been found to facilitate in the LDT, relative to a control prime matched on orthographic similarity to the target (Grainger & Ferrand, 1996; Lee & Turvey, 2003; Lukatela, Frost, & Turvey, 1998; Perea & Carreiras, 2006; Ziegler, Bertrand, Lété, & Grainger, 2014). However, the literature is somewhat inconsistent, with Acha and Perea (2010) and C. Davis, Castles, and Iakovidis (1998) having failed to find evidence of phonological facilitation. According to a review and two empirical studies by

Rastle and Brysbaert (2006), when phonological recoding is discouraged, masked priming effects by pseudohomophones are small but reliable in the LDT.

The role of phonological overlap in priming based on orthographic similarity remains relatively unexplored. Phonological overlap between an orthographic prime and its target does not appear to produce a detectable increase in priming facilitation (Zeguers, Snellings, Huizenga, & van der Molen, 2014). On the other hand, a disruptive effect of phonological discrepancy between an orthographic prime and its target can be observed. This is the approach that was taken for assessing phonological effects in the present experiments. The available evidence indicates that masked one-letter-different primes show decreased priming when they are made phonologically distinct from the targets (Frisson, Bélanger, & Rayner, 2014; Pollatsek, Perea, & Carreiras, 2005). The latter authors compared Spanish prime–target pairs in which the initial consonant (always *c*) had the same versus a different pronunciation in a one-letter-different nonword prime and the target (as in *conal*–*CANAL* vs. *cinál*–*CANAL*). They found that the results depended on the stimulus onset asynchrony (SOA), with discrepant phonology having an effect at an SOA of 66 ms, but a negligible effect at 50 ms.

There is clear evidence that phonological and orthographic information become available over different time courses, with phonological activation trailing letter processing. For example, Ferrand and Grainger (1992) found evidence of phonological priming by pseudohomophones at an SOA of 64 ms, but not at 32 ms, and in an electroencephalographic study, Grainger, Kiyonaga, and Holcomb (2006) found that orthographic priming emerged about 50 ms prior to phonological priming in the event-related potentials.

In the present studies, the effects of misspelled primes were assessed against unrelated prime words. The impact of phonological overlap was examined by assessing priming by orthographically similar primes that were made phonologically distinct from the targets, as was done by Pollatsek et al. (2005). A phonological change removes the resemblance of the primes to typical misspellings and renders them more like typically used orthographic primes. A short SOA (47 ms) and a long SOA (80 ms) were used to tease out orthographic and phonological effects.

In summary, masked priming by misspellings was examined here at a short and a longer SOA for high-, medium-, and low-frequency words. (The results for nonword targets were not of direct interest, and the priming effects for these items are summarized in the [General Method](#) section.) The misspelled primes were similar to their targets orthographically and phonologically, and are designated *O + P+*. In additional experiments, significant orthographic-priming effects were followed up for medium-frequency words and for misspelled primes that had one letter changed to make their phonology distinct from the target-word phonology

(designated *O + P–*). A comparison with identity priming was included at the long SOA. The foci of interest were whether the target-word frequency would moderate (a) priming effects and (b) the role of phonological information in priming, as well as (c) the time course of orthographic and phonological effects.

General method

All targets in the experiments were eight or nine letters long (mean 8.4 letters), with two to four syllables.

For each target, an unrelated prime was a word matched to the target in length and approximately in frequency, but sharing no more than one letter in position with the target. The remaining prime conditions varied over the experiments and could include identity primes or nonword primes that were either misspelled primes (orthographically and phonologically similar) or orthographically similar primes with a phonological discrepancy from the target (*O + P–*). The frequency and orthographic neighbor counts are shown in Table 1, together with the average orthographic Levenshtein distances between the targets and the two types of orthographic primes. The frequency counts are given per million from the British National Corpus (Kilgariff, 1996) and as the Zipf measure (based on the $\log_{10}$ of the frequency per billion words) from the recent British subtitle frequency corpus, SUBTLEX-UK (see van Heuven, Mander, Keuleers, & Brysbaert, 2014).

Pronounceable nonword targets (e.g., *venabent*, *lomistary*, *disbidge*, and *soparate*) made up 50 % of the trials. The prime type compositions varied somewhat between Experiments 1, 2, and 3, but in all cases there was an approximate balance over word and nonword targets in the numbers of word and nonword primes and the proportions of prime types. Thus, unrelated-word and -nonword primes (e.g., *spightly*–*VENABENT*, *lemonade*–*DISBIDGE*) were presented, as well as orthographically similar nonword primes that varied in phonological similarity in line with the word-target conditions (e.g., *O + P–*, *lemistery*–*LOMISTARY*; *O + P+*, *gridance*–*GRIDENCE*). In addition, similar-word primes were presented. The latter were always phonologically distinct (e.g., *separate*–*SOPARATE*), in order to limit the error rate for nonword targets. The assignment of primes to nonword targets was the same in all lists. The nonword results are summarized below.

Procedure

The experiments were controlled by a PC running the E-Prime program (Schneider, Eschman, & Zuccolotto, 2002). Participants sat at a comfortable distance from a computer monitor running at a refresh rate of 85 Hz, and rested the index fingers of their left and right hands on the corresponding left

Table 1 Characteristics of the word targets and orthographic Levenshtein distances (OLD) for the targets from the two orthographic prime conditions

Target Frequency	BNC Freq. per Million	Zipf SUBTLEX-UK	<i>N</i>	OLD vs. O + P+	OLD vs. O + P–
Low	2.2	2.9	0.1	1.2	1.2
Medium	20.2	3.6	0.2	1.1	1.1
High	161.5	4.8	0.3	1.2	

and right buttons of a response box. They used their preferred hand for a word decision. All trial stimuli were displayed in black 20-point Courier New lettering in the center of a white screen. On each trial, a ready signal (+) appeared for 500 ms, followed by a 250-ms blank screen; a forward mask of ten ampersands was displayed for 500 ms, then the prime for the specified duration (in lower case), then the target (upper case), which remained on the screen until a response was made. The screen remained blank for 2 s, and then the next trial began. Participants were instructed that they would see letter strings in upper case and that they should make word-versus-nonword decisions about them as quickly and accurately as possible. The trials were presented in four blocks of trials, with a brief rest between blocks.

Results for nonword targets

Analyses by participants for the five experiments revealed a consistent picture (see Table 2). As compared to unrelated word primes, orthographically similar word primes lengthened response latencies (by 18 to 67 ms) and increased error rates. The effect on latencies was significant in three experiments (1A, 1B, and 2B), but not in the remaining two experiments (2A and 3). The increases in the error rate were significant in all five experiments, with error rates ranging from 4 % to 11 % in the unrelated condition and 13 % to 20 % in the similar-prime condition. With respect to nonword primes, orthographically similar nonword primes did not significantly affect response latencies, but in all cases except for one O + P+ condition, they significantly decreased error rates (as compared with the unrelated-nonword prime condition). The error rates ranged from 9 % to 18 % for the unrelated and 6 % to 14 % for the orthographically similar conditions (O + P+ and O + P–). In the two experiments including an identity-prime condition (2A and 2B), the identity primes significantly decreased response latencies to nonword targets (by 35 and 48 ms) but did not significantly affect errors.

Experiments 1A and 1B

In Experiments 1A and 1B, the prime–target SOA was 47 ms. The target frequency levels were high and low in Experiment 1A and medium and low in Experiment

1B. In each experiment, unrelated word primes were compared with standard misspelled primes that captured the target phonology (O + P+) and orthographic primes that were altered to be phonologically distinct from their targets (O + P–).

Method

Participants A total of 36 introductory psychology students with a mean age of 21.3 years (21 women, 15 men) participated for course credit.

Materials and design For Experiment 1A, 42 high-frequency and 42 low-frequency words were chosen as targets. For the unrelated-prime condition, a dissimilar word was chosen for each target, matched to it in length and approximately matched in frequency. For each target, two orthographically similar nonword primes were constructed. For the phonologically similar (O + P+) condition, changes or movements of one to two letters were made such that the phonology of the target was preserved. For the phonologically distinct (O + P–) condition, a stressed vowel or a consonant was replaced to change the pronunciation (see the Appendix). Similar primes ranged in length from seven to ten letters and were matched in length over the O + P+ and O + P– conditions. Eighty-four pronounceable nonwords were matched in length to the target words, and primes were assigned to them to match the proportions of similar and unrelated primes in the word set, with one third having word primes and the remainder nonword primes.

For Experiment 1B, the high-frequency words were replaced by medium-frequency words. Otherwise, the materials were identical to those of Experiment 1A.

The assignment of word targets to conditions was counterbalanced over three lists, such that each target appeared once in each list and was paired with each of the three prime types over the three lists. In each list, 14 targets occurred in each prime condition within each frequency set. The set of nonword prime–target pairs was added to each list, and the trial sequence was randomized. Four unrelated practice pairs were placed at the beginning of each list.

Procedure The prime duration was 47 ms.

Table 2 Mean response latencies (in milliseconds) and error percentages in the lexical decision task for nonword targets as a function of prime type

Prime Type	Experiment and SOA				
	1A (47 ms)	1B (47 ms)	2A (80 ms)	2B (80 ms)	3 (80 ms)
Mean Response Latencies					
Unrelated W	783	753	837	739	872
O + P– W	850	786	858	780	890
Unrelated NW	810	778	831	768	869
Identity NW			796	720	
O + P+ NW	820	778			886
O + P– NW	790	755	847	747	850
Mean Error Percentages					
Unrelated W	3.50	7.27	11.19	5.26	5.00
O + P– W	13.60	13.33	19.67	16.81	16.00
Unrelated NW	9.44	11.24	15.56	17.82	13.50
Identity NW			10.28	9.49	
O + P+ NW	7.41	8.70			13.70
O + P– NW	5.71	6.30	19.17	11.81	9.63

W, word; NW, nonword

Results

Experiment 1A In analyses of variance (ANOVAs), the Greenhouse–Geisser correction was applied in cases of violations of the sphericity assumption. Effect size estimates are reported for analyses by participants, and major analyses for word targets were conducted by participants and items. In this and all subsequent experiments, the latency data were preprocessed by excluding errors and latencies in excess of 2,000 ms, and thereafter within each condition for words (and pooled over conditions for nonwords), latencies more than three standard deviations from a participant's mean were excluded. In Experiment 1A, 1.82 % of word trial data were lost due to extreme latencies.

The mean response latencies and error percentages for high- versus low-frequency words are shown in Table 3. A Frequency (high, low) $\times$ Prime Type (unrelated, O + P+, O + P–) ANOVA on the mean latencies showed significant main effects of both frequency, with a substantial advantage of 182 ms for high-frequency targets, $F_1(1, 35) = 204.06$, $MSE = 8,765$, $\eta_p^2 = .85$; $F_2(1, 82) = 149.95$, $MSE = 16,301$, and prime type, reflecting facilitation by orthographic primes, $F_1(2, 70) = 17.75$, $MSE = 3,568$, $\eta_p^2 = .33$; $F_2(2, 164) = 18.41$, $MSE = 5,898$. A follow-up comparison showed no significant difference between prime conditions O + P+ and O + P–, F_1 and $F_2 < 1.04$. In addition, a significant interaction of frequency and prime type was apparent, with a larger priming effect for low-frequency words, $F_1(2, 70) = 3.76$, $MSE = 2,729$, $\eta_p^2 = .10$; $F_2(2, 164) = 4.88$, $MSE = 5,898$. Simple effects of prime type confirmed a significant priming effect ($ps < .01$) at each level of frequency, averaged over O + P+ and O + P–

primes (71 and 30 ms for low- and high-frequency targets, respectively).

Error rates were negligible for the high-frequency targets. A one-way ANOVA on error rates for the low-frequency targets revealed a priming benefit that was not significant by participants, $F_1(2, 70) = 2.46$, $MSE = 116$, $p = .09$; $F_2(2, 82) = 3.60$, $MSE = 92$.

Experiment 1B After preprocessing, 1.98 % of the word-target latencies were lost as extreme. The mean response latencies and error percentages for medium- versus low-frequency words are shown in Table 3. A Frequency (medium, low) $\times$ Prime Type (unrelated, O + P+, O + P–) ANOVA on mean latencies showed significant main effects of both frequency, with a substantial advantage of 90 ms for medium-frequency targets, $F_1(1, 29) = 49.44$, $MSE = 7,268$, $\eta_p^2 = .63$; $F_2(1, 82) = 36.55$, $MSE = 14,345$, and prime type, reflecting facilitation by orthographic primes (mean of 63 ms, averaged over O + P+ and O + P–), $F_1(2, 58) = 26.45$, $MSE = 3,052$, $\eta_p^2 = .47$; $F_2(2, 164) = 17.61$, $MSE = 7,486$. In contrast to Experiment 1A, no interaction emerged, $F_1(2, 58) = 1.32$, $p = .28$; $F_2 < 1$. Follow-up comparisons for the prime effect showed that the difference between the unrelated and O + P– conditions was significant, $F_1(1, 29) = 35.52$; $F_2(1, 82) = 18.93$, but the difference between O + P+ and O + P– was not significant, $F_1(1, 29) = 2.38$, $p = .13$; $F_2(1, 82) = 1.09$, $p = .30$.

A Frequency $\times$ Prime Type ANOVA on error rates confirmed a main effect of frequency, $F_1(1, 29) = 37.28$, $MSE = 130$, $\eta_p^2 = .56$; $F_2(1, 82) = 21.42$, $MSE = 318$. There were no other effects.

Table 3 Experiments 1A and 1B: Mean response latencies (in milliseconds) and error percentages in the lexical decision task as a function of target frequency and prime type (unrelated vs.

orthographically and phonologically similar vs. orthographically similar and phonologically distinct), at an SOA of 47 ms

	Prime Type			
	Target Frequency	Unrelated Word	O + P+ Nonword	O + P– Nonword
Experiment 1A				
Mean latencies	Low	825	759	749
	High	616	589	582
Mean % errors	Low	23.41	19.25	18.06
	High	0.99	0.79	1.19
Experiment 1B				
Mean latencies	Low	759	676	701
	Medium	659	604	604
Mean % errors	Low	16.91	13.33	14.52
	Medium	5.71	4.05	3.81

Discussion

The frequency manipulation effectively differentiated performance, with response latencies to low-frequency targets being significantly longer than those to medium-frequency targets. A cross-experiment analysis on the unrelated-prime condition confirmed that the magnitudes of the frequency effects differed over the experiments: $F_1(1, 64) = 20.055$, $F_2(1, 166) = 87.92$, $p < .001$, for the Experiment $\times$ Frequency interaction. The difference between the high- and medium-frequency targets in the unrelated-prime condition was marginally reliable, $F_1(1, 64) = 3.27$, $p = .08$; $F_2(1, 82) = 6.41$, $p < .003$. The participants in Experiment 1A were slower on low-frequency words than those in Experiment 1B, $F_1(1, 64) = 4.38$. This difference may reflect time-of-semester differences between the student samples and criterion differences in the LDT arising from the differences in the frequency compositions of the lists.

The results for the prime conditions were clear cut. The key finding was that priming facilitation was observed for targets of high, medium, and low frequency, and at similar magnitudes for phonologically similar and distinct orthographic primes. Medium- and low-frequency targets exhibited similar magnitudes of priming, whereas Experiment 1A revealed a larger priming effect for low- than for high-frequency targets. Although response latencies were longer to low-frequency targets in Experiment 1A than in Experiment 1B, the average priming effects for low-frequency targets (unrelated vs. the mean of the phonologically similar and distinct prime conditions) did not differ over Experiments 1A and 1B (71 and 70 ms, respectively).

Experiments 2A and 2B

In Experiments 2A and 2B, phonologically similar primes were assessed at a long SOA of 80 ms, and their effects were

compared with an identity prime condition. In Experiment 2A, the materials were those used in Experiment 1A (high- vs. low-frequency targets), whereas the items for Experiment 2B came from Experiment 1B (medium- vs. low-frequency targets). The primary question was whether at the longer SOAs participants would be more sensitive to orthographic inconsistencies between misspelled primes (O + P+) and their targets, and consequently, would show a reduced priming benefit. Additional information was sought by assessing whether the priming effect for misspellings was significantly less than the identity-priming effect.

Method

Participants Introductory psychology students with a mean age of 21.9 years participated for course credit. In total, 30 students (18 women, 12 men) took part in Experiment 2A, and 36 (23 women, 13 men) in Experiment 2B.

Materials and design The targets and O + P+ and unrelated primes were those used in Experiment 1A (high and low frequencies) and Experiment 1B (medium and low frequencies). The third prime type was an identity prime. With respect to the nonword targets, 36 had nonword primes (identity, unrelated, and O + P– conditions), and 48 had word primes (O + P– and unrelated conditions).

Procedure The prime duration was 80 ms.

Results

Experiment 2A After preprocessing, 1.03 % of the word-target latencies were lost as extreme. The mean response latencies and error percentages for high- versus low-frequency words are shown in Table 4. A Frequency (high, low) $\times$ Prime Type (unrelated, misspelled, identity) ANOVA on the mean

Table 4 Experiments 2A and 2B: Mean response latencies (in milliseconds) and error percentages in the lexical decision task as a function of target frequency and prime type (unrelated vs. similar vs. identity), at an SOA of 80 ms

		Target Frequency	Prime Type			O + P+ Effect	Identity Effect
		Unrelated Word	O + P+ Nonword	Identity			
Experiment 2A							
Mean latencies	Low	796	710	728	86	68	
	High	631	618	568	13	63	
Mean % errors	Low	25.00	14.52	15.23	10.49	9.77	
	High	2.14	1.91	1.43	0.23	0.71	
Experiment 2B							
Mean latencies	Low	730	631	649	99	81	
	Medium	654	600	572	54	82	
Mean % errors	Low	18.25	11.91	14.09	6.34	4.16	
	Medium	6.55	4.17	5.36	2.38	1.19	

latencies showed significant main effects of both frequency, with a substantial advantage (139 ms) for high-frequency targets, $F_1(1, 29) = 73.18$, $MSE = 11,879$, $\eta_p^2 = .17$; $F_2(1, 82) = 188.79$, $MSE = 7,184$, and prime type, with facilitation by identity and misspelled primes, $F_1(2, 58) = 24.33$, $MSE = 2,869$, $\eta_p^2 = .46$; $F_2(2, 164) = 19.33$, $MSE = 63,613$. In addition, a significant Frequency $\times$ Prime Type interaction emerged, reflecting a selective effect of misspelled primes on low-frequency targets, $F_1(2, 58) = 8.81$, $MSE = 2,810$, $\eta_p^2 = .23$; $F_2(2, 164) = 8.34$, $MSE = 63,613$. Comparisons with the unrelated-prime condition within each level of frequency revealed that the misspelling priming effect for low-frequency targets (86 ms) was significant, $F_1(1, 29) = 21.12$, $F_2(1, 41) = 23.37$, whereas the 13-ms effect for high-frequency targets was not, $F_1(1, 29) = 1.13$, $p = .30$; $F_2 < 1$. For low-frequency targets, the 18-ms difference between the identity and misspelled prime conditions was not significant, $F_1(1, 29) = 2.30$, $p = .14$; $F_2(1, 41) = 1.40$, $p = .24$. An additional Frequency $\times$ Prime Type ANOVA for just the unrelated and identity conditions revealed no interaction, F_1 and $F_2 < 1$, with the identity priming effect of similar magnitudes for high- and low-frequency targets (68 and 63 ms, respectively).

Error rates for high-frequency words were low and were not analyzed. For low-frequency targets, a significant effect of prime type was visible in a one-way ANOVA, $F_1(2, 58) = 8.09$, $MSE = 127$, $\eta_p^2 = .22$; $F_2(2, 82) = 9.95$, $MSE = 145$, with more errors in the unrelated-prime condition. A follow-up test showed that the misspelled and identity conditions did not differ, F_1 and $F_2 < 1$.

Experiment 2B After preprocessing, 0.6 % of word-target latencies were lost as extreme. The mean response latencies and error percentages for medium- versus low-frequency words are shown in Table 4. A Frequency (medium, low) $\times$ Prime Type (unrelated, misspelled, identity) ANOVA showed

significant main effects of both frequency, with a substantial advantage of 61 ms for medium-frequency targets, $F_1(1, 35) = 95.62$, $MSE = 2,113$, $\eta_p^2 = .73$; $F_2(1, 82) = 25.07$, $MSE = 9,866$, and prime type, with facilitation by identity and misspelled primes, $F_1(2, 70) = 43.78$, $MSE = 3,432$, $\eta_p^2 = .52$; $F_2(2, 164) = 47.41$, $MSE = 4,151$. In addition, a significant Frequency $\times$ Prime Type interaction emerged, reflecting larger priming effects for low-frequency targets (90 ms) than for medium-frequency targets (68 ms), $F_1(2, 70) = 4.49$, $MSE = 2,795$, $\eta_p^2 = .11$; $F_2(2, 164) = 3.51$, $MSE = 4,151$. Two 2×2 (Frequency $\times$ Prime Type) ANOVAs were conducted to assess the interaction with frequency separately for the misspelled and identity conditions relative to the unrelated-prime condition. The misspelling priming effect was significantly larger for low-frequency targets (99 ms) than for medium-frequency targets (54 ms): for the interaction, $F_1(1, 35) = 5.91$, $F_2(1, 82) = 7.48$. Follow-up tests for medium-frequency targets confirmed that the misspelling priming effect was significant, $F_1(1, 35) = 20.07$; $F_2(1, 41) = 33.72$, $p < .001$. The latencies for the misspelled-prime condition were longer by 28 ms than in the identity condition, $F_1(1, 35) = 5.89$, $p = .02$, with the difference being only marginal by items, $F_2(1, 41) = 3.60$, $p = .07$. In the analysis of the identity-priming effect, there was no interaction with target frequency, F_1 and $F_2 < 1$, with the mean identity-priming effects being 82 (medium) and 81 (low) ms.

A Frequency $\times$ Prime Type ANOVA on error rates confirmed a main effect of frequency, $F_1(1, 35) = 66.25$, $MSE = 72$, $\eta_p^2 = .65$; $F_2(1, 82) = 14.76$, $MSE = 377$. A main effect of prime type was also visible, $F_1(2, 70) = 4.41$, $MSE = 79$, $\eta_p^2 = .11$; $F_2(2, 164) = 6.60$, $MSE = 62$, with higher error rates for the unrelated-prime condition. In a separate Frequency $\times$ Prime Type ANOVA for the misspelled and identity conditions, no significant effect of prime type emerged.

Discussion

The main effects of target frequency were replicated. As in Experiments 1A and 1B, latencies were longer to low-frequency targets in the context of high-frequency targets (Exp. 2A) than in the context of medium-frequency targets (Exp. 2B). The consistent pattern suggests that the difference was at least in part due to list composition effects on the response criterion (Kinoshita, Mozer, & Forster, 2011). In the present case, the participants did not show the typical speeding of responses to difficult words (low frequency) in the context of easy words (high frequency). Perhaps a context of high-frequency words causes participants to adopt too low an evidence criterion for a correct decision about low-frequency targets, and some orthographic checking was required. In line with this idea, the error rates for low-frequency words tended to be higher in the context of high- than of medium-frequency words in both Experiments 1 and 2.

The orthographic-priming results showed that facilitation was compromised for misspelled primes when the SOA was lengthened, but this effect depended on target frequency. Low-frequency targets showed substantial facilitation relative to the unrelated word prime, whereas high-frequency targets showed no benefit of a misspelled prime. For medium-frequency targets there was facilitation, but significantly less than for low-frequency targets. As had been observed in Experiment 1, the magnitudes of orthographic priming for low-frequency targets were similar over the two experiments (86 vs. 99 ms), and the Prime Type $\times$ Experiment interaction was not significant.

The comparison with identity primes revealed that for low-frequency targets, the magnitude of priming by misspellings was fully as large as the identity-priming effect, with the misspelled and identity prime conditions not differing. For medium-frequency targets, the identity-priming condition was a little faster than the misspelled prime condition, and of course, for high-frequency targets it was much faster. These results suggest that for lower-frequency targets, a misspelling has a substantial overlap with the internal orthographic representation.

In line with a substantial body of previous work (Bodner & Masson, 1997; Forster & Davis, 1984; Humphreys, Quinlan, Evett, & Besner, 1987; Segui & Grainger, 1990), the identity-priming effects were similar over the levels of target frequency. Kinoshita (2006) suggested that the failure to find a larger identity masked-priming benefit with low- than with high-frequency targets is caused by the inclusion of low-frequency items that are not within participants' vocabularies. When the low-frequency targets from Experiment 2A were divided into the 21 highest and the 21 lowest in frequency, the identity-priming effect tended to be greater for the higher low-frequency words (98 ms) than for the lower low-frequency words (62 ms) and for high-frequency words

(63 ms), although the Frequency $\times$ Prime Type interaction was not significant in the items analyses for these two sets of targets ($F_2 < 1$) or in the ANOVA on higher low- versus high-frequency items, $F_2(1, 61) = 2.51, p = .12$. In Experiment 2B, a smaller and nonsignificant trend was in the same direction, with the repetition-priming effects being 95 ms for the higher low-frequency words and 81 and 80 ms for the lower low-frequency and the high-frequency words, respectively. The trend for a larger priming effect for more-familiar low-frequency words is consistent with Kinoshita (2006). However the trend was small, especially in Experiment 2B, and it remains to be seen whether the differential priming effect would be observed if low-frequency words were all selected to be familiar to participants.

Experiment 3

In Experiment 3, the effect of phonologically distinct (O + P–) primes was examined at the long SOA of 80 ms. Because no priming benefit occurred in Experiment 2A with O + P+ primes for high-frequency targets, only medium- and low-frequency targets were examined. Given the reduction in O + P+ priming for medium-frequency targets at the long SOA in Experiment 2B, a further reduction in priming was expected in the present experiment. The long SOA should foster the recruitment of prime phonology, with a consequent cost for phonological inconsistency between the prime and the target. A key question was whether evidence would emerge of a cost for a phonological discrepancy for low-frequency targets.

Method

Participants A group of 30 introductory psychology students with a mean age of 20.8 years (17 women, 13 men) participated for course credit.

Materials and design The materials were the same as in Experiment 1B.

Procedure The experiments were conducted as described previously, with a prime duration of 80 ms.

Results

After preprocessing, 1.51 % of the word-target latencies were lost as extreme. The mean response latencies and error percentages for medium- versus low-frequency words are shown in Table 5. A Frequency (medium, low) $\times$ Prime Type (unrelated, O + P+, O + P–) ANOVA showed significant main effects of both frequency, with a substantial advantage of 80 ms for medium-frequency targets, $F_1(1, 29) = 96.36$, $MSE = 2,987$, $\eta_p^2 = .77$; $F_2(1, 82) = 20.74$, $MSE = 164$, and

Table 5 Experiment 3: Mean response latencies (in milliseconds) and error percentages in the lexical decision task as a function of target frequency and prime type (unrelated vs. orthographically and phonologically similar vs. orthographically similar and phonologically distinct), at an SOA of 80 ms

Target Frequency		Prime Type			O + P+ Effect	O + P- Effect
		Unrelated Word	O + P+ Nonword	O + P- Nonword		
Mean latencies	Low	846	744	762	102	84
	Medium	727	684	702	43	25
Mean % errors	Low	16.91	14.29	14.52	2.62	2.39
	Medium	7.13	4.05	5.71	3.08	1.42

prime type, with facilitation by O + P+ and O + P- primes, $F_1(2, 58) = 26.99$, $MSE = 3,147$, $\eta_p^2 = .48$; $F_2(2, 164) = 26.79$, $MSE = 13,619$. In addition, a significant Frequency $\times$ Prime Type interaction was apparent, reflecting a larger priming effect for low-frequency targets, $F_1(2, 58) = 5.62$, $MSE = 3,162$, $\eta_p^2 = .16$; $F_2(2, 164) = 3.41$, $MSE = 5,712$. Comparisons with the unrelated-prime condition within each level of frequency revealed that the O + P- priming effect for low-frequency targets (84 ms) was significant, $F_1(1, 29) = 27.54$, $F_2(1, 41) = 18.55$, whereas the effect for medium-frequency targets (25 ms) only approached significance, $F_1(1, 29) = 3.23$, $p = .08$; $F_2 = 3.61$, $p = .07$. By contrast, the O + P+ priming effect was robust at both levels of target frequency, with the smaller effect (for medium-frequency targets, 43 ms) being significant separately, $F_1(1, 29) = 7.91$, $F_2(1, 41) = 9.22$.

A Frequency $\times$ Prime Type ANOVA on error rates showed only a frequency effect, $F_1(1, 29) = 27.38$, $MSE = 152$, $\eta_p^2 = .49$; $F_2(1, 82) = 20.74$, $MSE = 49$.

Discussion

As in Experiment 2B, significant priming by O + P+ primes emerged at both levels of target frequency. For O + P- primes and medium-frequency targets, the expectation that priming would be reduced by a phonological discrepancy between primes and targets was met, in that the O + P- effect was only marginally significant. There was substantial priming by O + P- primes for low-frequency targets.

The relative magnitudes of the O + P+ and O + P- priming effects should be interpreted within the context of larger priming effects overall for low-frequency targets in both Experiments 2B and 3. The difference between the O + P+ and O + P- prime conditions was 18 ms and did not differ over levels of target frequency. However, the reduction in priming for the O + P- condition was sufficient to render the smaller priming effect for medium-frequency targets marginally significant.

General discussion

The results of the present experiments can be summarized simply. First, robust main effects of word frequency were observed in all experiments. Second, of primary interest, the orthographic-priming effects depended on target frequency and prime–target SOA. They are summarized in Fig. 1. Regardless of whether misspelled primes completely matched the phonology of their targets, there was substantial facilitation at the short SOA of 47 ms for all levels of target frequency (high, medium, and low). However, at a longer SOA of 80 ms, the priming benefit was observed only for low- and medium-frequency words, and for the latter items, it was rendered nonsignificant by a phonological discrepancy between prime and target. The phonological effect was evident at an SOA considerably longer than the SOA of 43 to 57 ms found for phonological effects by Ferrand and Grainger (1992), and a little longer than the SOAs of 64 ms and 66 ms, respectively, reported by these authors in a later study (Ferrand & Grainger, 1994) and by Pollatsek et al. (2005). This result may reflect the use of long words in the present studies.

Third, for identity versus unrelated primes, facilitation was observed at both short and long SOAs, with the magnitude of

Fig. 1 All experiments: Orthographic-priming effects on latencies, expressed as the prime condition mean subtracted from the mean for the unrelated-word prime condition. The target frequency was high (HF; Exps. 1A and 2A), medium (MF; Exps. 1B, 2B, and 3), or low (LF; all experiments), and the means are averaged over replications (LF: 1A, 1B, 2A, 2B, and 3 for O + P+ primes; MF: 2B and 3 for O + P+ primes). Error bars show the standard errors of the means

the priming effect not varying as a function of target frequency. These results are consistent with much of the literature, although there has been some debate about whether the failure to find a larger masked identity-priming effect for low- than for high-frequency words reflects a problem with low-frequency items that are unfamiliar to participants (Kinoshita, 2006). In the present Experiment 2A, a nonsignificant trend emerged for priming to be greater for more familiar (higher-frequency) low-frequency words than for both less familiar low-frequency words and high-frequency words.

For nonword targets, orthographically similar word primes had a generally detrimental effect on latencies and error rates. In line with the analysis by Kinoshita and Norris (2009), this result is likely to be an artifact of the LDT, with word primes biasing evidence in favor of an incorrect “word” decision. Orthographically similar nonword primes generally decreased error rates without affecting latencies. Identical primes reduced latencies without affecting error rates.

Priming at the 47-ms SOA

The general facilitation by orthographically similar primes, together with the absence of an effect of phonological similarity, suggests that the basis of the priming effect was orthographic. An orthographic basis of priming facilitation is in keeping with a substantial body of work at SOAs of 50 to 60 ms that has shown facilitation with one-letter-different nonword primes (C. J. Davis, 2003; Forster, 1999; Grainger & Jacobs, 1999; Humphreys, Besner, & Quinlan, 1988). These primes usually have a phonological discrepancy from their targets. Abundant evidence supports the idea that phonological activation lags behind orthographic processing, with the lag being captured by variation in prime–target SOAs and prime types (Ferrand & Grainger, 1992; Grainger & Jacobs, 1999; Grainger et al., 2006). The effect of prime phonology would therefore depend upon the SOA and the rate of target processing. At the short SOA of 47 ms, the time appears to be insufficient for prime phonology to be recruited before the target letter string is presented to the lexical-processing system.

Priming at the 80-ms SOA

Frequency and phonological dissimilarity had substantial effects on orthographic priming at the longer SOA. First, high-frequency targets failed to show a benefit from phonologically similar misspelled primes at the longer SOA. For low-frequency targets, priming was observed regardless of whether the orthographically similar prime was phonologically similar to the target, and there was no difference between the phonologically similar versus distinct prime types. Furthermore, Experiment 2 revealed that for low-frequency targets, there was no difference in the latencies for targets

paired with phonologically similar misspelled primes and identity primes. Finally, medium-frequency targets showed significant facilitation by phonologically similar and identity primes, but only a trend ($p = .08$) for facilitation by phonologically distinct primes. For the latter targets, prime similarity had a graded effect, with the identity condition being faster than the phonologically similar condition, $F_1(1, 35) = 5.89$, $p = .021$.

In contrast to the shorter SOA, it appears that at the 80-ms SOA, prime phonology is available and can disrupt responses if it is discrepant from the target phonology. There are no strong grounds for supposing that prime phonology played a major role in access to the target in lexical memory, given that the orthography of the prime appears to have a robust and earlier effect on target processing. Consistent with a key role of orthographic overlap in priming facilitation, the magnitude of priming for low-frequency targets was no larger for the phonologically similar than for the phonologically distinct orthographic primes. The phonology of the prime may have played a role in the decision stage of the LDT. Word phonology is thought to be activated implicitly during reading, regardless of whether it has an early role in lexical identification (Filik & Barber, 2011; Perrone-Bertolotti et al., 2012). Furthermore, given the evidence for the use of phonological codes for verbal material in working memory (Baddeley & Hitch, 1994), it is likely that phonological representations of words and nonwords serve a useful short-term memory function during response preparation in lexical tasks. A conflict between the pronunciation of the prime and the target has the potential to impair production of the target phonology if there is a temporal overlap between prime and target phonological activation. As will be discussed below, the degree of temporal overlap may depend on the target frequency.

The role of target frequency in the effects of prime orthography and phonology

The priming effect ($O + P+$ and $O + P-$) at the 47-ms SOA was significantly larger for low- than for high-frequency targets (but not for low- than for medium-frequency targets). The priming effect was also numerically larger for medium-frequency targets than for high-frequency targets, but the Frequency $\times$ Prime Type interaction was not significant in a cross-experiment analysis (in which frequency was varied between participants). The moderating effect of frequency on the magnitude of priming was even larger at the 80-ms SOA. Additionally, the effects of $O + P+$ and $O + P-$ primes diverged, with low- but not medium-frequency targets showing benefits of phonologically distinct ($O + P-$) primes. Thus, for example, the medium-frequency target *phenomena* showed no priming benefit from the $O + P-$ prime *thenomena*, whereas the low-frequency target *fluoride* showed a substantial benefit from the prime *gluoride*.

A possible confounding variable to be considered is that the primes for high-frequency words were less similar to their targets than in the other frequency conditions. However, there was no difference over levels of target frequency in the use of transpositions versus substitutions to produce the similar primes.

The clear effects of target frequency on the magnitude of priming in the present experiments suggest that targets that are processed more slowly can be more susceptible to the effects of any prime that preactivates the target representation. However, this analysis fails for the identity-priming condition, which, with the same item set, showed substantial and similar priming effects over levels of target frequency.

According to the analysis of masked priming effects by Forster and colleagues (1987), facilitation reflects activation by the prime of the lexical representation of the target (best-match hypothesis). The number of competitor words for each prime was examined by finding the number of words other than the target that had the same orthographic overlap as the prime and target. This examination for both the O + P+ and O + P− conditions indicated that the similar primes were in the vast majority of cases a better match to the target than to any other word. Therefore, it is assumed that the similar primes produced a head start in target identification. A viable explanation of the frequency effect is that the head start is smaller for high-frequency targets because their orthographic representations are less tolerant of spelling discrepancies with the prime than are those of low-frequency targets. (Of course, identity primes have no discrepancies from their targets, so this factor would not affect the magnitude of identity priming.) It has been argued by Forster et al. that words with many orthographic neighbors have more finely tuned orthographic representations. The need to prevent confusion between similar words is thought to drive changes in the specification of the orthographic representations. Arguably, high-frequency words also have more finely tuned orthographic (and perhaps phonological) representations. In this case, the changes would come as a result of substantial learning. By contrast, longer low-frequency words may have poorly specified orthographic representations that better match their misspellings. Consistent with this idea, in a comparison of identity and misspelled primes with mainly lower-frequency words, Holmes and Davis (2002) found that a correct target word was more strongly primed by a participant's confident misspelling of the target than by the correct spelling (identity prime).

As was already discussed, word frequency has infrequently been examined in masked orthographic-priming studies with nonword primes. However, as was noted, at an SOA of 60 ms with six- to ten-letter targets, Forster et al. (1987) found comparable priming for low- and high-frequency words. The frequency differences were similar in their study and the present one, except that the maximum frequency of low-frequency

words was a little less in the present experiments (7 per million) than in the Forster et al. study (9 per million). The low-frequency targets in the present experiments also were long and probably more difficult to spell than those used by Forster et al., and thus these words may have more poorly specified orthographic representations and a higher susceptibility to orthographic facilitation. Spelling production data for the low-frequency targets were available from a different sample of 60 university students (Burt & Tate, 2002), showing a mean accuracy of 51 % (range 20 %–92 %). However, correlational analyses showed no consistent relationship between item spelling accuracy and the magnitude of the misspelled-prime effect.

The most obvious explanation of the discrepancy with previous findings for word frequency is that the present use of misspelled primes contributes to the effect of frequency on priming. Specifically, at least with low-frequency targets that are difficult to spell, misspelled primes may be a better match with the individual's orthographic representation than the orthographic primes used in previous research would be. By contrast, neither prime type would be a good match to the orthographic representation of a well-learned (high-frequency) word.

With respect to phonology, less well-learned words may also have less well-specified phonological representations and may be less affected by phonological mismatches in the context of considerable overlap in phonology and orthography. Most importantly, frequency effects on the time course of the activation of target phonology may be a key factor in the effects of a phonological discrepancy between the prime and the target. The temporal overlap between prime and target phonology may be less for low-frequency targets. Because the nonword primes for the most part were pronounceable from the spelling–sound rules of English, it seems likely that the phonology of primes for low-frequency words became available at about the same time as the phonology of primes for high-frequency targets. On the other hand, target identification and retrieval of lexical phonology is likely to be slower for low-frequency targets. As a result, conflicts between prime and target phonology may be more likely for higher-frequency targets, whose phonology is activated sooner after prime presentation.

Conclusion

The present experiments add to the increasing support for the idea that letter position is not rigidly coded in the matching of an input letter string with the internal representation of a word's orthography (C. J. Davis et al., 2009). They also support findings that phonological information is recruited more slowly than orthographic information during word reading (Grainger et al., 2006), in that a phonological mismatch with

the target had a disruptive effect only at a long SOA. Importantly, identity-priming effects were of similar magnitudes over levels of target frequency, whereas orthographic-priming effects were larger for lower-frequency words. These two results suggest that the representations of better-learned words are more finely tuned to the word's orthography and less tolerant of mismatches than are representations of less-well-learned words. An effect of frequency on the magnitude of priming was observed here but not in previous studies, arguably because the present orthographic primes were de-

signed to mimic typical spelling errors, and perhaps also reflecting the difficulty (atypical orthography) of the present items. Finally, the quality of the internal orthographic representation of a word is reflected both in participants' ability to spell it (Andrews & Lo, 2012) and in the frequency of occurrence of the word.

Author note The data for Experiment 3 were collected by Brian Sherman for an undergraduate research project.

Appendix

Targets and primes with their mean response latencies by condition, pooled over replications

Target	O+P+	O+P-	P+ 47 ms SOA	P- 47 ms SOA	Un	Id 80 ms SOA	P+	P-	Un
accessory	acesory	accegory	632	608	574	643	649	588	707
acoustic	accoustic	accoistic	701	675	687	692	663	637	799
acquaint	aquaint	aquamt	882	903	874	632	835	736	815
adherent	adherent	adhurent	733	654	720	711	643	627	749
aggravate	aggrevate	iggravate	649	648	734	650	743	606	756
assessor	assesor	assenor	827	958	808	762	744	923	823
asymmetry	assymetry	assyetry	788	865	924	656	749	926	889
avalanche	avolanche	evalanche	871	624	770	818	769	814	779
broccoli	brocolli	breccoli	764	617	878	611	682	704	776
buoyancy	bouyancy	buotancy	696	647	659	613	691	766	761
cartilage	cartalage	carpilage	706	794	822	743	745	528	800
crescent	cressent	croscnt	748	632	745	647	639	798	786
diligent	dilegent	ditigent	715	742	749	641	668	712	674
dissuade	disuade	disuede	808	731	747	819	669	854	772
equivocal	aquivocal	equidocal	709	710	888	776	630	817	926
facsimile	faxsimile	facsumile	676	635	821	670	671	680	789
fluoride	flouride	gluoride	654	613	757	597	660	767	828
graffiti	grafitti	graffuti	675	748	886	666	659	850	829
gullible	gullable	gulsible	685	670	848	722	653	814	830
hydraulic	hydrollic	hybrolic	704	757	984	747	739	866	750
hypocrite	hyppocrit	hyspocrit	632	604	705	685	673	782	786
insolent	insalent	ansolent	669	767	702	676	666	707	835
lacerate	laserate	laterate	869	1076	901	775	785	886	931
massacre	massacer	messacre	663	759	837	635	678	676	867
oblivion	oblivian	oblinion	672	736	741	632	674	776	810
pacifist	pasifist	pocifist	717	822	836	688	638	627	786
parachute	parashute	garachute	601	704	672	651	684	616	742
pinnacle	pinnacle	pintacle	739	734	931	657	691	740	809
pistachio	pastachio	pistochio	723	944	862	708	741	816	850
porcelain	porcelin	porcelit	703	740	726	707	676	698	765
precipice	presipice	procipice	696	927	872	768	699	930	863

ravenous	ravinous	rivenous	694	727	811	706	684	726	816
rebuttal	rebuttle	rebuttle	788	768	1126	894	811	910	893
rheumatic	rhuematic	theumatic	822	748	836	713	779	754	743
rigidity	ridgidity	ridgadity	659	650	782	685	663	689	768
scavenger	scavinger	scovenger	607	636	804	641	672	828	744
scenario	senario	senurio	645	669	646	582	618	668	724
stratify	stratefy	stretify	712	702	1048	765	733	766	886
subtlety	subtlty	sibtly	853	901	1034	764	832	851	918
succinct	sucsinct	succunct	821	632	765	742	704	647	755
tranquil	tranquill	trasquill	722	678	846	604	606	680	676
vigilant	vigilent	vagilant	675	615	743	626	623	749	691
advisory	advisery	advusory	701	595	636	522	679	690	702
alliance	allience	aldiance	640	587	593	518	584	678	628
associate	ascociate	aspociate	553	587	593	573	591	624	670
astronomy	astronemy	astrinomy	646	521	599	617	547	730	692
category	catagory	cutegory	554	577	575	486	636	677	676
cigarette	cigerette	ciganette	547	609	566	586	610	642	691
civilian	civillian	cinillian	604	763	561	515	647	585	718
decisive	desisive	demisive	661	566	546	565	590	616	631
democracy	democrecy	demacracy	563	574	611	503	601	707	606
detergent	detergant	deterpent	739	629	649	570	700	752	743
diffusion	deffusion	diffosion	676	574	715	544	632	681	709
empirical	empyricl	espirical	563	536	675	548	612	641	675
envelope	enveloppe	envelosse	525	571	538	576	612	548	661
flexible	flexable	flixiible	556	505	650	509	641	687	578
generous	genorous	gunerous	648	559	641	499	556	816	634
heritage	heritege	horitage	572	564	580	536	607	537	743
identify	identafy	idestify	632	585	633	510	598	674	536
imitation	immitation	immitution	738	698	612	539	709	767	751
infinite	infinite	iffinite	722	595	625	523	622	699	651
inherent	inherent	inhorent	557	696	666	585	698	664	669
luncheon	lunchion	kuncheon	736	685	730	516	658	706	736
marginal	margenal	murginal	556	650	705	544	726	639	773
minority	minorety	minarity	526	552	556	641	598	628	688
monument	monuement	monuevent	712	654	709	628	700	719	666
narrative	narrotive	nargative	582	663	672	531	683	747	703
oxidation	oxadation	oxidotion	690	615	699	636	700	789	841
particle	partecle	palticle	634	571	660	580	653	720	691
pertinent	pertenant	pertisent	654	662	1061	689	832	806	948
phenomena	phenomina	thenomena	555	585	836	598	697	882	725
rational	racional	retional	585	555	561	563	604	659	626
recommend	reccommend	recommund	564	572	740	544	581	749	788
regiment	regament	rogiment	576	499	715	686	693	751	725
relevant	relevent	rlevant	597	663	556	544	707	686	735
scarcely	scarsely	scamely	709	741	1070	903	752	698	770
specimen	specemen	spocimen	517	528	656	598	654	654	639
strategy	stratigy	sprategy	560	622	670	621	682	805	669
tangible	tangible	talgible	541	656	740	580	629	653	757
telegraph	telegraph	talegraph	575	517	678	546	560	660	647
theology	theolagy	treology	467	669	657	648	612	823	644
thorough	thorough	therough	690	732	743	679	613	804	651
velocity	velocity	vepocity	476	613	670	549	566	687	675

voluntary	volentary	veluntary	518	572	614	552	604	594	679
activity	activaty	actovity	498	536	615	509	620		552
actually	actuelly	artually	683	523	575	713	573		748
analysis	analysys	anolyis	506	508	641	496	628		641
approach	approach	appreach	623	570	608	522	602		635
attention	attension	attantion	639	536	648	493	600		648
attitude	attatude	astitude	578	545	593	566	570		563
audience	audiance	ardience	557	508	673	561	871		540
available	availible	avoiable	550	543	605	623	592		638
beautiful	beuatiful	beratiful	541	538	675	547	611		663
business	business	basiness	676	535	658	645	635		729
character	charicter	choracter	574	649	617	495	591		628
consider	concider	conbider	541	560	649	505	629		638
continue	contineu	contanue	607	497	537	513	652		848
decision	desision	demision	578	620	641	549	590		611
determine	ditermine	detormine	630	579	771	588	717		661
direction	derection	dipecton	590	603	576	576	563		642
division	devision	divosion	581	619	704	603	630		664
economic	ecanomic	econamic	643	629	661	540	549		669
evidence	evedence	ovidence	535	567	560	573	531		637
existence	existance	exastence	650	635	666	602	708		672
function	funcxion	finction	519	488	594	524	512		576
important	importent	impirtant	519	535	603	607	682		631
industry	indastry	incustry	569	603	725	591	591		574
influence	influnace	anfluence	637	711	652	625	551		675
knowledge	knowledge	snowledge	563	539	590	693	547		716
language	languge	lunguage	522	580	526	615	486		582
material	matirial	maferial	574	594	613	630	486		656
military	militery	molitary	711	649	615	620	548		610
national	nacional	nitonal	555	593	594	528	627		552
necessary	nesessary	nebessary	669	686	564	575	736		610
original	origenal	orivinal	555	557	515	484	663		567
physical	phisycal	phasical	525	520	554	506	549		593
possible	possable	gossible	601	586	573	509	674		565
president	prescident	prasident	612	628	640	562	681		696
principle	princaple	pronciple	713	646	578	574	695		581
property	proparty	prolerty	653	714	637	531	677		558
religion	relegion	relugion	598	584	576	525	583		605
research	reaserch	besearch	543	679	595	558	579		636
secretary	secreatary	socretary	656	636	738	679	721		614
specific	spacific	spelific	636	528	618	561	682		610
straight	streight	spraight	512	527	543	589	636		604
technical	tecknical	tuechnical	591	588	595	550	682		684

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