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Solely soles: Inter-lemma competition in inflected word recognition

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ABSTRACT

It was found that the unmasked presentation of a complex form that corresponded to only one definition of a homograph (e.g., *solely*, which is related to the ‘alone’ meaning of *soles*) did not inhibit the subsequent recognition of a complex form that was related to the competing meaning (e.g., *SOLES*, which is related to the ‘shoe’ meaning). Further studies found that inhibitory priming only emerged when the unmasked prime was related to the subordinate meaning of the homograph (e.g., *fined*) and the target to the dominant meaning (e.g., *FINEST*), but not when the prime was dominant (e.g., *longer*) and the target subordinate (e.g., *LONGING*). These findings suggest that the relative dominance of the prime-target pair dictates whether inhibitory priming occurs. Implications for frameworks of morphological processing are discussed.

Introduction

One of the key questions in the domain of visual word recognition is how morphological structure is captured in the lexical processing system. Studies using the unmasked visual priming paradigm (e.g., Feldman & Soltano, 1999; Marslen-Wilson, Tyler, Waksler, & Older, 1994) have found that genuinely suffixed words (i.e., semantically transparent words such as *hunter*) facilitate the recognition of their stems (i.e., *hunt*), whereas pseudo-suffixed words (i.e., semantically opaque words such as *corner*) do not prime their pseudo-stem (i.e., *corn*). This has led to the assertion that morphological decomposition (i.e., the process in which a complex word activates the representations of its constituents) is semantically driven, where a complex word will only be decomposed if it is semantically transparent. Later studies (e.g., Longtin, Segui, & Halle, 2003; Rastle, Davis, & New, 2004), however, have demonstrated a priming effect for both transparent and opaque words when the prime is masked from consciousness, which cannot be attributed merely to orthographic overlap given that words that have no apparent suffix produce no priming (e.g., *turnip-TURN*[1]).

Based on these findings, many researchers (e.g., Diependaele, Sandra, & Grainger, 2009; Rastle & Davis, 2008; Rastle et al., 2004; Taft, 2006; Taft & Nguyen-Hoan, 2010) have adopted a two-stage perspective on morphological processing. During the early stage of recognition, there is the form-driven “morpho-orthographic” processing, which will decompose a letter-string as long as it is morphologically complex in its appearance. This is followed by “morpho-semantic” processing which will only treat a word as morphologically complex if it is semantically transparent.

Feldman, O’Connor, and del Prado Martín (2009) argue against the existence of early morpho-orthographic processing on the grounds that they find no opaque masked

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[1] As a convention, an in accordance with the way items are presented in experiments, primes will be illustrated in lower case and their targets in upper-case.

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priming in their experiment. However, that result appears to be an anomaly because so many other studies have found such priming (including Feldman, Kostic, Gvozdenovic, O'Connor, & del Prado Martín, 2012). While it might be true that the effect for opaque primes is weaker than that for transparent primes (as argued by Feldman et al., 2009, though see Rastle & Merkx, 2011), this does not preclude the existence of morpho-orthographic decomposition followed by a modulating semantic influence (e.g., Taft & Nguyen-Hoan, 2010).

There exist several theoretical accounts of morphological processing that incorporate morpho-orthographic processing (e.g., Crepaldi, Rastle, Coltheart, & Nickels, 2010; Diependaele et al., 2009; Taft, 2006; Taft & Nguyen-Hoan, 2010), which are similar in the sense that morphological relationships are defined by how the representations of complex words interact with their constituent morphemes. Whole words and their constituents that support one another (i.e., a transparent word and its stem) may be connected by an excitatory link where the increase of activation in one unit leads to the increase of activation in the connected unit. This means that the activation in the representation of the transparent stem will be retained, which gives rise to facilitatory priming. How then, does the system deal with entries in the lexicon that are morphologically related on the basis of form, but do not share that relationship in terms of meaning? An opaque word and its stem are an example of this. Based on the findings of the masked priming studies (e.g., Longtin et al., 2003; Rastle et al., 2004), the presentation of an opaque word (e.g., *corner*) will activate both of its constituents (i.e., *corn* and *-er*). The system would then need to suppress the activation in the opaque stem *corn* in order to avoid confusion with *corner*.

Another example in which lexical entities could potentially be confused are ambiguous words (i.e., homographs) where there are individual lexical representations corresponding to each meaning. For example, the word *sole* possesses a representation related to the 'shoe' meaning and another related to the 'alone' meaning. If there is morpho-orthographic decomposition when the word *soles* is presented, the units related to both definitions of its stem would be activated, even though only the 'shoe' version is relevant. As such, the activation in the unit associated with the 'alone' meaning must be suppressed so that the appropriate lexical entry (i.e., the one related to 'shoe') would achieve recognition. One way in which the suppression of the stem could be accomplished is by means of an inhibitory mechanism, where the activation in the *sole* unit that is related to 'alone' is actively inhibited by the system (Allen & Badecker, 1999; Taft & Nguyen-Hoan, 2010). The alternative to such active suppression would be for the activation in the inappropriate unit to simply fall to a baseline level (i.e., its activation is not maintained within the system).

Evidence to support a mechanism of active suppression comes from a series of studies by Allen and Badecker (1999, 2002) conducted in Spanish. An inflected word was presented as an unmasked prime corresponding to one meaning of a homograph, followed by an inflected target word that was exclusive to a different meaning of the same homograph. For example, the prime *cerrar* (i.e., 'to close', with the bound stem *cerr-* and the suffix *-ar*) was paired with the target *CERRO* (i.e., 'hill', with the homographic bound stem *cerr-*), and it was found that the response times to the target were longer than when preceded by an unrelated prime *pasear* (i.e., 'to walk'). This inhibitory priming effect suggests that the incompatible prime *cerrar* suppressed the activation in *CERRO*, so that the target had to overcome the inhibition from the competing prime before its level of activation could be raised to the threshold for recognition.

The possibility exists, however, that the inhibitory priming effect for *cerrar-CERRO* could have arisen entirely from overlap in orthography since there is evidence to suggest that unmasked primes inhibit the subsequent recognition of orthographically similar targets (e.g., Colombo, 1986). Allen and Badecker (1999) dismissed this possibility by showing that the magnitude of inhibition from *cerrar* to *CERRO* was greater than that found between orthographically similar prime-target pairs that did not share a stem (e.g., *cerdo-CERRO*, where *cerdo* means 'pig'). Additional experiments using orthographically dissimilar allomorphs of the competing prime (e.g., *cierrar*, 'he closes') also produced an inhibitory priming effect on *CERRO* that was greater in magnitude than an orthographic control (*cierto-CERRO*, where *cierto* means 'certain'). Given that allomorphs do not have sufficient form overlap to elicit inhibition between orthographic units, the authors argued that the inhibitory priming effect cannot be attributed to overlap in orthographic form, but to a level that is sensitive to genuine morphological relationships (i.e., similar to a morpho-semantic stage). The inhibition could not have arisen purely from a semantic level, given that a prime that was semantically associated with the competing stem homograph (e.g., *puerta-cerro*, where *puerta* means 'door' which is related to *cerrar*) did not produce inhibition (Allen & Badecker, 2002). Therefore, the inhibitory priming effects between competing stem homographs were attributed to the competition between lexical representations and not feedback from the semantic level.

An Italian study by Laudanna, Badecker, and Caramazza (1989) obtained similar results using a 'double lexical decision task' in which two letter-strings were presented on screen simultaneously and participants had to decide whether both were real-words or not. It was found that competing letter-strings (i.e., those that corresponded to different meanings of a homograph) showed an inhibitory effect, while pairings that were inflected forms referring to the same homograph showed a facilitatory effect. For example, the response to *portare* ('to carry') and *porte* ('doors') was slower than the response to unrelated word pairs (e.g., *causa* and *ponte*, 'cause' and 'bridge'), while the response to two morphologically related words *voltare* ('to turn') and *voltavo* ('I was turning') was faster than the response to an unrelated word pair.

On the whole, this body of research provides strong evidence in support of an inhibitory mechanism. However, there is a potential issue with the way in which Allen and Badecker (1999) controlled for orthographic overlap between the prime and the target. Orthographic similarity between the incompatible homographs and their orthographically similar primes was controlled by matching the number of letters shared with the target (e.g., *cerrar*, the homograph, and *cerdo*, the orthographic relative, both share the initial letters *c*, *e* and *r* with the target *cerro*, while the former also shares the second *r* and the latter shares the final *o*). The concern with this approach is that it does not account for the number of adjacent letters pairs that the prime-target pairs have in common. As the literature has shown (Weber, 1970), orthographic similarity is not only determined by the number of common letters, but also whether those letters are adjacent to one another. Therefore, a comprehensive measure of orthographic similarity should incorporate the number of common adjacent letter pairs as well as the number of common letters.

A post-hoc analysis using a quantification of orthographic similarity that takes these factors into account (i.e., the OS measure of Van Orden, 1987) revealed that the targets actually did have a higher degree of orthographic similarity with the primes than with the orthographically related primes, $t(23) = 4.28$, $p < .01$. In the experiment using allomorphic primes (e.g., *cierra-CERRO*), such a post hoc analysis also revealed a greater degree of orthographic similarity between the homograph prime-target pairs than the orthographically related pairs, $t(23) = 3.18$, $p < .01$. Therefore, the inhibition between the incompatible prime and target, which was found to be stronger than the effect from the orthographically related prime-target pairs, may be attributable to the variation in orthographic similarity after all. The study by Laudanna et al. (1989) did not report the items used, so it is uncertain as to whether this was also an issue in their study.

The aim of the current study, then, is to revisit the issue of incompatible stem homographs, this time in English, and with a more stringent control over the degree of orthographic similarity.

Experiment 1

The first experiment attempts to replicate the inhibitory priming effect of competing stem homographs that was observed by Allen and Badecker (1999), using unmasked visual primes in a lexical decision task with English materials. For example, it is expected that the system will associate the word *solely* with the unit for *sole* linked to the 'alone' meaning, and this will subsequently inhibit the incompatible meaning for *sole* linked to the 'shoe' meaning. To test this, *solely* was used as a prime for the target *SOLES* because the latter is a word that must be recognized through the unit that is linked to the 'shoe' meaning. Therefore, *SOLES* should be harder to recognize when preceded by *solely* than by an unrelated prime (e.g., *crowns*). As in the study by Laudanna et al. (1989), prime-target pairs that correspond to the same meaning of the homograph (i.e., 'compatible' pairs) were also included. For example, both *slipped* and its target *SLIPPING* correspond to the 'fall' meaning of *slip*. Because compatible prime-target pairs activate the same unit, the pre-activation of that unit by the prime should facilitate the subsequent recognition of the target.

A set of orthographically related prime-target pairs was also included to gauge the effects of orthographic similarity. As was the case with the prime-target pairs in the other conditions, the orthographically related primes always shared their initial letter cluster with their targets (e.g., *campus* as a prime for *CAMPING*). Unlike the previous studies by Allen and Badecker (1999), the current study uses the measure of orthographic similarity developed by Van Orden (1987), which considers the number of common letters as well as the adjacent letter pairings. Based on previous research, it was expected that orthographically related primes would produce an inhibitory priming effect (e.g., Allen & Badecker, 1999; Colombo, 1986), or no priming at all (e.g., Forster & Veres, 1998). Importantly, the magnitude of any inhibitory effect that may emerge from the orthographically related primes was expected to be smaller than the inhibition from the competing primes.

Method

Materials

Twenty-two inflected English words were selected as targets for the "Incompatible" condition, and the same number were assigned to the "Compatible" condition. Each of the targets corresponded to only one meaning of a homograph (e.g., *SOLES* refers to the 'shoe' meaning of *sole*, and is unrelated to the 'alone' meaning). The targets in the Incompatible condition were paired with a related prime that corresponded to the competing target (e.g., *solely* as the prime for *SOLES*), as well as an unrelated prime with the same affix as the related prime (e.g., *manly-SOLES*). The related primes in the Compatible condition always corresponded to the same meaning as the target (e.g., *slipped*, which is associated with the same meaning as the target *SLIPPING*), and the unrelated primes had the same affix (e.g., *touched-SLIPPING*). The unrelated primes for both the Incompatible and Compatible conditions did not necessarily possess stems that were homographs, and had little if any orthographic overlap with their targets. All of the targets in the study were inflected. However, as a result of the fact that incompatible prime-target pairs in which both items are inflected are extremely rare in English, the primes were necessarily a mix of derived and inflected words.[2]

The Compatible prime-target pairs corresponded to a different set of homographs to those in the Incompatible condition (i.e., the targets were different in each condition). Therefore, it could be argued that this potentially presents an additional source of variability compared to Allen and

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[2] This may appear to be problematic, as a study by (Laudanna, Badecker, & Caramazza, 1992) found that the recognition of Italian targets (e.g., *rapa*, 'turnip') was only inhibited when the prime was an inflected form of the incompatible homograph (e.g., *rapire*, 'abduct'), not when it was a derived form (e.g., *rapimento*, 'abduction'). The authors argued from this that derived words in Italian are represented in terms of their "stem", which is a combination of the bound root (e.g., *rap-*) and the derivational suffix (e.g., *-ment-*), and that the stem is then attached to the inflectional suffix (e.g., *-o*). Because inflected words are represented in terms of their root (e.g., the *rap-* in *rapire*), pre-activation of that unit inhibits the incompatible root that corresponds to the target (i.e., the *rap-* of *rapa*). On the other hand, the competition between the stem *rapiment-* (i.e., from *rapimento*) and the root *rap-* of the target *rapa*, would not be as strong given that the two can be disambiguated on the basis of orthography. According to this account, then, the same issue should not be present in English given that derived and inflected words alike are composed of base word plus suffix. That is, the stem of a derived prime should compete with the stem of an inflected target just as much as should the stem of an inflected prime.

Table 1
The mean surface frequencies (occurrences per million) of the targets and primes from each condition in Experiment 1, along with their degree of orthographic similarity. Standard deviations are reported in parentheses.

	Compatible	Incompatible	Orthographic
Prime SF	10.0 (22.2)	9.0 (30.1)	9.5 (15.0)
Target SF	7.3 (11.9)	5.5 (7.9)	6.7 (10.0)
Orth similarity	.7 (.1)	.6 (.1)	.6 (.1)

Badecker (1999) who used the same stem-homographs in each of their conditions. However, the design of the current experiment could not be avoided, as it is difficult to find complex forms in English that exclusively correspond to only one definition of a homograph. Nevertheless, by comparing each condition to its own unrelated baseline, any extraneous variability between conditions was circumvented.

In addition to the Incompatible and Compatible conditions, there were 22 items in the "Orthographic" condition, where the target was inflected and the prime had a matching initial letter cluster, but was not an affixed version of the stem of the target (e.g., *campus* was the prime for *CAMPING*). These also had corresponding unrelated primes (e.g., *marble-CAMPING*). The targets in this condition did not necessarily have homographic stems.

Word frequency data was obtained from the SUBTLEX word frequency database (New, Brysbaert, Veronis, & Pallier, 2007), the average whole-word frequency (i.e., surface frequency) of the targets and their primes are reported in Table 1, along with the degree of orthographic similarity between the prime and target. The log frequencies of the targets and their primes did not differ across the three conditions (*p*'s > .05), and neither did the degree of orthographic similarity (*p*'s > .05). A list of all items can be found in Appendix A.

A Latin-square design was employed in which the targets from each condition were divided into two lists, and participants were randomly assigned to two subgroups. The items and subgroups were set up so that participants in the first subgroup saw targets in the first list with their related primes and those in the second list with their unrelated primes, while the second subgroup saw the reverse. This ensured that participants saw each target once, while each target was still presented with both its related and unrelated primes.

A total of 66 nonwords were also included as distractors. The use of nonword targets with nonsense stems (e.g., *THOIKER*) would potentially allow participants to differentiate real words from nonwords simply by establishing whether the stem is an existing word or not (see Taft, 2004; Taft & Ardasinski, 2006). As such, participants would not need to identify which meaning was appropriate for the affix and that could potentially circumvent any competition between the stems. Therefore, the current study employed nonword targets with real word stems (e.g., *LIZARDING*, *WAKED*, *SANKING*, *FUNNED*), so that participants had to place a greater emphasis on whether the combination of the stem and affix was appropriate. The primes for distractors were all words, half of which were related to their nonword targets (e.g., *waking* as a prime for *WAKED*), so that there was no way to differentiate between words and nonwords based merely on the orthographic relatedness of the prime to the target.

Procedure

Items were presented using DMDX (Forster & Forster, 2003) in size 20 Arial font. The lower-case primes were presented on screen for 200 ms and replaced by the target in upper-case. The target was presented for 1000 ms. Response latencies were measured from the time the target appeared, and an error was recorded if no response was made within 2000 ms. There was an inter-trial interval of 1000 ms, with the order of item presentation randomized for each participant. Participants were instructed to decide as quickly but as accurately as possible whether the uppercase letter string was a real English word or not. Responses were recorded via keyboard, with a 'yes' key for words, and 'no' key for nonwords. A total of 12 practice trials were included, which contained similar items to those used in the main experiment.

Participants

Forty-four students from the University of New South Wales participated in the study in exchange for course credit. All participants were English monolinguals, and were randomly assigned to one of the two subgroups in the Latin-square design.

Results

The data were analyzed using linear mixed effects (LME) modelling in R (Baayen, Davidson, & Bates, 2008), with a focus on the correct response times and error rates for the targets. Subjects and items were entered as crossed random factors, and type of prime as a nested random factor. Before fitting the models, five participants who obtained error rates of over 25% were excluded from the reaction time analyses and, for the rest, response times faster than 200 ms and slower than 2000 ms were excluded (Baayen & Milin, 2010). After further consideration, two of the items from the Orthographic condition were removed as they potentially had a morphological/semantic relationship (i.e., *phonetic-PHONED* and shovel-*SHOVED*). An inverse transformation on reaction times was then applied to reduce the positive skew in the data. The analysis for error rates was conducted using the binomial function, with z scores being generated. Stimulus attributes of both prime and target were also entered into the fixed-effect structure of the LME analysis. These comprised surface frequency (including the relative frequency of the prime and target expressed as a proportion of prime/target frequency), bigram frequency, neighborhood size, word length (in letters), and affix length. A more detailed report of the models examined in the analysis is included in Appendix B. The average untransformed reaction times and error rates can be found in Table 2.

In the analysis of response times, the interaction between Compatible and Orthographic conditions was significant, $|t| = 2.64$, $p < .01$, where the facilitatory priming effect from the Compatible condition (e.g., *slipped-SLIPPING*), $|t| = 2.96$,

Table 2
Mean lexical decision times (in ms) and percentage error rates (reported in parentheses) from each condition in Experiment 1.

Prime	Incompatible	Compatible	Orthographic
Related	966 (14.1)	898 (7.9)	940 (10.7)
Unrelated	963 (13.8)	936 (7.7)	931 (12.2)
Priming (RT's)	−3	+37	−9

$p < .01$, was statistically discernible from the null effect in the Orthographic condition (e.g., *campus – CAMPING*), $|t| = .81$, $p > .05$. The interaction between the Compatible and Incompatible conditions was also significant, $|t| = 2.55$, $p < .05$, where the null effect from the Incompatible condition, $|t| = 1.44$, $p > .05$, was statistically discernible from the priming in the Compatible condition. There was no difference between the Incompatible and Orthographic conditions, $|t| = .91$, $p > .05$. Analyses of error rates produced no significant outcomes, all p's > .05.

Discussion

The results from the Compatible condition were consistent with past research (i.e., Laudanna et al., 1989), suggesting that if the prime activates the unit that corresponds to the target, recognition of that target will be facilitated. The absence of inhibitory priming in the orthographically related condition was consistent with the findings of Forster and Veres (1998), which may be attributed to the fact that inhibitory effects from orthographically related unmasked primes are typically found when the targets are of high surface frequency (Lupker & Colombo, 1994), notably when their primes are of a lower frequency (Segui & Grainger, 1990). Segui and Grainger (1990) argued that when reading the prime, the orthographically related targets that present the strongest competition (i.e., those of high surface frequency) must be inhibited so as not to interfere with the recognition of the prime. A closer examination of the items in this experiment revealed that, in each condition, there was no significant difference between the primes and targets in terms of their log surface frequencies, p's > .05. Therefore, the absence of inhibition due to orthographic similarity could be attributed to the lack of difference between the primes and targets in terms of surface frequency.

Unlike Allen and Badecker (1999), however, no inhibitory priming was found for the Incompatible items. Based on the proposed mechanism of inhibition, it was expected that the presentation of a prime that corresponds to one meaning of a homograph would suppress the activation in the representation of the competing homograph. For example, when trying to recognize the word *sole* that is related to the 'alone' meaning of the homograph, the system would need to inhibit the representation of *sole* that is related to the 'shoe' meaning. The latter would then have to overcome that inhibition before accumulating enough activation to achieve recognition if presented as a target. Thus, an inhibitory priming effect was expected for the incompatible prime-target pairs.

Although inhibitory priming did not emerge from the current experiment, the presence of facilitatory priming in the Compatible condition and its absence in the Incompatible condition, still suggests that the lexical recognition process is sensitive to morpho-semantic relationships. That is, a complex prime will only facilitate the recognition of a target that corresponds to the same root morpheme (i.e., those in the Compatible condition), but not when the morphemes share orthography and not semantics (i.e., the Incompatible condition). For the Compatible prime-target pair, the facilitatory priming can be attributed to the decomposition of the prime, which activates the stem that is also involved in the recognition of the target.

The lack of inhibitory priming in the Incompatible condition seems to suggest that the activation in the stem of the target simply falls to baseline once the system has recognized that it does not match the stem of the prime. That is, the stem of the target does not have to overcome any suppression from the stem of the prime during recognition. If so, the inhibitory priming effects observed in previous studies (e.g., Allen & Badecker, 1999, 2002), might be attributed to their orthographic overlap instead of competition between the homographic stems. That is, competition could arise within an orthographic level that is sublexical, where the system must inhibit competitors that are orthographically similar to the prime so that the right word may achieve recognition. This does not apply to the current study, though, given the lack of inhibitory priming in the Orthographic condition.

An issue that was not considered in the earlier studies, however, is the influence of constituent frequency on complex word processing. The frequency of the stem would be expected to impact on the competition between homographic stems given that genuinely suffixed words are all recognized via their stem. If so, the degree of competition between an incompatible prime and target should be influenced by the relative frequency of their stems, and inhibitory priming might only be observed when competition for the prime is maximized. In the context of the current study, this would be the situation when primes correspond to the subordinate meaning of the homograph and targets to the dominant meaning.

The dominant meaning of a homograph should possess a stronger presence in the lexical processing system and be accessed more readily than its subordinate counterpart. So, when the complex form is related to the subordinate meaning (e.g., *safes* being related to the less common 'vault' meaning of the homograph *safe*), the system must inhibit the dominant meaning (i.e., the 'secure' meaning of *safe*) to the extent that it will not be activated inadvertently and hence confuse the reader as to which meaning of the homograph is appropriate. Therefore, if the prime is subordinate (e.g., *safes*) and the target is dominant (e.g., *SAFER*), the level of residual activation in the stem of the latter will be reduced relative to an unprimed target. On the other hand, if the prime is dominant (e.g., *safer*) and the target subordinate (e.g., *SAFES*), the system would not need to have inhibited the stem of the target to any great extent as the highly accessible prime can be recognized with little competition from the other version of the stem. In other words, inhibitory priming is more likely to emerge if the incompatible targets correspond to the dominant meaning, but not when associated with the subordinate meaning.

Perhaps the inhibitory priming effects found in the previous studies in Spanish (e.g., Allen & Badecker, 1999, 2002) and Italian (Laudanna et al., 1989) arose because the targets happened to be more often the dominant than the subordinate meaning of the homographic stem. Such a factor was not considered in those studies.

To determine whether the relative dominance of the prime-target pairs might have had an impact in Experiment 1 here, a further group of 34 native English speakers were asked to generate sentences using the stems of the Incompatible items (e.g., "Use *sole* in a sentence"). Dominance was then established from the responses generated by determining whether the prime or target meaning was more often given, and it was found that as many as 15 of the 22 items had dominant primes and subordinate targets (74% versus 21% of responses on average[3]). In other words, the majority of primes were associated with the dominant meaning of the homograph, which is not the ideal context for inhibitory priming. Therefore, the influence of relative frequency will be directly examined in the following experiment, where the items comprise primes that are all linked to the subordinate meaning and targets to the dominant meaning. In such a context, where the system needs to inhibit the representation of the target in order to recognize the prime, inhibitory priming is expected to emerge.

Experiment 2

If the individual stems of a homograph inhibit one another during recognition, then an inhibitory priming effect is most likely to arise in Incompatible prime-target pairs with dominant targets and subordinate primes in an unmasked lexical decision task. This was tested in Experiment 3. Compatible primes and targets were also included, with both corresponding to the same dominant meaning. As in Experiment 1, a facilitatory priming effect was expected for such items, given that the target should activate the same stem as the prime. Finally, the possibility of purely orthographic effects was again established by the use of orthographically related prime-target pairs.

It should be noted that a recent study by Tsang and Chen (2013), using unmasked priming with Mandarin Chinese compound words, failed to find inhibitory priming with subordinate primes and dominant targets. For example, responses to the target 利益, 'interest', were not inhibited by the prime 利刃, 'razor', where the meaning of the homograph 利 is more often used in the sense of 'interest' than in the sense of 'razor'. However, although no inhibitory priming was found under these putatively optimal conditions for its emergence, such an outcome could be attributed to the short prime duration used. The primes in the Tsang and Chen (2013) study were presented for only 100 ms, as opposed to the 250 ms of the Allen and Badecker (1999) study and the 200 ms of Experiment 1 here. That is, there might not have been enough time for the prime to have inhibited the target. Therefore, the impact of relative salience on inter-homograph competition is worth exploring further in English, using a prime duration longer than that adopted by Tsang and Chen (2013).

Method

Materials

A pre-test was conducted with 30 participants to determine the relative dominance of definitions attached to a list of 60 homographs following the same procedure as that used for the post-hoc analysis of Experiment 1. For a meaning to be considered subordinate, the bias toward that meaning had to be lower than 40% of the responses given. Twenty Incompatible targets were then generated by inflecting the homographic stem in a way that corresponded only to the dominant meaning (mean bias = 71.0%, s.d. = .15). Each target was paired with a prime that was a complex form associated only with the subordinate meaning of the same homograph (mean bias = 15.8%, s.d. = .11). For example, in the pair *fined-FINEST*, the prime is associated with the subordinate 'penalty' meaning while the target is associated with the dominant 'good quality' meaning.

Another 20 inflected words were chosen for the Compatible condition where both the target and their related prime corresponded to the same dominant meaning. For example, both the prime *punched* and its related target *PUNCHING* correspond to the 'hit' meaning, which dominates over the 'beverage' meaning. The average proportion of responses biased toward the targets in the Compatible condition was 70.6% (s.d. = .11), which was statistically the same as for the Incompatible condition, $p > .05$.

The Orthographic prime-target pairs were mostly taken from Experiment 1, but were slightly modified in order to correspond with the frequencies and orthographic similarity of the other two conditions, all p's > .05. As with the previous experiment, the frequency of the primes did not differ significantly from their targets, p's > .05. The surface frequencies of the targets and their primes, as well as their orthographic overlap are reported in Table 3.

Each target was also paired with an unrelated prime selected in the same way as in Experiment 1. All of the items used in Experiment 2 can be found in Appendix A. The nonword distractors in Experiment 2 were the same 66 items that was used in the previous experiment.

Procedure

The procedure was identical to that used in Experiment 1.

Table 3
The mean surface frequencies (occurrences per million) of the targets and primes from each condition in Experiment 2, along with their degree of orthographic similarity. Standard deviations are reported in parentheses.

	Compatible	Incompatible	Orthographic
Prime SF	10.6 (13.0)	9.2 (9.3)	8.3 (8.2)
Target SF	16.7 (26.3)	21.1 (30.1)	13.2 (31.1)
Orth similarity	.7 (.1)	.7 (.2)	.7 (.1)

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[3] The proportion of responses toward the meaning of the prime and target do not sum to 100% because participants sometimes provided responses that did not correspond to either meaning.

Table 4
Mean lexical decision times (in ms) and percentage error rates (in parentheses) from each condition in Experiment 2.

Prime	Incompatible	Compatible	Orthographic
Related	970 (12.1)	826 (5.4)	951 (11.6)
Unrelated	934 (11.1)	880 (6.6)	952 (8.3)
Priming (RT's)	−36	+54	+8

Participants

A new set of 40 undergraduate students from the University of New South Wales participated in the experiment in exchange for course credit. All were English monolinguals and were randomly assigned to the subgroups within the Latin-square design.

Results

The data analysis followed the same procedures as in the previous experiments. The average untransformed reaction times and error rates can be found in Table 4. In the RT analysis, the interaction between the Compatible and Incompatible conditions in terms of the priming effect was significant, $|t| = 2.83$, $p < .01$, arising from the fact that the Compatible items showed a facilitatory effect, $|t| = 2.56$, $p < .05$, while the Incompatible items showed an inhibitory effect, $|t| = 2.74$, $p < .01$. The null priming effect in the Orthographic condition, $|t| = 0.45$, $p > .05$, was statistically discernible from the facilitatory priming in the Compatible condition, $|t| = 1.99$, $p < .05$, as well as the inhibitory priming from the Incompatible condition, $|t| = 2.15$, $p < .05$. In the analysis of error rates, there were no significant outcomes, *p*'s > .05.

Discussion

The facilitatory priming from the Compatible condition was as expected, as both the prime and target correspond to the same stem. Importantly, an inhibitory priming effect was found this time in the Incompatible condition indicating that the pre-activation of a competing meaning does interfere with the recognition of a dominant target (e.g., *fined-FINEST*). Here, the highly accessible stem of the target must be inhibited when the prime is presented for recognition because, otherwise, it would compete too strongly with the stem for the subordinate prime. It would be difficult to attribute the inhibitory priming effect from the Incompatible condition to the orthographic similarity between the prime-target pairs, given that the items in the Orthographic condition produced no inhibitory priming despite a comparable degree of orthographic similarity. As explained in the discussion of Experiment 1, the absence of inhibitory priming in the Orthographic condition may be attributed to the fact that the frequency of the primes were not statistically lower compared to their targets. For the same reason, orthographic similarity cannot account for the inhibitory priming between Incompatible prime target pairs.

The failure of Tsang and Chen (2013) to observe comparable inhibitory priming from Incompatible prime-target pairs with dominant targets could potentially be explained in terms of the shorter prime duration they used. That is, 100 ms may not have given participants enough time to fully process the prime, unlike the 200 ms used in the current study. Alternatively, there might be something special about the processing of Chinese compounds compared to English affixed words, even if it is not possible to identify exactly what this might be.

The impact of relative dominance on the presence of inhibitory priming between competing prime-target pairs also addresses the question as to why inhibitory priming was found in the studies of Allen and Badecker (1999, 2002) where relative salience was not considered. It was pointed out earlier that the competing primes used in those studies actually possessed a greater degree of orthographic similarity with their targets than the items that putatively controlled for orthographic similarity. Therefore, the inhibitory priming between competing prime-target pairs, which was stronger than that found in the orthographically related condition, could potentially be traced back to the form level. However, given that Experiment 2 here suggests that the emergence of inhibitory priming is determined by the relative frequency between the competing homographs, a more likely explanation for the results of Allen and Badecker (1999, 2002) is that the majority of their prime-target pairs happened to possess subordinate primes and dominant targets. This cannot be established without collecting data of the sort used to determine dominance in the present study.

Experiment 3

If the relative dominance of the prime-target pairs in Experiment 2 were to be reversed, that is, if the prime were dominant (e.g., *finest*) and its competing target subordinate (e.g., *FINED*), the stem of the prime would be readily activated. In this case, it is unnecessary for the system to suppress the activation in the competing stem in order to avoid confusion with the prime. The competing target will still be activated following the morpho-orthographic decomposition of the prime, but then should recede to baseline once it is deemed to be semantically unrelated to the prime. Thus, the level of activation remaining in the target's stem should be no different to the level that exists when it is unprimed, which means that Incompatible prime-target pairs with dominant primes and subordinate targets should produce no priming at all.

So, the aim of Experiment 3 was to determine whether or not inhibitory priming would emerge from competing prime-target pairs with dominant primes and subordinate targets. While, no priming was expected from competing prime-target pairs, based on the results from Experiments 1 and 2, there should still be facilitatory priming when the prime has the same (subordinate) meaning as the target. An orthographically related condition was not included in this experiment as it was clear by now that no priming would be found with such items.

Method

Materials

Primes and targets were assigned to their respective conditions based on their average ratings from the pre-test

Table 5
The mean surface frequencies (occurrences per million) of the targets and primes from each condition in Experiment 3, along with their degree of orthographic similarity. Standard deviations are reported in parentheses.

	Compatible	Incompatible
Prime SF	10.6 (13.0)	10.2 (9.5)
Target SF	16.7 (26.3)	22.1 (30.9)
Orth similarity	.6 (.2)	.6 (.2)

Table 6
Mean lexical decision times (in ms) and percentage error rates (in parentheses) from each condition in Experiment 3.

Prime	Incompatible	Compatible
Related	870 (16.8)	829 (13.1)
Unrelated	879 (17.0)	877 (14.1)
Priming (RT's)	+9	+48

described in the previous experiment. The targets in the Incompatible condition were composed of 22 inflected words, all of which corresponded to the subordinate version of the homograph (mean bias = 17.5%, s.d. = .10). Each target was paired with a prime that was a complex form associated with the dominant meaning of the same homograph (mean bias = 73.3%, s.d. = .12). For example, in the pair *longer-LONGING*, the prime is linked to the dominant 'length' meaning and the target to the subordinate 'yearning' meaning.

Twenty-two inflected words were also chosen as targets in the Compatible condition where both the target and their related prime corresponded to the same subordinate meaning. For example, both the prime *darted* and the target *DARTING* correspond to the 'move quickly' meaning, which is subordinate to the 'projectile' meaning. The average proportion of responses from the meaning-generation task that were biased toward the targets in the Compatible condition was 20.0% (s.d. = .15). The average surface frequency of the primes and targets are reported in Table 5, along with their degree of orthographic overlap. None of these measures differed from the Incompatible condition, all *p*'s > .05. As with the previous experiments, the surface frequency of the primes did not differ significantly from their corresponding targets, *p*'s > .05.

The unrelated primes had the same characteristics as those in the other experiments. A list of the items can be found in Appendix A. To correspond with the number of prime-target pairs in this experiment, 44 nonwords and their corresponding primes were chosen from the 66 used in the previous studies, with half being morphologically related (e.g., *waking* – WAKED). Items were assigned to subgroups in the same manner as before.

Participants

A total of 50 undergraduate students from the University of New South Wales participated in the experiment in exchange for course credit. All were English monolinguals and were randomly assigned into subgroups within the Latin-square design.

Procedure

The procedure was identical to that used in Experiments 1 and 2.

Results

The data analysis followed the same procedure as in the previous experiments. Seven participants obtained error rates of over 25% and were not included in the reaction time analyses. The average untransformed reaction times and error rates can be found in Table 6. There was a significant interaction between the Compatible and Incompatible conditions, $|t| = 2.42$, $p < .05$, where the facilitatory priming in the Compatible condition, $|t| = 2.77$, $p < .01$, was discernible from the null effect in the Incompatible condition, $|t| = 0.285$, $p > .05$. The analyses of error rates yielded no significant results, *p*'s > .05.

Discussion

Inhibitory priming did not emerge from the Incompatible condition. This outcome can be attributed to the notion that the extent to which the target is inhibited depends on the relative salience of the prime-target pair. In this case, the dominant prime is easily recognized with little interference from the competing subordinate target and, although the stem for the prime might still inhibit the stem of the target, the extent of this suppression is not strong enough to produce an inhibitory effect.

General discussion

The purpose of the current study was to gather evidence for competition between morphemes during the recognition of words with homographic stems. The first experiment failed to find inhibitory priming between homographs under unmasked conditions, unlike past research (e.g., Allen & Badecker, 1999, 2002; Laudanna et al., 1989). However, the results of Experiment 2 indicated that such inhibitory priming can emerge in a context where the inhibition of the target is maximized, namely, when the prime corresponds to the subordinate meaning of a homograph and the target to the dominant meaning. Because representations of dominant meanings have a high level of baseline activation, it is more readily activated and likely to be confused with the subordinate meaning. Therefore, to ensure that the correct meaning is accessed upon the presentation of the subordinate prime, the dominant meaning must be suppressed to a level that is lower than its baseline. In contrast, when the relative salience of the prime-target pair is reversed (i.e., with dominant primes and subordinate targets, as in Experiment 3), the subordinate target does not have a strong enough presence in the system to be confused with the prime. Consequently, the system has no need to inhibit the stem of the target, which would account for the absence of inhibitory priming in that situation. Therefore, it appears that lexical entities do compete with one another, but the effects of this will only be evident in a priming context where the inhibition from the prime to its target is maximized. On the other hand, an inhibitory mechanism does not exist between a compatible

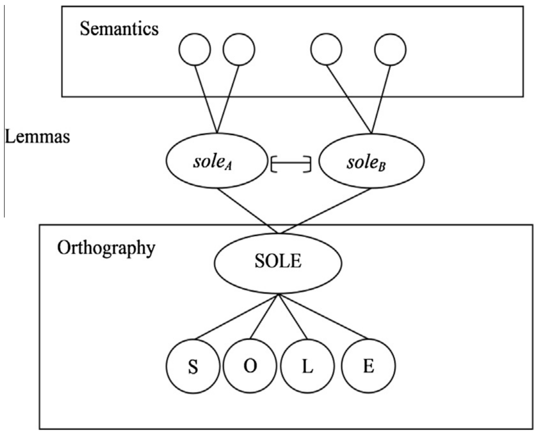

Fig. 1. A two stage lexical processing framework from Taft and Nguyen-Hoan (2010). The *sole*$_A$ lemma is related to the 'shoe' meaning of sole, and the *sole*$_B$ lemma corresponds to the 'alone' meaning. The two lemmas are connected by an inhibitory link.

prime-target pair because they are recognized through the same stem representation.

How then, can the current results be explained in terms of existing models of morphological processing? One possible account is the lemma-based framework depicted in Fig. 1 (see, Taft, 2004; Taft & Ardasinski, 2006; Taft & Kougious, 2004; Taft & Nguyen-Hoan, 2010). In this model, morpho-orthographic processing takes place at a form level (labeled "Orthography" in the figure), while morpho-semantic processing resides at a level that mediates between form and semantics, namely, a lemma level (see also Schreuder & Baayen, 1995). A lemma unit is abstract in the sense that it is not restricted to a single modality of language (i.e., orthography or phonology), with its role being to capture the correlation between form and function (both semantic and syntactic). Hence, any unit that is associated with a consistent function will possess its own lemma, including monomorphemic words (e.g., *hunt*, *corn*, *corner*) and affixes (e.g., -*er*, *ly*). Polymorphemic words (e.g., *hunter*, *solely*, *soles*) are recognized after their stem and affix are recombined either via access to another lemma representing the whole word or via functional information associated with the stem and affix (see e.g., Taft, 2004).

In order to maximize the correlation between form and meaning, homographic words (e.g., *sole*, *fine*) have separate lemma units for each definition. Taft and Nguyen-Hoan (2010) present explicit support for such a conceptualization by showing that the meaning ascribed to a homograph can be biased by the masked presentation of a derived word related only to that meaning (e.g., the masked prime *sticky* biases the interpretation of *stick* toward its 'adhere' meaning). Since no such bias was found when the masked prime was semantically but not morphologically related (e.g., *glue* not biasing the meaning given to *stick*), it was concluded that the effect did not arise at the semantic level, but rather at a level where morphologically relationships are represented. It was further argued that the locus of the effect could not have been at the form level either since, by definition, the two versions of a homograph are activated through the same form representation. Instead, it is the lemma level that provides separate and competing representations for the two meanings of a homograph while capturing the morphemic relationship between an affixed word (e.g., *sticky*, *solely*) and the relevant meaning of its stem.

During the initial stages of complex word recognition, then, the letter string is broken down into constituents via morpho-orthographic decomposition and the lemmas corresponding to these constituents are activated. For example, *corner* will activate the lemmas for *corn* and -*er*, while *solely* will be decomposed into *sole* and -*ly*, the stem of which will activate the *sole*$_\mathrm{A}$ lemma corresponding to the 'shoe' meaning as well as the *sole*$_\mathrm{B}$ lemma corresponding to the 'alone' meaning. The pre-activation of the orthographic unit SOLE by the prime may provide an advantage during the recognition of the target (i.e., produce facilitatory priming), but this would be offset by the inhibition at the lemma level. That is, once morpho-semantic processing comes into play, the system identifies that the *sole*$_\mathrm{A}$ lemma is appropriate as it is the only one that can be attached to the affix -*ly*. The *sole*$_\mathrm{B}$ lemma is then inhibited. When the relative dominance of the prime-target pair does not maximize the inhibition on the lemma of the target this will lead to the absence of an inhibitory priming effect (i.e., Experiments 1 and 3), but when the inhibition on the target is maximized (i.e., Experiment 2), inhibitory priming will emerge as the suppression of the target's lemma outweighs the facilitatory effects from the pre-activation of the orthographic stem. The compatible prime-target pairs show facilitatory priming, as they are recognized via the same stem representation (i.e., the same lemma).

An alternative possibility to a morpho-orthographic decomposition account of this sort is that the constituent morphemes are only activated after the whole-word representation has been accessed. This is the supralexical-decomposition framework proposed by Giraudo and Grainger (2000, 2001). Here, morphemic units mediate between form representations of the whole word and the corresponding semantic information and, therefore, stems will only be activated if they are semantically transparent. The inhibition observed between incompatible prime-target pairs can then be attributed to the competition between homographic stems, just as in the lemma model. Similarly, compatible prime-target pairs show facilitatory priming because the prime pre-activates the same stem through which the target is recognized.

While both the lemma and supralexical models are able to provide a reasonable explanation for the results reported in the present study, the latter runs into difficulty when attempting to explain facilitatory priming for opaque prime-target pairs (i.e., *corner* priming *corn*) under masked conditions (e.g., Longtin et al., 2003; Rastle et al., 2004). In particular, the supralexical model dictates that the activation of the constituent morphemes is dependent on their semantic relatedness to the whole word (i.e., *corner* should not activate the representation of *corn*). As previously pointed out, while it might be the case that priming from opaque words is weaker than from transparent words (cf. Feldman et al., 2012; Taft & Nguyen-Hoan, 2010) the opaque word nevertheless does provide at least some activation to the representation of its apparent stem, a finding that is incompatible with the supralexical account. The supralexical model also runs into problems when considering nonwords. Since morphological information is only extracted once a whole-word representation is accessed, there is no basis for the greater difficulty in classifying nonwords in lexical decision when they are composed of meaningful morphemes (e.g., *relaugh*, *invive*) than when they are not (e.g., Taft, 2004; Taft & Forster, 1975). Such morphological structure could never be established through supralexical decomposition, since a nonword has no lexical representation.

It appears, then, that a model along the lines of Fig. 1 (e.g., Taft & Nguyen-Hoan, 2010) provides a more comprehensive picture of morphological processing. Not only does it incorporate a locus for the inhibitory priming observed between affixed words with incompatible homographic stems (i.e., competing lemmas), but it also handles the pattern of morphological priming observed in the masked priming paradigm. In particular, the facilitatory priming for opaque prime-target pairs is attributed to the pre-activation of the target's stem by the prime via morpho-orthographic decomposition. Because there is not enough time for the lemma of the opaque prime (e.g., *corner*) to fully inhibit the lemma of the pre-activated stem (e.g., *corn*) when masked, facilitatory priming is still found. Within this account, it is not necessarily the case that the facilitation for opaque prime-target pairs be equivalent to the facilitation for transparent pairs, because presentation of the opaque prime under masked conditions can potentially generate at least some inhibition on the lemma of its stem (Taft & Nguyen-Hoan, 2010).

The explanation for inhibitory priming has so far been couched in terms of an inhibitory connection established between localist units representing the competing meanings of a homograph. Alternatively, though, the results could potentially be attributed to inhibitory feedback from the semantic level, consistent with the view of Feldman et al. (2009, 2012) that semantics comes into play at an early stage of morphological processing. According to this account, morphemic representations might be seen as being similar to lemmas in the sense that they are units of both form and meaning. So, as in the model presented in Fig. 1, there should be individual units for each meaning of the homograph. However, in contrast to the lemma model, early morphological processing is sensitive to semantic relationships. Therefore, when presented with the prime *solely*, the competing stem (i.e., the *sole* unit that is related to the 'shoe' meaning) will receive less activation from the input than the stem that corresponds to the prime (i.e., the 'alone' meaning) because the former does not share a morpho-semantic relationship with the prime. To explain inhibitory priming, then, the semantic information linked with the stem associated with the prime will be used to inhibit the other activated stem (i.e., the one related to the target *soles*). In terms of the model presented in Fig. 1, rather than there being a direct inhibitory link between the two lemmas for *sole*, the semantic information linked to the lemma associated with the prime (e.g., *sole*$_A$) would be used to inhibit the other activated lemma (i.e., *sole*$_B$).

A problem facing such an account, however, would seem to be the finding that inhibitory priming is dictated by the relative dominance of the incompatible prime-target pair. Specifically, the dominance of one version of a homographic stem over the other is something that must be captured within their representations (e.g., in terms of their baseline level of activation) rather than in terms of a set of semantic features associated with each. As such, it is difficult to see how the inhibition from the semantic level could be modulated by the relative salience of the prime-target pair. While it could be argued that the salience of a homograph will influence the speed at which the effects of semantically-based inhibition come into play, it would be the dominant or more accessible primes that gain access to these mechanisms before the subordinate primes (i.e., we would expect to see inhibitory priming from dominant primes and subordinate targets). The fact that inhibition was actually maximized when the prime was subordinate and the target dominant is therefore more compatible with the notion that inhibition occurs between the stem representations, where, in order to recognize the subordinate prime without potentially confusing it with the highly salient target, the stem of the target must be suppressed.

In summary, the current study builds upon the existing studies of inhibitory priming between homographic stems with the additional manipulation of relative salience between the prime-target pairs. It was found that inhibitory priming was only found when the inhibition on the representation of the target is maximized (i.e., subordinate primes and dominant targets). Such a pattern of results is argued as favoring an account of lexical processing where separate representations exist for each meaning of a homograph with an inhibitory mechanism between them that allows the relevant meaning to be accessed.

Appendix A

Listed below are items used in each of the experiments.
Experiments 1

Incompatible condition			Compatible condition		
Related prime	Unrelated prime	Target	Related prime	Unrelated prime	Target
bits	grips	biting	bonded	mugged	bonding
countess	waitress	counting	bowler	killer	bowling
cricketer	grinder	crickets	courting	donating	courted
duckling	underling	ducked	darted	hulked	darting

Appendix A (*continued*)

Incompatible condition			Compatible condition		
Related prime	Unrelated prime	Target	Related prime	Unrelated prime	Target
fairness	blackness	fairs	grounded	churned	grounds
faster	walker	fasted	lettered	riddled	lettering
figurine	chlorine	figuring	marching	clutching	marched
fined	gorged	finest	matched	jammed	matching
fitness	stillness	fitted	novelist	chemist	novels
lastly	briskly	lasting	playing	missing	played
leaning	filling	leanest	plotted	mocked	plotting
longer	runner	longing	punched	flossed	punching
mouldy	musky	moulding	rooted	sighed	roots
patience	sentience	patients	rosy	spiny	roses
plains	crypts	plainest	sealant	tolerant	sealing
racial	fractal	racing	shared	trained	sharing
solely	manly	soles	slipped	touched	slipping
stability	agility	stables	spelling	tacking	spelled
tendency	solvency	tending	sticker	floater	sticking
ventral	ethereal	venting	stripped	faulted	stripping
wavy	pulpy	waving	stroked	footed	stroking
wellness	staleness	wells	typist	dentist	typing

Orthographically related		
Related prime	Unrelated prime	Target
bunch	reduce	buns
button	flask	butting
campus	marble	camping
chancellor	funnel	chances
dialog	opaque	dialling
electron	seminar	elected
entertain	forlorn	enters
extract	fossil	extras
forceps	smuggle	forcing
fortune	target	forts
freeze	obvious	freed
harmony	instruct	harmed
phonetic	appendix	phoned
demonstrate	intention	demons
shovel	narrow	shoved
sightsee	distant	sighed
stampede	defect	stamped
terminal	content	terms
textile	mason	texts
turnip	degree	turning
twinkle	advise	twins
villain	extreme	villas

Experiment 2

Incompatible condition			Compatible condition		
Related prime	Unrelated prime	Target	Related prime	Unrelated prime	Target
angler	masker	angles	bonded	mocked	bonding
bitten	darken	bits	duckling	sapling	ducks

(*continued on next page*)

Appendix A (*continued*)

Incompatible condition			Compatible condition		
Related prime	Unrelated prime	Target	Related prime	Unrelated prime	Target
countess	waitress	counting	grounded	moulded	grounds
crickets	ticker	cricketer	hidden	driven	hiding
fasted	blasted	faster	played	creased	playing
fined	greeted	finest	punched	studded	punching
fitness	stillness	fitted	recorded	donated	recording
lasting	basing	lastly	roller	digger	rolling
leaning	bolder	leanest	rooted	accepted	roots
longing	pasting	longer	sensory	advisory	senses
patience	grievance	patients	shared	mellowed	sharing
racial	glacial	racing	slipped	flaked	slipping
rashly	briskly	rashes	spelled	clutched	spelling
safes	faints	safer	stripped	cashed	stripping
seconded	basked	seconds	swallowed	misted	swallowing
shorts	kills	shorter	ticking	sticking	ticked
solely	woolly	soles	trusted	equipped	trusting
stability	agility	stables	typist	dentist	typing
tendency	agency	tending	watched	cropped	watching
ventral	doctoral	vents	wounds	waters	wounded

Orthographically related		
Related prime	Unrelated prime	Target
bunch	rumble	buns
button	extends	butting
campus	refrain	camped
chancellor	target	chances
demonstrate	mention	demons
dialog	mollusc	dials
electron	novel	elected
entertain	classic	entered
extract	mourn	extras
forceps	dedicate	forced
fortune	mistake	forts
freeze	frequent	freed
fuselage	influence	fused
harmony	resolve	harmed
monkey	extend	monks
parenthesis	freeze	parents
phonetic	recognise	phoned
plaintiff	motion	plains
scrape	process	scrapped
shovel	explode	shoved

Experiment 3

Incompatible condition			Compatible condition		
Related prime	Unrelated prime	Target	Related prime	Unrelated prime	Target
bits	boxes	bitten	bowler	kinder	bowling
cricketer	grinder	crickets	courting	donating	courted
duckling	changeling	ducked	darted	hulked	darting

Appendix A (*continued*)

Incompatible condition			Compatible condition		
Related prime	Unrelated prime	Target	Related prime	Unrelated prime	Target
fairness	blackness	fairs	lettered	riddled	lettering
fanciness	smugness	fancied	marching	clutching	marched
figurine	chlorine	figured	matched	watered	matching
finest	largest	fined	mugger	cashier	mugged
jarful	cupful	jarring	patiently	blindly	patience
lastly	briskly	lasting	plotted	flaked	plotting
leanest	mixer	leaning	pooled	creased	pooling
longer	killer	longing	projected	mellowed	projecting
manly	boldly	manned	reared	mocked	rearing
mouldy	dusty	moulding	sealant	acceptant	sealing
plainly	faintly	plains	stalled	clouded	stalling
safer	ticker	safes	statement	equipment	stated
sentential	ethereal	sentencing	sticky	misty	sticking
tinfoil	airship	foiled	stroked	drugged	stroking
wavy	pulpy	waving	tired	walked	tiring
wellness	staleness	wells	tripped	cropped	tripping
windy	stringy	winding	vaulted	masked	vaulting

Appendix B

Analyses were conducted in R, using the lme4 (Bates, Maechler, & Dai, 2008) and languageR packages (Baayen, 2008).

Linear fixed effect models of Reaction Times (RT).

For Experiments 1–3, the statistical models were design to assess the difference between the Relatedness of the prime (related versus unrelated) in a particular interaction or condition. Subjects, items, and the prime were included as random factors.

$$\text{e.g., } \mathrm{InvRT} \sim \mathrm{Related} * \mathrm{INvOint} + (1|\mathrm{subject}) + (1|\mathrm{item}) + (1|\mathrm{prime})\mathrm{InvRT} \sim \mathrm{Related} * \mathrm{INse} + (1|\mathrm{subject}) + (1|\mathrm{item}) + (1|\mathrm{prime})$$

Attributes of the primes and targets were then entered. Including:

ClogSFT – log of the surface frequency of a target,
ClogSFP – log of the surface frequency of the prime,
rfPT – relative frequency of prime/target,
CalT – affix length of target,
CalP – affix length of prime,
CnsizeT – neighborhood size of target,
CnsizeP – neighborhood size of prime,
CbfT – bigram frequency of target,
CbfP – bigram frequency of prime,
ClenT – length of target,
ClenP – length of prime,
CprevRT – the response time on the previous trial.

All variables were centered to the mean with the exception of relative frequency (rfPT).

The relevance of the variables to the final model was determined by whether or not they provided a better fit for the data, and so a model with a certain variable was compared to one without. A model with better fit was indicated by a significant Chi-squared statistic ($p < .05$).

Models that included by-subject and by-item random slopes for Related were also included in the analyses (e.g., (1 + Related|subject) and (1 + Related|item)) – although they did not account for any more variance.

The following variables improved model fit across all 3 experiments:

ClogSFT
ClenT
CprevRT
CalP
CbfT
CnsizeT

The remaining variables were not included in the final model.

The inclusion of prime frequency (ClogSFP) and relative frequency of prime and target rfPT did not change the outcome of the LME.

Linear fixed effect models of Error Rates (ER).

A similar process was used on the error rate data, with the exception of using prevERR (whether a previous error was made) instead of CprevRT, although this did not account for anymore variance.

Nsize of target and magnitude of priming.

Additional analyses were conducted to determine whether target N size interacts with the priming from each of our conditions.

$$\text{e.g., } \mathrm{InvRT} \sim \mathrm{Related} * \mathrm{INvOint} * \mathrm{CnsizeT} \ldots$$

For all 3 experiments, the influence was target N size on facilitation was not statistically discernable in when comparing the 3 conditions (p's > .05).

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