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How are Lexical Decisions to Word Targets Influenced by Unrelated Masked Primes?

Linda Bayliss[1], Colin J. Davis[1], Marc Brysbaert[1], Stephanie Luyten[2], & Kathleen Rastle[1]

[1] Royal Holloway, University of London

[2] University of Leuven, Belgium

Address for correspondence:
Linda Bayliss
Department of Psychology
Royal Holloway, University of London
Egham, TW20 0EX
United Kingdom
e-mail:Linda.Bayliss@rhul.ac.uk

Abstract

This paper reports two lexical decision experiments that investigated whether masked priming effects for word targets varied for different types of unrelated primes. In Experiment 1, the primes were always unrelated to the target, and were either high frequency words, low frequency words, legal nonwords, or consonant strings. Results showed no differences across these prime conditions. The design of Experiment 2 was identical to Experiment 1, except that the low frequency word primes were replaced by identity primes, and consonant strings were replaced by false-font primes. Results showed a typically large identity priming effect, but once again failed to show any difference between unrelated prime conditions. These findings are problematic for models that assume homogeneous lateral inhibition, including the original interactive activation (IA) model and the dual-route cascaded model, but are in agreement with the modified IA model proposed by Davis and Lupker (2006) or the entry-opening model of Forster (1987).

How are Lexical Decisions to Word Targets Influenced by Unrelated Masked Primes?

The masked priming paradigm has been used extensively in research on lexical processes. In this paradigm a briefly-presented prime (usually presented for less than 60 ms) is sandwiched between a forward mask (e.g., #####) and a target word to which participants respond. Though participants report being unaware of the prime, their response latencies indicate that they are nevertheless influenced by its presence. In particular, researchers have presented evidence that lexical decisions to target words are faster when the primes are morphologically related to the targets (e.g., faster in *viewer-VIEW* than in *ranger-VIEW*; Rastle, Davis, & New, 2004), when the primes are orthographically related to the targets (e.g., faster in *colos-COLOSSAL* than in *sapph-COLOSSAL*; Forster, 1998), when the primes are phonologically related to the targets (e.g., faster in *korce-COARSE* than in *roipe-COARSE*; Rastle & Brysbaert, 2006), and when primes and targets are semantically associated (e.g., faster in *scope-VIEW* than in *tight-VIEW*; Lukatela & Turvey, 2000). The priming effect is measured by looking at the speed with which participants respond to the target when it is preceded by a related prime, relative to the speed of response when the target is preceded by an unrelated control prime.

Because the rest of this article is focused on orthographic priming, we will hereafter limit our discussion to this type of overlap. In investigating orthographic priming, we typically compare effects from related primes that share some letters with the target (e.g., *list-LOST*) against effects from control primes that are completely unrelated to the target (e.g., *fame-LOST*) or that share some letters with the target in distant positions (e.g., *tame-LOST*). Researchers have generally been far less interested in the nature of their unrelated control primes than in their related primes, usually ensuring only that there is a clear difference in orthographic overlap between related and unrelated primes. For instance, in some of his pioneering studies of orthographic priming, Forster used nonword primes in the related condition while using word primes in the unrelated condition (e.g., *skun-SKIN* vs. *rear-SKIN*; Forster, 1987).

One of the reasons why researchers have not paid much attention to the characteristics of their unrelated primes may relate to the fact Forster’s entry-opening model (e.g., Forster & Davis, 1984) predicts that the priming effect in the masked priming procedure is due entirely to the orthographic overlap between the prime and the target. In this model, a fast search process flags lexical entries that closely match the prime input; these entries are subsequently opened and the information within them extracted. Because unrelated primes do not overlap with the target, they are not expected to have any impact on the speed with which the lexical entry of the target word is opened.

Possibly as a consequence of the predictions made by the entry-opening model, researchers have assumed that other word recognition models would predict null-effects of unrelated primes as well. However, this assumption is not quite true. It turns out that the nature of an unrelated prime may well matter in many of the models based on the interactive-activation (IA) framework (e.g., Grainger & Jacobs, 1996; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) specifically because (a) unrelated primes can inhibit the recognition of targets in these models and (b) the extent of this inhibition may depend on the nature of the unrelated prime. Simulations demonstrating these characteristics of particular IA models were conducted by Davis (2003) and by Davis and Lupker (2006) in their attempts to simulate the inhibitory masked neighbor priming (IMaNeP) effect. The IMaNeP effect is the finding that low-frequency target words such as *AXLE* are more difficult to recognize when preceded by high-frequency orthographically-related primes like *able* than by unrelated controls of the same frequency like *door* (Segui & Grainger, 1990; De Moor & Brysbaert, 2000; Grainger & Ferrand, 1994; Davis & Lupker, 2006).

To see whether the IMaNeP-effect could be simulated by IA-models, Davis (2003) and Davis and Lupker (2006) worked as follows. On each trial, all feature, letter, and word nodes were initially reset to resting levels of activation. The prime stimulus was then presented by setting the appropriate binary codes at the feature level, and the model was allowed to run for 50 cycles of processing. At that point, the target stimulus was presented in the same manner as the prime (i.e., by setting binary codes at the feature level). The model was then allowed to continue processing until one of the word nodes (ordinarily the node corresponding to the target) exceeded a local activity threshold (of .65); the number of cycles to reach this threshold provided a measure of lexical decision times for word targets.

The first model Davis (2003) implemented was the original IA model of McClelland and Rumelhart (1981). He observed that this model predicted a strong inhibitory effect of unrelated primes relative to unprimed targets. This aspect of the model was further explored by Davis and Lupker (2006), who noted that the inhibitory effect of the unrelated primes in the model has two distinct loci. The first of these is the letter level, which sends inhibitory signals to incompatible word nodes. In the original model, it takes some time for the target to overwrite the prime at the letter-level, in part due to top-down feedback from active word nodes. This inertia at the letter-level implies that the target word node continues to be inhibited by the (still active) letters of the prime for some time following the onset of the target. Davis and Lupker (2006) observed that this feature of the original model decreased the fit to empirical human data, because the inhibition effects were underpredicted and the facilitation effects were overpredicted. As a result the model predicted, for example, that the unrelated prime *wind* inhibited the target *VERY* more than the related prime *verb*.

In order to achieve a better fit to the empirical data, Davis and Lupker (2006) proposed a modified version of the IA model in which the onset of the target leads to a reset of the letter-level activities, effectively eliminating the letter-level inertia discussed above. They suggested that this reset assumption was consistent with the original spirit of McClelland and Rumelhart's (1981) model, and considered some independent justifications for letter reset.

The second locus of the inhibitory effect of unrelated primes in the original IA model was at the word level. In the model, the lateral inhibitory signal to each word node is simply the total word-level activity minus the activity of the recipient word node. Thus, if the *MAIN* word node is active, it will add to the total word-level activity, and will thereby inhibit all other word nodes, including unrelated word nodes like *VERB*. In this respect, lateral inhibition is homogeneous. As a consequence, identification of the target *VERB* is slower following the unrelated prime *main* compared to when the same target is unprimed. Davis and Lupker (2006) observed that this inhibitory impact of unrelated primes also contributed to an underestimation of the IMaNeP effect from related primes, so that the fit of the model to human data was still suboptimal even when it was assumed that the target reset the letter level.

In order to eliminate this word-level locus of the unrelated prime inhibition effect, and thereby achieve a better fit to their empirical data, Davis and Lupker (2006) proposed a third version of the IA model which involved a change in the nature of lateral inhibition at the word-level. In this modified model, lateral inhibition was nonhomogeneous and selective: Only word nodes that coded orthographically overlapping words sent inhibitory signals to each other. Similar assumptions are made in other competitive network models of recognition, including the masking field model of Cohen and Grossberg (1987) and the TRACE model of speech perception (McClelland & Elman, 1986). The introduction of selective inhibition greatly reduced the word-level inhibitory component of unrelated word primes; for example, priming the target *VERB* with the unrelated word *main* produced negligible word-level inhibition of the target.

Overall, the simulations by Davis (2003) and Davis and Lupker (2006) show that within the IA-framework not all unrelated primes are the same. More specifically, depending on how the particular model has been implemented, a larger inhibition effect might be expected for unrelated word primes than for unrelated nonword primes and, possibly, a larger inhibition effect for unrelated high-frequency words than for unrelated low-frequency words. The former prediction is due to the fact that the activation level of word representations rises more rapidly when the input is a word stimulus (which fully activates the corresponding word representation in addition to the partial activation of the word representations that have a large orthographic overlap with input stimulus) than when the input is a nonword stimulus (which only partially activates those word representations with a large orthographic overlap). The difference between high and low frequency words is related to the question whether the higher activation level of high frequency word representations also results in more inhibition of incompatible representations.

However, the behavior of IA models is complex, involving the integration over time of a large number of interacting non-linear differential equations, and thus it is difficult to predict how a particular model will respond to different types of unrelated primes without actually testing it. Therefore, we decided to simulate the masked priming effect due to unrelated primes in the models we had at our disposal. These are the DRC model (Coltheart et al., 2001) and the different variants of the IA-model implemented by Davis and Lupker (2006).

We first examined the DRC model. Thirty-four target words were entered into the model, preceded by four types of primes. The target words were the monosyllabic target words used by Davis and Lupker (2006, Experiment 1) in their research on the inhibition effect of orthographic neighbors (DRC only works for monosyllabic words). Four types of unrelated primes were used: (1) a high frequency unrelated word (e.g., *give-BLUR*), (2) a low frequency unrelated word (*dive-BLUR*), (3) a legal nonword (*mive-BLUR*), and (4) a consonant string that did not have any orthographic word neighbor in DRC (*kgxm-BLUR*; an orthographic neighbor is a word that can be formed by changing one letter; e.g. *mite* is an orthographic neighbor of the nonword *mive*).

In accord with previous DRC simulations of masked priming effects, the primes were presented for 24 cycles [1], after which the target was presented with no reset of activations caused by the prime. We measured the number of cycles needed for the activity of the orthographic representation of the target node to reach the recognition threshold of .69. Table 1 shows the results of the simulations. There was a significant effect of prime type ($F(3,99) = 6.86$, $p < .001$, $\eta^2 = .172$), reflecting the difference between word and nonword primes: The model needed 4 or 5 additional cycles before the activation of the target node exceeded the recognition threshold when it was preceded by an unrelated word prime compared to when it was preceded by an unrelated nonword prime. There was little difference as a function of the frequency of the word primes or the nature of the nonword primes (legal or illegal letter strings).

To examine the various IA models of Davis (2003) and Davis and Lupker (2006), we ran a simulation of all the four-letter stimuli used by Davis and Lupker (2006, Experiment 1), preceded by the four types of unrelated primes explained above. This time we could use all the relevant stimuli, because these models are not restricted to monosyllabic words. This also allowed us to retain the difference between high and low frequency target words Davis and Lupker had in their design. We tested the four versions of the IA model outlined in Davis and Lupker (2006): (1) the original model, (2) a version in which the activation of the letter nodes was reset by the target, (3) a version in which competition was limited to word forms with orthographic overlap, and (4) a version that included selective inhibition and the letter node reset assumption. We also used the same procedure as Davis and Lupker (2006) to examine the models' predictions. The mean decision latencies for these four conditions are shown in Table 2.

The original IA model resulted in (1) a strong effect of prime vs. no prime, (2) a strong effect of target word frequency, and (3) a small but reliable effect of type of unrelated prime ($F(3,159) = 136.04$, $p < .001$, $\eta^2 = .720$) that did not interact significantly with target word frequency. There is an effect of word status of the prime (slower latencies after word primes than after nonword primes), word frequency of the prime (slower latencies after high frequency primes than after low frequency primes) and orthographic legality of the prime (slower latencies after legal nonwords with orthographic neighbors than after illegal nonwords with no neighbors). The absolute magnitude of these effects is, however, considerably smaller (5 cycles between the extremes) than the effect due to prime vs. no prime (more than 20 cycles) and high vs. low frequency target words (some 15 cycles). Very much the same pattern is observed in the IA version in which the activation of the letter nodes is reset by the target. The main difference is a much smaller time cost of a prime vs. no-prime.

As expected, the introduction of selective inhibition takes away all differences between the unrelated primes, as there no longer is competition between the representations of primes and targets that have no orthographic overlap. The resetting of the letter nodes by the target only results in the flattening of the time cost when the target word is preceded by a prime relative to when it is not.

Overall, a rather consistent picture emerges from the simulations. Both DRC and the original IA model predict a – rather small – effect due to the status of the unrelated prime. Both predict more inhibition from an unrelated word prime than from an unrelated nonword prime. In addition, the original IA model predicts a small effect of the frequency of the prime word and whether or not the prime nonword has orthographic neighbors. In contrast, the changes Davis and Lupker (2006) had to introduce in order to be able to simulate the data about orthographically related versus unrelated primes in humans result in a model that no longer predicts an effect of the lexical status of an unrelated prime, in line with Forster's original claim (see above).

Given the simulation data of the different models, it is worthwhile to see what pattern of results is obtained with human participants. The only relevant study we could find was Perea, Fernández and Rosa (1998). These authors published a study in Spanish reporting no difference between unrelated high frequency word, low frequency word and nonword primes. Unfortunately, very little information is given about the prime characteristics in addition to the word frequencies. Nor were the prime-target combinations tested in computer models to see whether any difference between the conditions was expected. This makes it difficult to draw firm conclusions from the reported null-effect, as seems to be acknowledged by the lead author of the study: “little, if anything, is known about what aspects of a prime might affect the latency of an unrelated target, particularly, in a masked priming situation” (Perea & Lupker, 2003, p. 833). Therefore, we decided to re-address the issue, also because the results would allow us to verify whether Davis and Lupker (2006) were right in their changes of the original IA-model in order to be able to simulate the IMaNeP=effect.

Experiment 1

Experiment 1 was designed to investigate whether the frequency, lexicality, and legality of primes have any effect on lexical decision latencies to orthographically unrelated word targets.

Method

Participants. Forty-five participants volunteered for this experiment, most of whom were undergraduate psychology students from Royal Holloway University of London participating in exchange for course credits. Participants all had normal or corrected-to-normal vision, were native English speakers, and were free from any known reading impairments.

Design. There were three factors in this experiment: target type (two levels: high frequency and low frequency), prime type (four levels: high frequency word, low frequency word, legal nonword, and consonant string), and version (four levels). All of these factors except version were varied within participants. Participants were randomly allocated to different counterbalanced versions based on the order in which they arrived at the lab. The dependent variables were reaction time (RT) and error rate.

Stimuli. The target words in this experiment were identical to those used by Davis and Lupker (2006, Experiment 1). This set consisted of 64 pairs of words that differed from one another by a single letter (e.g., AXLE-ABLE). Half of these pairs were four letter words and the other half were five letter words. Each pair consisted of a high frequency word (mean frequency = 365.5) and a low frequency word (mean frequency = 5.4; Kucera & Francis, 1967). The mean neighborhood sizes (N) of the high frequency and low frequency words in each pair were 2.2 and 2.4, respectively (Davis, 2005). The 64 pairs of words used by Davis and Lupker (2006) were presented separately in our experiment as 128 individual target words.

In addition to these 128 target words, a set of 128 nonword targets was also selected. Some of these were taken from the target nonwords used by Davis and Lupker (2006); the remainder were created with the help of WordGen (Duyck , Desmet, Verbeke, & Brysbaert, 2004) and the ARC nonword database (Rastle, Harrington, & Coltheart, 2002). Half of these were four letter nonwords and the other half were five letter nonwords. The mean N value of the nonword targets was 3.1.

Four sets of 256 primes were selected using WordGen so that each word and nonword target (e.g. DRUG) had four unrelated primes: a high frequency word (e.g., *milk*), a low frequency word (e.g., *mink*), a legal nonword (e.g., *misk*) and consonant string (e.g., *zbpz*). The average CELEX frequencies of the high-frequency and low-frequency word primes were 288.1 and 6.0 per million, respectively (Baayen, Piepenbrock, & van Rijn, 1993). The mean N values for high frequency word primes, low frequency word primes and legal nonword primes were 7.0, 7.2 and 6.4, respectively. See Appendix A for a full list of the stimuli.

The target words were divided into two equal lists (A and B), each containing one member of Davis and Lupker’s (2006) original pairings and an equal number of high frequency and low frequency words. This division was done to ensure that orthographically-similar targets (e.g., *ABLE-AXLE*) were never presented one after another as this could, in itself, produce a priming effect. Half of the nonword targets were assigned to List A and the other half were assigned to List B, so that each list of targets contained 64 target words and 64 target nonwords. List A and List B were presented in separate experimental blocks to all participants, and the order of these blocks was counterbalanced so that half the participants received List A first and the other half received List B first.

Four versions of the experiment were created. Each version contained all of the target words but these targets were paired with different prime types across each version, such that each participant responded to each target but did so only once.

Procedure. Participants were seated approximately 60 cm from the computer monitor and were told that they would be presented with a series of letter strings. They were instructed to press the right response button if the stimulus was a word and the left response button if it was a nonword. Participants were asked to make this decision as quickly as they could without making too many errors.

Each trial began with a 514 ms presentation of a forward mask consisting of seven hash marks (#######) in the centre of the screen. The mask was immediately followed by the prime in lowercase letters which was displayed for 57 ms. Following this the target was presented in uppercase letters and remained on the screen until the response. Following a response there was an inter-trial interval of 1028 ms before the next stimulus was presented. Stimulus presentation and data recording were controlled by DMDX software (Foster & Forster, 2003) running on a Pentium III PC with a 19 inch CRT flat-screen monitor. All stimuli appeared in the same position on the screen and were presented in black Courier New font against a white background. Reaction times were measured from target onset until the participant's response.

Each participant completed a practice block consisting of four trials followed by two experimental blocks (one for List A, the other for List B) consisting of 128 items each. The stimuli were randomized in these blocks so that each participant received a different random order of the stimuli.

Results

Incorrect responses (4.7% of the data) were excluded from the latency analysis. The data from two outlying participants were excluded from the analysis because their mean error rates were over 30%. Further, the data from eight items producing more than 30% errors were removed (*alto*, *aria*, *awry*, *duly*, *farce*, *nigh*, *rotor* and *wren*), as were 24 outlying data points of over 2000 ms.

Target word data were analyzed using analyses of variance (ANOVAs) carried out both by subjects (F_1) and by items (F_2), with target frequency, prime type, and version as variables. In the analysis by subjects, target frequency and prime type were treated as repeated factors and version was treated as an unrepeated factor. In the analysis by items, prime type was treated as a repeated factor, whereas target frequency and version were treated as unrepeated factors.

Mean RTs and error rates from the subjects analysis are shown in Table 3. Latency data from the analysis of target words yielded a significant main effect of target frequency [$F_1(1, 39) = 91.56$, $MSE = 5{,}323.28$, $p < .0005$; $F_2(1, 112) = 40.71$, $MSE = 17{,}325.05$, $p < .0005$; minF'(1, 149) = 28.18, $p < .0005$], with RTs being 77 ms (95%CI = ± 23) faster in response to high frequency targets compared with low frequency targets (604 ms vs. 679 ms).

The main effect of prime type was significant in the subject analysis but not in the items analysis [$F_1(3, 117) = 2.75$, *MSE* = 1,419.86, $p = .046$; $F_2(3, 336) = 2.08$, *MSE* = 3,523.85, $p = .103$, *ns*; minF'(3, 392) = 1.18, $p = .316$, *ns*]. This pattern of results was further backed up by a mixed-models analysis of target word latencies (Brysbaert, 2007), which showed a robust effect of target frequency [$F(1, 4836) = 224.12$, $p < .0005$] but no effect of prime type [$F(3, 4792) = 1.68$, $p = .170$, *ns*]. This model only included the intercepts of the participants and stimuli as random variables. A full model including the interaction terms with these random variables was also carried out but this did not explain any more variance despite the increased number of parameters (see Brysbaert, 2007, for more details about these two types of models).

Error data from the analysis of target words revealed a main effect of target frequency [$F_1(1, 39) = 27.62$, *MSE* = 0.008, $p < .0005$; $F_2(1, 112) = 18.35$, *MSE* = 0.017, $p < .0005$; minF' (1, 137) = 11.02, $p = .001$] with error rates being 5.25% (95%*CI* = ± 2.8%) higher for low frequency targets compared with high frequency targets. No other effects were significant.

Discussion

A comparison of the data of Experiment 1 with those of the various simulations indicates that the human data are not in line with what is predicted by the DRC-model or what is predicted by the original IA-model. There was no evidence whatsoever that unrelated nonword primes induced slower lexical decision times for target words than unrelated high-frequency primes. Indeed, there was a tendency in the *opposite* direction, with longer RTs and more errors after the consonant strings than after the word primes (Table 3).

Because there were no reliable differences between any of the prime conditions, we were also confronted with the possibility that maybe the participants did not pay attention to the primes (e.g., because all stimuli were unrelated and, hence, unhelpful for target recognition) or – in the worst of all worlds – that stimulus presentation was somehow deficient (notice that same is true for the Perea et al., 1998, study).

Therefore, before we discuss the implications of the present study, we decided it desirable first to collect more data and to include a condition that would allow us to verify that the primes indeed were perceived and had the expected impact on target processing. Also we decided that we needed to give the participants more motivation to attend to the primes. Bodner and Masson (2001) found that the repetition priming effect in masked priming was greater when repetition primes made up a high rather than a low proportion of trials. They called this the prime validity effect and suggested that this provided evidence that even in a masked priming experiment participants can use the primes strategically depending on how beneficial they are. If that is the case, then it might be that the null-effect of the primes in Experiment 1 was due to the fact that the primes were never helpful and, therefore, were not attended to.

Experiment 2

Experiment 2 was designed to address two concerns that may be raised against Experiment 1. The first is that the overall null-effect could be due to the fact that the primes were not attended to or, possibly, were not well presented and that we had no safeguards that allowed us to check this. The second concern is that the exclusive use of unrelated primes in some way may induce the participants to block out the information revealed by the primes. If this is the case, our findings would have little bearing for experiments in which related and unrelated primes are compared.

To counter both concerns we first added a repetition priming condition. Repetition priming in the masked priming paradigm is well-documented and often produces an effect that nearly equals the presentation time of the prime (indicating that the change of font between prime and target has little influence on word processing). In addition, we added related filler trials to the stimulus list to make our experiment more in line with a typical experiment in which related and unrelated prime-target pairs are compared with one another.

Because of the need to include an identity condition and because it looked unlikely that we would find a big difference between high-frequency and low-frequency primes, we decided to drop the (supposedly) weakest of these, namely the low frequency prime words. Finally, we also decided to replace the unrelated consonant strings by false letter fonts (these are signs that resemble letters but have no meaning). We did so because this would provide us with information about Davis and Lupker's (2006) letter node resetting hypothesis. This aspect of the model, together with selective inhibition, predicted no difference between the absence of a prime and an unrelated prime (see Table 2, model 4), as long as there was no difference in the visual interference caused by the primes.

Overall, we retained two conditions from Experiment 1: an unrelated high frequency word and an unrelated legal nonword. These were completed with an identity prime condition and a condition with a false font. The critical trials were interleaved with filler trials in which the target stimulus was preceded by a related prime, to encourage the participants to pay attention to the prime.

Method

Participants. Forty four participants volunteered for this experiment. Participants were undergraduate students from Royal Holloway University of London.

All had normal or corrected-to-normal vision, were native English speakers, and were free from any known reading impairments. They were paid £5 (about $US9) for their time and travel expenses.

Stimuli. The target words and nonwords were identical to those used in Experiment 1. The four prime types for each target (e.g. DRUG) in this experiment were high frequency words (e.g. milk), repetition primes (e.g. drug), legal nonwords (e.g. misk), and false font stimuli (e.g. גΔגד). High frequency word primes and legal nonword primes were identical to those in Experiment 1. The repetition primes consisted of the target word in lowercase letters and the false font primes consisted of Greek, Cyrillic, Hebrew and Arabic characters. The false font characters were similar in complexity to letters but did not look like any letters in the Roman alphabet. False font primes were made by replacing each consonant of the consonant string primes in Experiment 1 with a particular false font character.

In addition to these targets and primes, filler target-prime pairs were also included in the experiment. These consisted of 128 related prime-target pairs differing by one letter (e.g. dake-BAKE). Half of these filler targets were words and half were nonwords. All primes were related non-words, because we know that these produce positive priming effects and because they do not induce a confound between type of prime and the response to the target (which is the case when repetition primes are used; then, the primes to word targets are words and the primes to nonword targets are nonwords) . The prime-target filler pairs were divided into two equal sets (A and B) each containing 32 target words and 32 target nonwords and were added onto the two lists of targets that each participant received (List A and List B). Prime-target fillers were the same for all four versions of the experiment. Counterbalancing procedures were identical to those used in Experiment 1. See Appendix B for a full list of the stimuli. Because of the filler items, each experimental block of 192 items comprised 50% related trials (32 identity primes + 64 filler trials) and 50% unrelated trials (32 high frequency words, 32 legal nonwords, and 32 false fonts).

Design & Procedure. The design and procedure were identical to Experiment 1 with the following exceptions: (a) participants responded ‘yes’ with their dominant hand; (b) stimuli appeared as white characters on a black background; (c) the inter-trial interval was increased to 1999 ms to reduce carry-over effects from one trial to the next; and (d) each participant completed a practice block consisting of eight trials followed by two experimental blocks consisting of 192 items each.

Results

Incorrect responses (4.7% of the data) were excluded from the latency analysis. The data from one outlying participant were excluded from the analysis because their mean reaction time was over 1000 ms. The data from seven items producing more than 30% errors were also removed (*alto, aria, awry, defy, duly, nigh* and *rotor*), as were 11 outlying data points of latencies under 200 ms or over 2000 ms.

The analysis of target word data was conducted in exactly the same manner as in Experiment 1. Mean RTs and error rates from the subjects analysis are shown in Table 4.

The analysis of target word latencies revealed a significant main effect of target frequency [$F_1(1, 39) = 130.59$, $MSE = 3{,}945.02$, $p < .0005$; $F_2(1, 113) = 43.15$, $MSE = 17{,}527.35$, $p < .0005$; minF’(1, 152) = 32.43, $p < .0005$], with RTs being 77ms (95%CI = ± 20) faster in response to high frequency targets compared with low frequency targets (575 ms vs. 652 ms). There was also a significant main effect of prime type [$F_1(3, 117) = 21.98$, $MSE = 2{,}142.78$, $p < .0005$; $F_2(3, 339) = 29.67$, $MSE = 2{,}464.34$, $p < .0005$; minF’(3, 298) = 12.62, $p < .0005$]. Pairwise comparisons showed that responses in the repetition prime condition were significantly faster than in all other prime conditions (repetition primes were 47 ms(95%*CI* = ± 29) faster than high frequency primes, 46 ms (95%*CI* = ± 29) faster than legal nonword primes and 48 ms (95%*CI* = ± 31) faster than false font primes). These analyses were backed up by a mixed-models analysis of the target word latency data, which revealed robust effects of target frequency [F(1, 4897) = 265.80, p < .0005] and prime type [F(3, 4837) = 26.16, p < .0005]. Pairwise comparisons showed that this effect of prime type was due to faster reaction times in the repetition prime condition compared to all other prime types.

The analysis of target word errors revealed an effect of target frequency [F_1(1, 39) = 36.36, *MSE* = 0.004, *p* < .0005; F_2(1, 109) = 19.64, *MSE* = 0.011, *p* < .0005; minF’(1, 142) = 12.75, *p* < .0005], with 4.4% (95%*CI* = ± 2%) fewer errors for high-frequency targets than for low-frequency targets (2.6% versus 7.0%). The main effect of prime type was significant in the subject analysis, but not in the item analysis [F_1(3, 117) = 3.41, *MSE* = 0.003, *p* = .020; F_2 (3, 327) = 1.89, *MSE* = 0.004, *p* = .131, *ns*; minF’(3, 425) = 1.22, *p* = .304, *ns*]. Pairwise comparisons showed that error rates in the false font prime condition were significantly higher than in all other prime conditions (error rates in the false font prime condition were 1.9% (95%*CI* = ± 0.03) higher than high frequency primes, 2.4% (95%*CI* = ± 0.03) higher than repetition primes and 1.8% (95%*CI* = ± 0.03) higher than legal nonword primes).

Discussion

Experiment 2 contained an identity prime condition to ensure that participants paid attention to the prime. As expected, RTs in this condition were considerably faster (578 ms) than in the unrelated conditions (625 ms). The difference in time, 47 ms, makes up a big part of the prime presentation duration (57 ms), as was expected.

This ensures that the primes were indeed properly presented in our experiment and attended to by the participants. This observation also makes us more reassured that the null-effect in Experiment 1 was not due to an experimental flaw.

Despite the changes we introduced, there still was no difference between RTs to target words that were preceded by unrelated high-frequency words (625 ms) and target words preceded by unrelated legal nonwords (624 ms). This is in line with the findings of Experiment 1 and the results of Perea, Fernández and Rosa’s (1998) Spanish study. Together these findings strongly suggest that the lexical status of an unrelated prime does not matter.

Finally, just like the consonant letter string, a string of false font letters did not speed up the lexical decision. If anything, it tended to slow down the process and make it slightly more error prone. The implications of this finding will be outlined in the general discussion.

General Discussion

This article deals with Forster’s assumption that unrelated primes in a masked priming experiment do not have a prime-specific effect on the processing of the target word. This assumption was based on the entry-opening model (Forster & Davis, 1984) and has been adopted by researchers working within the IA framework, without giving proper consideration to the question what type of interactions exist between non-overlapping word representations in these models.

The workings of IA models of visual word recognition are usually summarized as follows: An input letter string activates word representations that are compatible with this input (in particular the word itself and its orthographic neighbors) and these compete with each other until one dominates and exceeds the recognition threshold. In this description it looks like only a few words become activated and inhibit each other. However, this is not quite what happens, certainly not in McClelland and Rumelhart’s (1981) original model and also not in Coltheart et al.’s (2001) DRC model. In these models active word nodes inhibit all other word nodes, whether or not they overlap orthographically. In general, these models predict that a word prime in a masked priming paradigm will inhibit a target word more than a nonword prime. In addition, Davis and Lupker (2006) showed that *any* prime consisting of unrelated letters induces an inhibition effect in these models because it takes some time for the target to overwrite the prime at the letter level.

To get a better idea of what exactly the models are doing, we looked at the effects of four different types of unrelated primes in the original IA model and in DRC. These primes consisted of high-frequency words, low-frequency words, legal nonwords, and consonant strings that do not induce perceptible activation at the word level. As expected, the models showed the predicted difference between unrelated word and non-word primes (Tables 1 and 2). In addition, the original IA-model produced a difference between high-frequency and low-frequency primes. .

Although the differences in the simulations were robust in statistical terms[2], it should be noted that they were rather small in absolute numbers. This fact is due to the tendency of lateral inhibition to normalize total activity. If we take, for instance, the difference between high-frequency and low-frequency word primes, we see that the total lexical activation elicited by the high and low frequency words (which is what matters for the word inhibition) does not differ that much. For example, consider the state of network activity after 50 cycles of processing the words “very” versus “verb”. The former is a high frequency word that leads to an activity of .16 in the VERY node, whereas the latter is a low frequency word that leads to an activity of .11 in the VERB node. However, despite this difference in maximum node activity, the *total* lexical activity is .21 in both cases (“very” activates the VARY node to .04 and the VERB node to .02; “verb” activates the VERY node to .07 and the HERB node to .03). The similarity of total activation explains why the difference between the high and low frequency word primes in the original IA model is only 2 cycles and why it is absent in the DRC model.

None of Davis and Lupker’s (2006) IA models predict a difference between the low frequency words and the legal nonwords. The reason for this is again that legal nonwords generate substantial lexical activity in the original IA model, and this activity is not much smaller than that generated by words. Interestingly, DRC here predicts a much more robust effect, because the drop of activation in the word nodes as a function of diminishing orthographic overlap is much steeper in DRC than in the original IA model (as a consequence of the greater role played by letter-word inhibition in the DRC model).

The illegal consonant strings were constructed so as not to activate any word nodes. The expectation was that this would greatly reduce the lexical component of the unrelated prime inhibition effect. Despite this, they only resulted in a relatively small effect in the original IA model and no effect relative to the legal nonwords in DRC.

Nevertheless, because DRC predicts a robust difference between lexical and non-lexical primes and because the original IA model predicts a more graded difference as a function of word frequency and orthographic overlap with lexical representations, both models predict a difference between unrelated high frequency prime words and unrelated illegal consonant strings. Therefore we set out to directly test the hypothesis that not all unrelated primes were equivalent in the masked priming paradigm. This test was of additional interest because recent changes to the original IA model introduced by Davis and Lupker (2006) to simulate orthographic priming effects eliminated the competition between unrelated words. So, these versions of the model do not predict any effect of the lexical status of the prime (see versions 3 and 4 in Table 2).

Our results were extremely clear. In two successive experiments we consistently failed to find longer RTs to target words preceded by an unrelated high frequency prime word compared to target words preceded by illegal consonant strings or strings of false font letters (Tables 3 and 4). As it happens, there was twice a tendency in the opposite direction, a tendency which is difficult to explain with either the IA or the DRC models. One possible explanation could be that this trend reflects incongruence between the response activated by the prime stimulus (nonword) and the response activated by the target stimulus (word; see Klinger, Burton, & Pitts, 2000). In that case we should find that RTs to nonwords were faster after illegal letter-strings or after false font strings than after word stimuli. Such a trend was present in Experiment 1 (RTs to nonwords after high frequency prime = 775 ms, after consonant strings = 764 ms), but not in Experiment 2 (RTs to nonwords after high frequency prime = 691 ms, after false font strings = 708 ms).

Our findings are important for two reasons. The first one is practical. We have clear evidence now that researchers indeed are allowed to use both words and nonwords in the unrelated condition. As indicated in the introduction, this has been done in several experiments in the past, without published pretesting about this possible confound. Now we know that these results can indeed be compared with other experiments that controlled the lexicality of the primes.

The main reason why our findings are important is that they provide us with further constraints to which computational models of visual word recognition must adhere. In this particular case, we tested the changes Davis and Lupker (2006) recently introduced to the original IA model in order to be able to simulate the human data with respect to orthographically related primes. These changes include selective inhibition (limited to words with an orthographic overlap) and resetting of the letter nodes by the target stimulus. Neither of these changes were empirically tested by Davis and Lupker (2006), even though they lead to predictions that clearly deviate from the original IA model and from DRC.

Our data provide clear support for the selective inhibition change, but less so for the resetting of the letter nodes assumption. In particular, the fact that the false fonts in Experiment 2 did not lead to faster LDTs suggests that more research needs to be done on the latter issue, to see to what extent longer reaction times in masked prime conditions relative to unprimed control conditions are due to interference at the letter level or to more general visual interference.

The fact that the data of the present experiments, just like those of Davis and Lupker (2006), are in line with the selective inhibition assumption, highlights the need for modelers to think more about the homogeneous lateral inhibition assumption in their computational models, and to make explicit how far reaching the inhibition goes in visual word recognition. As Tables 1 and 2 show, both the original IA-model and the DRC-model seem to overestimate the amount of inhibition taking place in the mental lexicon.

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Appendix A

Stimuli used in Experiment 1

High frequency (HF), low frequency (LF), legal nonword (NW) and consonant string (CS) primes for high and low frequency target words and target nonwords (targets in capital letters).

Target-Prime Set A

Primes				**Target**	**Primes**				**Target**
HF	**LF**	**NW**	**CS**	**Word**	**HF**	**LF**	**NW**	**CS**	**Nonword**
four	dour	zour	jhxh	ABLE	rest	jest	hest	xmvt	FLON
wash	dash	pash	qkhk	BLUE	camp	carp	casp	mrfj	EWLY
milk	mink	misk	zbpz	DRUG	some	sore	sove	gtsq	PALF
food	fond	foid	qzhx	TERM	wave	pave	zave	vdwz	CLIG
mass	bass	rass	txqf	OVEN	hang	fang	kang	qgsz	VOUP
poor	moor	coor	vlbc	THUD	what	chat	ehat	vlpq	DUIR
idea	ides	iden	hmqw	TURF	week	peek	zeek	xrkf	TOIT
test	teat	tert	khfv	DULY	wood	hood	vood	gvcq	LAUT
seat	peat	zeat	qtpq	FROM	work	fork	bork	xzfh	JUDS
room	doom	goom	gmsx	INCH	look	loom	loob	qxvx	SHEY
half	calf	malf	sxhx	IRON	york	cork	mork	pnzf	TETH
heat	feat	veat	zjtz	ONLY	shop	shoo	shol	jbdb	TUCE
dead	bead	vead	kxvr	SIGH	down	gown	wown	vnxs	TAFF
come	comb	comy	jqls	KNIT	sort	soot	sopt	vtgq	BLEN
suit	quit	puit	ncgp	AWRY	past	pact	paut	qdjq	WEEF
ring	rind	rini	xvnh	CLUE	pull	gull	jull	xqlv	KIDE

foot	fort	fout	dxqx	HIGH	must	bust	wust	qsdl	VOON
wall	wail	wawl	xlgk	JURY	need	heed	veed	lwxc	BOSK
most	host	wost	jmqm	AREA	east	mast	hast	qhgj	WILF
cent	bent	fent	zcpk	ALSO	know	knob	knom	ncfh	GLAT
main	maid	maip	qgfn	VERB	desk	deck	denk	qfvg	WOOB
less	lass	luss	qszl	MOTH	blow	blob	blos	qxbx	KNAM
wake	fake	zake	jmwh	DRIP	meet	beet	veet	qsdl	HOUG
rise	rife	rire	rsjx	LAZY	well	dell	zell	xdbn	PHAM
miss	hiss	viss	kdxc	OPEN	more	core	jore	kzjf	TUPT
draw	drab	dran	jhlg	TYPE	save	nave	bave	rzfq	THIM
lord	cord	jord	bpgj	WHEN	note	mote	fote	vlbc	PHAS
home	tome	vome	ksmj	BURN	hope	hose	hote	xjbg	AWID
push	gush	sush	rljq	DEFY	keep	keen	keer	xqrs	HULM
beat	beak	beab	qkgc	HURL	ride	aide	jide	zdtb	FLUG
rule	mule	nule	fghc	SKID	cook	rook	wook	qkjf	PUNE
dark	bark	kark	xldl	STEW	word	worm	worg	zgpv	DASS
while	chile	ghile	zwhck	ABOUT	child	chill	chilo	chklp	ABERT
fight	wight	jight	gpwnc	ABOVE	lunch	hunch	tunch	tzcnh	POODS
sound	hound	yound	nkcpn	AFTER	sleep	sleek	sleex	slfkx	ANITY
blood	bloom	bloob	ksphw	ANGER	phone	prone	plone	plmnb	STUST
trust	crust	brust	pxjwg	ANKLE	skill	skull	skoll	kslpl	FABRE
short	snort	slort	ghzhp	ABIDE	shock	chock	ohock	hskwc	TEIGN
stick	slick	smick	mscdk	WEAVE	brown	drown	prown	rpwmn	LELVE
allow	alloy	allop	cllkp	THIEF	quick	quirk	quisk	qzcsk	DENOW
eight	bight	dight	hfcnk	SOLAR	break	bream	breal	brvql	NOIST

fifty	fifth	fifts	rxsgp	DANCE	judge	budge	hudge	hjdgx	MOLKS
happy	nappy	dappy	dfppz	CRUEL	every	emery	ewery	cwzrm	QUALT
peace	peach	peacy	vzjqz	DRIFT	horse	horde	horve	hgrvz	PLUNT
since	mince	pince	qxfpq	VAULT	major	manor	malor	mplgr	THEST
drink	brink	grink	bvwdr	CELLO	lower	bower	zower	zpwqr	TINCH
sorry	lorry	horry	lrsqb	KNACK	party	patty	pafty	pbftr	VENSE
stuff	scuff	sluff	tdwcj	YEARN	march	larch	rarch	rbrch	DOUGE
shoot	scoot	spoot	psktn	LEGAL	smell	swell	scell	lcsdl	ANGOT
seven	sever	seves	dpnhv	MAGIC	field	wield	lield	lbxld	SHOSH
south	couth	nouth	ljwvn	MEDIA	small	stall	spall	lpskl	DRODE
basic	basil	basia	bhsdk	MOTOR	match	batch	zatch	tzhcs	PROOK
apply	amply	anply	wnplz	OTTER	shape	shame	shage	hsgjt	KNUFF
thing	thong	thung	htgxn	FARCE	share	scare	smare	qsbqp	DOWNK
glass	gloss	glyss	tfjdv	NIECE	cross	gross	tross	szstr	BLANE
think	chink	shink	bkwnx	QUEER	story	stony	stowy	stnwb	GEFIA
staff	stiff	stoff	mjfbn	REPLY	stand	staid	staad	tsldf	CHOUP
quite	suite	fuite	fwztg	ROYAL	daily	dally	daply	dxplc	WOMER
local	focal	jocal	jkcsl	THUMB	treat	tread	treac	trwmc	JOUGH
class	clash	clast	hpvfj	UNDER	shake	shaky	shaks	shjks	OITON
water	cater	jater	jhtpr	ONION	power	poker	poger	plgfr	BANCH
board	hoard	zoard	hcdjb	UNTIE	model	motel	mopel	mbpkl	VAINY
bring	briny	brino	rbzdn	SKATE	radio	ratio	rapio	rxpmg	SWECK
catch	hatch	gatch	rvzkf	MOUSE	marry	parry	zarry	zxrrg	THELK

Target-Prime Set B

	Primes			Target		Primes			Target
HF	**LF**	**NW**	**CS**	**Word**	**HF**	**LF**	**NW**	**CS**	**Nonword**
good	goof	gook	jfgw	AXLE	what	chat	ehat	vlpq	SOMB
give	dive	mive	kgxm	BLUR	rest	jest	hest	xmvt	AWLY
back	bask	bawk	fgwz	DRUM	camp	carp	casp	mrfj	GEED
hold	bold	lold	zvlj	GERM	some	sore	sove	gtsq	CLID
star	spar	slar	jxfm	EVEN	fast	fist	fost	qxpg	HURM
game	gale	gace	gwxq	THUS	hang	fang	kang	qgsz	DUIT
wife	wile	wike	zshq	TURN	show	shaw	shuw	zgpv	CERB
life	lime	lipe	bfvj	DUTY	work	fork	bork	xzfh	LANT
want	pant	yant	dqzj	FROG	york	cork	mork	pnzf	SHEB
near	sear	zear	qkfg	ITCH	shop	shoo	shol	jbdb	NIFT
sure	lure	hure	ghbz	ICON	down	gown	wown	vnxs	TICE
free	fret	frep	kwhc	OILY	sort	soot	sopt	vtgq	ZIMB
rate	rake	rame	lmqc	SIGN	past	pact	paut	qdjq	BLEK
book	boom	bood	xjzr	UNIT	pull	gull	jull	xqlv	ARCA
form	dorm	vorm	kztr	AWAY	must	bust	wust	qsdl	PIGE
tree	trek	trep	wtmz	CLUB	need	heed	veed	lwxc	POFT
worm	pork	sork	zkdj	NIGH	east	mast	hast	qhgj	BOLK
next	nest	nept	lsqc	FURY	take	bake	pake	wbxb	DUIL
stop	slop	scop	kdqx	ARIA	mine	mane	mone	mvfx	GRUR
deep	deed	deef	wzqc	ALTO	hide	hike	hise	zpqw	CRUG
wind	wand	wund	jcgc	VERY	know	knob	knom	ncfh	GEUR

deep	jeep	meep	xsml	BOTH	desk	deck	denk	qfvg	BLAT
bank	bang	bani	vwzh	DROP	blow	blob	blos	qxbx	FERK
rock	mock	bock	mtfz	LADY	your	lour	vour	klbq	HIGN
hard	hark	harb	zplh	OMEN	meet	beet	veet	qsdl	KNAX
kind	bind	nind	hcqc	TYRE	well	dell	zell	xdbn	CUCH
fall	gall	sall	xzpq	WREN	more	core	jore	kzjf	THID
name	dame	vame	qjsq	BURP	show	shaw	shiw	vphp	CUEM
part	cart	gart	kvzb	DENY	save	nave	bave	rzfq	WOCT
face	mace	nace	qknj	HURT	list	gist	tist	jldf	ZHAM
love	cove	yove	jgqr	SKIN	hope	hose	hote	xjbg	CIFF
long	gong	fong	kjfr	STEP	note	mote	fote	vlbc	AXID
sense	dense	mense	mznsd	ABORT	marry	parry	zarry	zxrrg	FLUDE
still	spill	snill	kcwgn	ABODE	child	chill	chilo	chklp	GRUER
pound	mound	gound	bhxmj	ALTER	lunch	hunch	tunch	tzcnh	ABERS
shout	scout	smout	xvhwz	ANGEL	sleep	sleek	sleex	slfkx	VIGRO
throw	throb	throd	fkdcv	ANGLE	phone	prone	plone	plmnb	AVITY
block	flock	plock	tpzlg	ASIDE	skill	skull	skoll	kslpl	DEAWN
front	frost	frono	dnhfj	LEAVE	shock	chock	ohock	hskwc	DABRE
plant	plank	plang	tqlbt	CHIEF	brown	drown	prown	rpwmn	TEEGS
scene	scent	scenx	gbhtn	POLAR	quick	quirk	quisk	qzcsk	VELVE
tooth	booth	zooth	bvgbd	LANCE	break	bream	breal	brvql	GUFST
paint	saint	naint	nbvnt	GRUEL	judge	budge	hudge	hjdgx	NOOST
close	clove	clope	clbpv	DRAFT	every	emery	ewery	cwzrm	LOUND
cover	cower	coper	czpkr	FAULT	horse	horde	horve	hgrvz	BUALT
start	stark	starm	tsgrm	HELLO	major	manor	malor	mplgr	VETSH

level	lever	levep	lmvbp	KNOCK	lower	bower	zower	zpwqr	THUST
touch	pouch	wouch	twshc	LEARN	party	patty	pafty	pbftr	LONCK
count	fount	jount	wqdsb	REGAL	march	larch	rarch	rbrch	ZENSE
speed	steeds	sleed	hfjkl	MANIC	smell	swell	scell	lcsdl	JOONT
grass	brass	trass	srstf	MEDIC	field	wield	lield	lbxld	ANJOT
clean	glean	plean	bphfk	ROTOR	small	stall	spall	lpskl	ROWCH
black	blank	blask	njvbf	OUTER	match	batch	zatch	zstch	DROFE
thank	shank	phank	ghklv	FORCE	shape	shame	shage	shjgt	CRIWN
shall	shawl	sharl	zkdts	PIECE	share	scare	smare	qsbqp	KLUFF
chair	choir	chrir	wkfzg	QUEEN	cross	gross	tross	szstr	MEFIA
stock	smock	snock	nscdk	REPAY	story	stony	stowy	stnwb	CLEEF
price	prick	prich	tvzqx	LOYAL	stand	staid	staad	stfld	POMER
wrong	wring	wreng	rwndg	THUMP	daily	dally	daply	dxplc	STOSK
watch	latch	fatch	xmhkc	UDDER	treat	tread	treac	trwmc	SILON
space	spade	spave	phzwc	UNION	shake	shaky	shaks	shjks	FROOL
paper	caper	maper	mzpcr	UNTIL	power	poker	poger	plgfr	VAINT
group	croup	wroup	cqhqn	STATE	model	motel	mopel	mbpkl	FRINS
train	grain	frain	frtgn	HOUSE	radio	ratio	rapio	rxpmg	CHELK

Appendix B

Stimuli used in Experiment 2

High frequency (HF), repetition (Rep), legal nonword (NW) and false font (FF) primes for high and low frequency target words and target nonwords (targets in capital letters).

Target-Prime Set A

Primes				Target	Primes				Target
HF	**Rep**	**NW**	**FF**	**Word**	**HF**	**Rep**	**NW**	**FF**	**Nonword**
four	able	zour	~Φ~כ	ABLE	rest	flon	hest	Φבאל	FLON
wash	blue	pash	Ψب~ب	BLUE	camp	ewly	casp	כوҐל	EWLY
milk	drug	misk	גרΔג	DRUG	some	palf	sove	ζΨבך	PALF
food	term	foid	Ψג~Φ	TERM	wave	clig	zave	אפצג	CLIG
mass	oven	rass	وΦΨב	OVEN	hang	voup	kang	Ψךζג	VOUP
poor	thud	coor	<Δرא	THUD	what	duir	ehat	Ψרرא	DUIR
idea	turf	iden	~לΨצ	TURF	week	toit	zeek	ΦҐوب	TOIT
test	duly	tert	אو~ب	DULY	wood	laut	vood	Ψ<אך	LAUT
seat	from	zeat	ΨברΨ	FROM	work	juds	bork	Φגو~	JUDS
room	inch	goom	ζΦלך	INCH	look	shey	loob	ΨΦאΦ	SHEY
half	iron	malf	ζΦ~Φ	IRON	york	teth	mork	وגΩר	TETH
heat	only	veat	גכבג	ONLY	shop	tuce	shol	ΔפΔכ	TUCE
dead	sigh	vead	ҐאΦب	SIGH	down	taff	wown	ΩΦζא	TAFF
come	knit	comy	ζرΨכ	KNIT	sort	blen	sopt	Ψךבא	BLEN
suit	awry	puit	Ω>רך	AWRY	past	weef	paut	ΨכפΨ	WEEF
ring	clue	rini	ΦאΩ~	CLUE	pull	kide	jull	ΦΨرא	KIDE

foot	high	fout	ΦΨΦפ	HIGH	must	voon	wust	Ψζפر	VOON
wall	jury	wawl	Φرךب	JURY	need	bosk	veed	<Φצر	BOSK
most	area	wost	לΨכל	AREA	east	wilf	hast	Ψ~כך	WILF
cent	also	fent	بר<ג	ALSO	know	glat	knom	Ω>و~	GLAT
main	verb	maip	ΨךوΩ	VERB	desk	woob	denk	Ψوאך	WOOB
less	moth	luss	Ψζגر	MOTH	blow	knam	blos	ΨΦΔΦ	KNAM
wake	drip	zake	~כלצ	DRIP	meet	houg	veet	Ψζפر	HOUG
rise	lazy	rire	Γ̓ζכΦ	LAZY	well	pham	zell	ΦפΔΩ	PHAM
miss	open	viss	<Φפب	OPEN	more	tupt	jore	بגכو	TUPT
draw	type	dran	ךر~כ	TYPE	save	thim	bave	Γ̓גوΨ	THIM
lord	when	jord	Δכךר	WHEN	note	phas	fote	<Δرא	PHAS
home	burn	vome	כלζب	BURN	hope	awid	hote	ΦכΔך	AWID
push	defy	sush	Γ̓רכΨ	DEFY	keep	hulm	keer	ΦΨΓ̓ζ	HULM
beat	hurl	beab	Ψבך>	HURL	ride	flug	jide	Δבפג	FLUG
rule	skid	nule	<~ךو	SKID	cook	pune	wook	Ψכבو	PUNE
dark	stew	kark	Φرפر	STEW	word	dass	worg	גךרא	DASS
while	about	ghile	ب<~גצ	ABOUT	child	abert	chilo	>~ربـר	ABERT
fight	above	jight	<Ωךרצ	ABOVE	lunch	poods	tunch	~Ω<בג	POODS
sound	after	yound	Ωب>רΩ	AFTER	sleep	anity	sleex	ζروبΦ	ANITY
blood	anger	bloob	צ~רζب	ANGER	phone	stust	plone	ΩΔלרر	STUST
trust	ankle	brust	ךכצΦר	ANKLE	skill	fabre	skoll	ررζب	FABRE
short	abide	slort	ך~ג~ר	ABIDE	shock	teign	ohock	~ζצב>	TEIGN
stick	weave	smick	بפ<ζל	WEAVE	brown	lelve	prown	Γ̓רצלΩ	LELVE
allow	thief	allop	>ررب	THIEF	quick	denow	quisk	Ψג>ζب	DENOW
eight	solar	dight	~و>Ωب	SOLAR	break	noist	breal	ΔΓ̓אΨر	NOIST

fifty	dance	fifts	ΓΦζרך	DANCE	judge	molks	hudge	~כפךΦ	MOLKS
happy	cruel	dappy	פورרג	CRUEL	every	qualt	ewery	>לΓצג	QUALT
peace	drift	peacy	אגכΨג	DRIFT	horse	plunt	horve	~אגΓך	PLUNT
since	vault	pince	ΨΦروΨ	VAULT	major	thest	malor	Γלרךر	THEST
drink	cello	grink	ΔאצפΓ	CELLO	lower	tinch	zower	ΓΨגרצ	TINCH
sorry	knack	horry	ζΨΔΓر	KNACK	party	vense	pafty	ΓבوΔר	VENSE
stuff	yearn	sluff	ɔ<בפצ	YEARN	march	douge	rarch	ΓΔΓ>~	DOUGE
shoot	legal	spoot	Ωבبζר	LEGAL	smell	angot	scell	رפζ<ر	ANGOT
seven	magic	seves	א~Ωפר	MAGIC	field	shosh	lield	פرΔΦر	SHOSH
south	media	nouth	Ωכצאر	MEDIA	small	drode	spall	ربζרر	DRODE
basic	motor	basia	Δ~ζפب	MOTOR	match	prook	zatch	ζ<~בג	PROOK
apply	otter	anply	גرרΩצ	OTTER	shape	knuff	shage	~ζךכב	KNUFF
thing	farce	thung	~ךבΦΩ	FARCE	share	downk	smare	ΨζΔΨר	DOWNK
glass	niece	glyss	בوכפא	NIECE	cross	blane	tross	ζגζבΓ	BLANE
think	queer	shink	ΔצبΩΦ	QUEER	story	gefia	stowy	ζבΩצΔ	GEFIA
staff	reply	stoff	ΔΩלכو	REPLY	stand	choup	staad	בζرפو	CHOUP
quite	royal	fuite	וצגבך	ROYAL	daily	womer	daply	<رרΦפ	WOMER
local	thumb	jocal	כب<ζر	THUMB	treat	jough	treac	<בΓצל	JOUGH
class	under	clast	~כוرא	UNDER	shake	oiton	shaks	ζ~כبζ	OITON
water	onion	jater	Γכ~בר	ONION	power	banch	poger	Γרرךو	BANCH
board	untie	zoard	~>כפΔ	UNTIE	model	vainy	mopel	ربרΔל	VAINY
bring	skate	brino	ΓΔפגΩ	SKATE	radio	sweck	rapio	ΓΦרלך	SWECK
catch	mouse	gatch	Γבــوאג	MOUSE	marry	thelk	zarry	ךΓΓΦג	THELK

Target-Prime Set B

Primes				Target	Primes				Target
HF	Rep	NW	FF	Word	HF	Rep	NW	FF	Nonword
good	axle	gook	כوצך	AXLE	what	somb	ehat	אرרΨ	SOMB
give	blur	mive	بךΦל	BLUR	rest	awly	hest	Φבאל	AWLY
back	drum	bawk	وגצך	DRUM	camp	geed	casp	לΓوכ	GEED
hold	germ	lold	כرגא	GERM	some	clid	sove	בךζΨ	CLID
star	even	slar	כΦول	EVEN	fast	hurm	fost	ΨΦךר	HURM
game	thus	gace	צךΦΨ	THUS	hang	duit	kang	Ψךζג	DUIT
wife	turn	wike	גζ~Ψ	TURN	show	cerb	shuw	ארךג	CERB
life	duty	lipe	Δوכא	DUTY	work	lant	bork	Φגو~	LANT
want	frog	yant	פΨכג	FROG	york	sheb	mork	רΩגو	SHEB
near	itch	zear	Ψـوـبך	ITCH	shop	nift	shol	כΔפΔ	NIFT
sure	icon	hure	ך~Δג	ICON	down	tice	wown	אΩΦζ	TICE
free	oily	frep	بצ~>	OILY	sort	zimb	sopt	ךבאΨ	ZIMB
rate	sign	rame	رלΨ>	SIGN	past	blek	paut	ΨכפΨ	BLEK
book	unit	bood	ΦגכΓ	UNIT	pull	arca	jull	ΦΨرא	ARCA
form	away	vorm	بבגΓ	AWAY	must	pige	wust	Ψζפر	PIGE
tree	club	trep	גלבצ	CLUB	need	poft	veed	رצΦ>	POFT
worm	nigh	sork	גبכפ	NIGH	east	bolk	hast	Ψ~כך	BOLK
next	fury	nept	رζΨ>	FURY	take	duil	pake	צΔΦΔ	DUIL
stop	aria	scop	بפΨΦ	ARIA	mine	grur	mone	אלوΦ	GRUR
deep	alto	deef	גצΨ>	ALTO	hide	crug	hise	רגΨצ	CRUG
wind	very	wund	ך<כ>	VERY	know	geur	knom	Ω>و~	GEUR

deep	both	meep	Φζرל	BOTH	desk	blat	denk	Ψאךو	BLAT
bank	drop	bani	אצג~	DROP	blow	ferk	blos	ΨΦΔΦ	FERK
rock	lady	bock	גوלב	LADY	your	hign	vour	بــرΔΨ	HIGN
hard	omen	harb	رגר~	OMEN	meet	knax	veet	Ψζرפ	KNAX
kind	tyre	nind	~>Ψ>	TYRE	well	cuch	zell	ΦפΔΩ	CUCH
fall	wren	sall	ΦגרΨ	WREN	more	thid	jore	وגכب	THID
name	burp	vame	ΨכζΨ	BURP	show	cuem	shiw	אר~ר	CUEM
part	deny	gart	אגبΔ	DENY	save	woct	bave	ҐوגΨ	WOCT
face	hurt	nace	ΨبΩכ	HURT	list	zham	tist	وפرכ	ZHAM
love	skin	yove	כךΨҐ	SKIN	hope	ciff	hote	ΦכΔך	CIFF
long	step	fong	وכبҐ	STEP	note	axid	fote	رאΔ>	AXID
sense	abort	mense	לגΩζפ	ABORT	marry	flude	zarry	גΦҐҐך	FLUDE
still	abode	snill	צך<بΩ	ABODE	child	gruer	chilo	>~רبــر	GRUER
pound	alter	gound	Δ~Φלכ	ALTER	lunch	abers	tunch	בג>Ω~	ABERS
shout	angel	smout	Φא~צג	ANGEL	sleep	vigro	sleex	ζروبΦ	VIGRO
throw	angle	throd	פ<אوب	ANGLE	phone	avity	plone	לرרΩΔ	AVITY
block	aside	plock	ךرברג	ASIDE	skill	deawn	skoll	بζرר	DEAWN
front	leave	frono	פΩ~وכ	LEAVE	shock	dabre	ohock	~ζצب>	DABRE
plant	chief	plang	בΨرΔב	CHIEF	brown	teegs	prown	ҐרצלΩ	TEEGS
scene	polar	scenx	ךΔ~בΩ	POLAR	quick	velve	quisk	Ψג>ζب	VELVE
tooth	lance	zooth	ΔאךΔפ	LANCE	break	gufst	breal	ΔҐאΨر	GUFST
paint	gruel	naint	ΩΔאΩב	GRUEL	judge	noost	hudge	~כפךΦ	NOOST
close	draft	clope	>رΔרא	DRAFT	every	lound	ewery	>צגҐל	LOUND
cover	fault	coper	>بגרҐ	FAULT	horse	bualt	horve	~ךҐאג	BUALT
start	hello	starm	בζךҐל	HELLO	major	vetsh	malor	ךرלרҐ	VETSH

level	knock	levep	רלאΔر	KNOCK	lower	thust	zower	צגרΨҐ	THUST
touch	learn	wouch	צבζ~>	LEARN	party	lonck	pafty	רΔבوҐ	LONCK
count	regal	jount	צΨפζΔ	REGAL	march	zense	rarch	ҐΔҐ>~	ZENSE
speed	manic	sleed	~בـردو	MANIC	smell	joont	scell	ر>ζפر	JOONT
grass	medic	trass	ζҐζבو	MEDIC	field	anjot	lield	رΔΦפر	ANJOT
clean	rotor	plean	Δר~وب	ROTOR	small	rowch	spall	ررζבـر	ROWCH
black	outer	blask	ΩאכΔو	OUTER	match	drofe	zatch	גζב>~	DROFE
thank	force	phank	ך~אבـر	FORCE	shape	criwn	shage	ζ~כבך	CRIWN
shall	piece	sharl	גפבבζ	PIECE	share	kluff	smare	ΨζΔΨר	KLUFF
chair	queen	chrir	צגךבـو	QUEEN	cross	mefia	tross	ζגζבҐ	MEFIA
stock	repay	snock	Ωζ>פب	REPAY	story	cleef	stowy	ζבΩצΔ	CLEEF
price	loyal	prich	גאבΨΦ	LOYAL	stand	pomer	staad	ζבפور	POMER
wrong	thump	wreng	ҐצΩפך	THUMP	daily	stosk	daply	פΦרر>	STOSK
watch	udder	fatch	Φל~ב>	UDDER	treat	silon	treac	בҐצל>	SILON
space	union	spave	צג~ר>	UNION	shake	frool	shaks	ζ~כبζ	FROOL
paper	until	maper	רלגר>Ґ	UNTIL	power	vaint	poger	רךروҐ	VAINT
group	state	wroup	>Ψ~ΨΩ	STATE	model	frins	mopel	לΔרبـر	FRINS
train	house	frain	وҐבךΩ	HOUSE	radio	chelk	rapio	ҐΦךלר	CHELK

Related prime-target fillers for target words and target nonwords (targets in capital letters).

Fillers A

Prime	Target word	Prime	Target nonword
dake	BAKE	hoan	HEAN
bist	BUST	suel	SULL
deef	DEED	wimb	WIME
dile	DIVE	cear	VEAR
cree	FREE	ryne	RONE
kalt	KILT	folt	FOUT
leik	LEAK	winn	WINT
malk	MALL	moce	LOCE
dode	NODE	bume	BAME
pust	PEST	pann	PARN
rawe	RAVE	folm	FOLE
ripa	RIPE	fath	DATH
neep	SEEP	reme	RAME
sirn	SIRE	dule	DURE
sulf	SURF	yenk	YENT
vink	VINE	wout	SOUT
meard	BEARD	banch	BINCH
betch	BUTCH	cloam	CLEAM
chuse	CHASE	darch	DATCH
clorn	CLOWN	flase	FLATE

Fillers B

Prime	Target word	Prime	Target nonword
geed	REED	nake	PAKE
soll	SILL	dest	DAST
perr	PEAR	tade	TAVE
rach	RACK	kelf	KELL
gret	FRET	keal	GEAL
gupe	GAPE	woce	WICE
bolb	BOLD	bine	BIRE
fabe	FAME	sird	SIND
nent	DENT	dipt	DIPE
sare	SORE	rure	MURE
lage	LACE	sult	SOLT
carf	CART	holf	HOLL
tane	SANE	toid	TOOD
waim	WHIM	yoll	FOLL
mant	MAST	pild	POLD
limk	LIME	virb	VILB
cloom	BLOOM	punct	PUNCE
bloon	BLOWN	snult	SKULT
blibe	BRIBE	smeaf	SMEAK
broof	BROOD	spean	SPOAN

curro	CURRY	fungh	FUNGE	bling	FLING	ghone	THONE
kread	DREAD	gneat	GLEAT	gride	GLIDE	thrub	THREB
flome	FLAME	nedge	JEDGE	pruck	PRICK	trark	TRARE
gnoss	GLOSS	ludde	LUDGE	vowal	VOWEL	nauge	SAUGE
heane	HEAVE	noish	NOISK	whalf	WHALE	clume	CRUME
hoark	HOARD	glone	PLONE	druck	TRUCK	drewl	DROWL
daval	NAVAL	renge	RINGE	tanse	TENSE	flene	FLERE
swent	SCENT	sclup	SCRUP	malor	MANOR	gheef	GHEEL
sheve	SHOVE	shilk	SHICK	dainy	DAIRY	crask	GRASK
speir	SPEAR	strus	STRUP	cursk	CURSE	lonch	LANCH
triac	TRIAD	droil	TROIL	strup	STRAP	mirch	MINCH
gruce	TRUCE	whunt	WHINT	gnort	SNORT	nurck	NURKE

Footnotes

1. The DRC and IA model simulation results differ in scale due to a difference in the temporal resolutions of the models. The size of the activity change on each cycle in the IA model is smaller than that in DCR; this means that the IA model requires more cycles in order to accomplish the same amount of processing (see Davis, 2003 for more on the temporal resolution of simulations). One cycle of processing in the DRC model roughly corresponds to two cycles in the IA model. Therefore the prime was presented for 50 cycles in the IA model compared with 24 cycles for the DRC simulation.
2. The simulations are carried out over items and it should be noted that, in simulations of this kind, there is no between-subject variability.

3. Author Note

Corresponding author: Linda Bayliss, Department of Psychology, Royal Holloway, University of London, Egham, TW20 0EX, United Kingdom. Email: Linda.Bayliss@rhul.ac.uk. This research was partly supported by the Socrates Erasmus exchange programme and was partly funded by grant RES-000-22-1875 from the Economic & Social Research Council (ESRC).

Table 1

Mean DRC predicted identification latencies as a function of prime type.

Prime Type	**Identification Latency**
HF Word	44.47
LF Word	44.12
Legal Nonword	39.88
Consonant String	40.35

Table 2

Mean predicted identification latencies as a function of prime condition and target frequency for four versions of the IA model

	IA (no reset)					IA (letter reset)					IA (selective inhibition)					IA (letter reset & selective inhibition)				
	UP	HF	LF	NW	CS	UP	HF	LF	NW	CS	UP	HF	LF	NW	CS	UP	HF	LF	NW	CS
HF Targets	171	203	200	199	197	171	181	179	178	174	171	195	194	195	195	171	172	172	173	173
LF Targets	189	216	214	214	212	189	194	192	192	189	189	210	210	211	211	189	187	187	188	188
Total	180	209	207	206	204	180	187	186	185	182	180	202	202	203	203	180	180	180	180	180
Frequency effect					*2*					*2*					*0*					*0*
Lexicality effect					*-2*					*-1*					*1*					*0*
Legality effect					*-2*					*-3*					*0*					*0*

Note: UP = Unprimed, HF = High-Frequency, LF = Low-Frequency, NW = Nonword, CS = Consonant String

Table 3

Latencies (in Milliseconds) and Error Rates (in Percentages) for High Frequency and Low Frequency Targets as a Function of Prime Type.

Target Frequency	Prime Type			
	High Frequency	Low Frequency	Legal Nonword	Consonant String
High	597 (1.5)	600 (2.0)	602 (2.5)	615 (2.9)
Low	688 (6.2)	669 (7.9)	679 (7.4)	686 (8.4)

Table 4

Latencies (in Milliseconds) and Error Rates (in Percentages) for High Frequency and Low Frequency Target Words as a Function of Prime Type.

Target Frequency	Prime Type			
	High Frequency	Repetition	Legal Nonword	False Font
High	581 (1.9)	542 (1.7)	584 (2.3)	592 (4.5)
Low	668 (6.9)	614 (6.2)	666 (6.8)	660 (8.1)