The e-detection task to measure the visibility of primes in masked-priming experiments

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Abstract

In masked priming studies the visibility of the primes depends on various factors besides the stimulus onset asynchrony between the prime and the target. Recent studies have indicated that researchers should be more careful about this aspect. We present an e-detection experiment that can easily be run in combination with the usual masked priming studies and that allows researchers to equate their presentation conditions and to assess the impact of various variables on the visibility of the primes. Two applications are given: One in which the prime visibilities in two different labs were compared, and one in which the implications of the insertion of a postmask between the prime and the target are examined.

The e-detection task to measure the visibility of primes in masked-priming experiments

In recent years the masked priming procedure has become the task of choice for research on visual word recognition. In this procedure, a target word is preceded first by a forward mask consisting of non-letter symbols (e.g., #######) and then by a prime presented so briefly that it is either not visible or only barely visible. Participants have to make a decision about the target word or name it. Researchers are interested in the difference in response latencies as a function of the overlap between the prime and the target (the so-called priming effect). Different forms of overlap that have been studied are orthographic similarity (related trials nurse-CURSE vs. control trials towel-CURSE), phonological similarity (yuice-USE vs. douke-USE), morphological similarity (viewer-VIEW vs. ranger-VIEW), semantic relatedness (butter-BREAD vs. buster-BREAD), and translation equivalence (e.g., amour-LOVE vs. terre-LOVE).

A variable that has received a lot of attention is the time delay between the onset of the prime and the onset of the target word, the so-called stimulus-onset-asynchrony (SOA). The briefer the exposure of the prime, the less perceptible it is and the less impact one expects from it. Typical exposure durations are 43 ms and 57 ms (these are multiples of the 14.3 ms refresh cycle of a typical 70 Hz computer monitor; Forster & Forster, 2003). Sometimes, researchers have used shorter SOAs (e.g., 14 or 29 ms) to examine whether orthographic, phonological, or semantic priming effects would still be observed at these exposure durations (see, e.g. Rastle and Brysbaert (2006) for a review of all the studies on the masked phonological priming effect in English).

Tzur and Frost (2007) recently made the case that researchers interested in the impact of SOA have typically assumed that the presentation duration of the prime is the only variable that matters in masked priming with verbal stimuli. This assumption is grounded on the belief that the processing of the prime starts as soon as the prime is presented and stops when the input of the prime is overwritten by the target. Throughout the years, there have been claims that this view is wrong as far as the end part is concerned. For instance, Dehaene et al. (1998) showed that the processing of the masked primes does not stop when the input is overwritten by the target stimulus, but continues all the way up to the motor cortex and results in response congruency effects. Tzur and Frost (2007) added to this that the processing of the stimulus not only depends on the time that is available between the onset of the prime and the onset of the target, but also on the total energy of the prime. Within the confines of a typical masked priming study, a prime with a higher contrast to the background will result in a stronger priming effect. So, researchers on visual word recognition have been misled by their conviction that the luminance of the stimuli and the background were of no importance. Tzur and Frost (2007) showed that depending on the luminance of the stimuli, a repetition priming effect could be present or absent at an SOA of 20 ms, leading them to advise researchers to report in their articles the luminance of the stimuli employed in the experimental setting, together with the screen contrast, the room luminance and the procedures used for dark adaptation.

Unfortunately, measuring the physical properties of a display is a time-consuming process and would need to be repeated for each monitor more than once. For example, it may be that the screen properties vary depending on how long the monitor has been switched on. Further, there is the possibility of individual differences in sensitivity and dark adaptation, and there is even the possibility that the participants alter the contrast and brightness settings of the monitor themselves. Finally, even if we have physical measurements of the stimuli, they tell us relatively little about the visibility of the primes. Some non-linearity in the relationship between the luminance and the visibility of a stimulus is to be expected (Tzur & Frost, 2007), making it difficult to compare the obtained physical values in terms of their consequences for behavioural performance. A far simpler and more direct way to measure the visibility of the prime is to administer a standardized detection task and to report the mean performance across all participants in the experiment on this task. Such a task is already in use for some time in the literature on unconscious processing. For instance, Greenwald, Klinger, and Schuh (1995) asked participants in some experiments to indicate on each trial whether a stimulus was presented or, in other experiments, where the stimulus was presented (left/right of the fixation location). Given that participants could not reliably perform this task under some conditions, it was concluded that these were conditions of unconscious processing if under those same conditions a masked priming effect was observed. A similar approach was suggested by Finkbeiner, Forster, Nicol, and Nakamura (2004). As part of their investigation of masked semantic and translation priming effects, they used an e-detection task in which participants were presented with the usual primes and targets, but this time they were not asked to make a decision about the target, but to indicate whether the prime contained the letter ”e” or not. The target was redundant in this task. By looking at the accuracy of the participants in the e-detection task, Finkbeiner et al. (2004) had objective information about the visibility of the primes in their study. Finkbeiner's (2004) task is appealing because it is a very straightforward way to measure the visibility of primes. Participants are asked to make judgments about primes that are presented in exactly the same way as they were presented in the actual experiment. In addition, the task is short enough so that it can easily be run after the experimental session on the same participants who took part in the experiment, making it possible to take the characteristics of the participants into account. In the present series of experiments, we investigate whether an extended version of the e-detection task, including a wide variety of SOAs, could serve as a benchmark to calibrate the equipment and the experimental conditions before one engages in masked priming experiments. Including the results of the benchmarking procedure in papers would allow comparison of the results from different laboratories with respect to the physical properties of their screens and the presentation parameters they used. The e-detection task we standardized includes English word and non-word primes followed by unrelated English target words. Participants have to indicate whether the prime contains the letter "e" or not. Although we tested the task with English stimuli, there are good reasons to believe that the task also works for non-English speakers or speakers who have English as a second language, as we will see below.

Experiment 1

In Experiment 1, we investigated the relationship between the e-detection accuracy and the duration of the prime. In addition, we examined to what extent e-detection is influenced by the lexical status of the prime. The latter was done in two ways. First, we compared e-detection in English words and in nonwords. In illegal nonwords, participants cannot use lexical top-down information to improve letter detection (Reicher, 1969). Second, we tested three groups of participants: Native English speakers, non-native English speakers whose first language shares the Roman alphabet, and non-native English speakers whose first language does not make use of the Roman alphabet. In this way, we were able to examine to what extent the results of the task differ for different types of participants researchers are likely to include in their experiments.

Method

Participants. All participants were undergraduate students from Royal Holloway, University of London. They were recruited on the campus. The first group consisted of 14 native English speakers. The second group consisted of 12 non-native English speakers whose first language made use of the Roman alphabet (Table 1). Finally, the third group consisted of 11 non-native English speakers with a first language that was not based on the Roman alphabet (Table 1). Participants either took part within a departmental research participation scheme or were paid 5 GBP.

Insert Table 1 about here

Materials. The experiment consisted of 336 trials, which had a different English six-letter word as the target. Half of these targets were preceded by another English word of six letters, the other half were preceded by illegal non-words of the same length. Half of the primes had one "e" in them and half did not contain an "e". The position of the "e" in the primes was equally distributed across the six letters in the nonwords and almost equally distributed in the words. When a nonword did not contain an "e", another vowel was inserted. Therefore all nonwords used in this experiment had at least one vowel. The identity of the inserted vowel was balanced across the positions in the nonwords (see table 2). All materials are listed in appendix A.

Insert Table 2 about here

Procedure. Participants were tested individually. On arrival they received oral and written instructions about the experiment. Participants were instructed to determine as accurately and rapidly as possible whether or not the first presented word of every prime-target pair contained the letter "e". They were informed that half of the stimuli would contain an "e". It was made clear to them that in many trials the prime would be presented too briefly to be perceptible. Participants were encouraged to make a guess on these trials and it was explained to them that often these guesses were more accurate than the participants thought. Participants responded by either pressing the left or the right shift key of the keyboard.

The experiment was controlled by DMDX software (Forster & Forster, 2003) on an IBM compatible PC with a CTX VL700 17 Inch monitor. Each trial in the experiment consisted of the presentation of a warning signal (######) in the center of the screen for 293 ms. After the warning signal a prime was presented on the same place followed by the target. The targets stayed on the screen until the participant responded or for a maximum of 2500 ms. All stimuli were presented in black in Courier New font, size 12, on a white background. No luminance measures of the screen could be made, but we used the brightness values that had been used at that work station for months (e.g., for word processing). The primes were presented in lowercase and the targets in uppercase. The inter trial interval time was 1170 ms.

The presentation times of the primes ranged from 35 ms to 105 ms, equally divided over 7 levels (35, 46, 58, 70, 81, 93 and 105 ms; multiples of 90Hz). This range was based on a pilot experiment that included 14 participants and was identical to the one here except for the presentation times of the primes. Thirty-five milliseconds was chosen as the lower bound because in the pilot experiment participants' accuracy was at chance level at prime durations of 35 ms and shorter. The presentation duration of a given prime was counterbalanced across the participants.

The experiment started with 20 practice trials. The presentation time of the primes in the practice trials was somewhat longer than during the actual experiment (presentation times ranging from 44 to 320 ms) to allow the participants to get familiarized with the task. The experiment itself was divided in 6 blocks of trials. Between each block participants were allowed to rest for a few moments before they continued by pressing the space bar. The order of the trials was randomized across the six blocks separately for each participant.

Results

All analyses reported in this paper were performed using R statistical software version 2.6.1, unless stated otherwise.

Trials in which the reaction latency deviated more than two standard deviations from the participant's mean reaction time were excluded from further analysis. Reaction times on trials on which participants responded incorrectly were not included in the response latency analyses either. A summary of the results can be found in figures 1-3.

Analyses were limited to ANOVAs over participants (the so-called F1 analysis). This is because we are not interested in generalization across stimuli. In all experiments we used exactly the same set of stimuli.

Insert Figure 1 about here

Insert Figure 2 about here

Insert Figure 3 about here

Group 1: Native speakers of English. The mean accuracy in the word trials was 0.70 (sd=0.14). In the nonword trials it was 0.67 (sd=0.15). A repeated measures analysis including two factors (prime presentation time type of stimulus) was performed on the accuracy data. This analysis revealed no significant difference between the words and the nonwords $[F(1, 13) = 3.393, p = 0.088]$, a significant effect of presentation time $[F(6, 78) = 35.479, p < 0.01]$, and no reliable interaction between the two factors $[F(6, 78) = 0.696, p = 0.654]$.

The dprime (Macmillan & Creelman, 2005) was calculated[1]. The mean dprime was 1.23 (sd=0.99) for words and 1.08 (sd=1.00) for nonwords. This difference was not significant $[F(1,13) = 1.701, p = 0.215]$. A significant effect of prime duration on dprime was observed $[F(6,78) = 27.337, p < 0.01]$. No significant interaction was found $[F(6,78) = 0.920, p = 0.485]$. The mean reaction time on the word trials was 745 ms (sd=168). On the nonword trials it was 727 ms (sd=129). An ANOVA analysis revealed no significant difference $[F(1,13) = 1.796, p = 0.203]$. The effect of presentation time was significant $[F(6,78) = 10.601, p < 0.01]$. The interaction effect of these two factors was not significant $[F(6,78) = 1.918, p = 0.088]$.

Group 2: Bilinguals with L1 based on Roman alphabet. The mean accuracy rate for the words was 0.74 (sd=0.15). In the nonwords trials it was 0.71 (sd=0.15). This difference was not significant $[F(1,11) = 1.610, p = 0.231]$. The presentation time of the prime had a significant effect on the accuracy level $[F(6,66) = 27.383, p < 0.01]$. There was no significant interaction effect between the two factors $[F(6,66) = 0.632, p = 0.704]$.

The mean dprime was 1.58 (sd=1.13) for words and 1.36 (sd=1.12) for nonwords. This difference was not significant $[F(1,11) = 3.309, p = 0.096]$. The effect of presentation duration was reliable $[F(6,66) = 21.659, p < 0.01]$. No significant interaction effect was found $[F(6,66) = 0.588, p = 0.739]$. The same pattern of results was found for the response latencies. The mean reaction time was 858 ms (sd=237) on the word trials and 853 ms (sd=255) on the nonword trials $[F(1,11) = 0.152, p = 0.704]$. A significant effect of the prime duration was found $[F(6,66) = 16.426, p < 0.01]$, but no interaction between prime type and presentation duration $[F(6,66) = 0.858, p = 0.532]$.

Group 3: Bilinguals with L1 not based on Roman alphabet. The mean accuracy level in the word prime trials was 0.70 (sd=0.13). The mean accuracy level in the nonword trials was 0.68 (sd=0.15). This difference did reach significance $[F(1,10) = 2.467, p = 0.015]$. The presentation time again yielded a significant effect $[F(6,60) = 15.352, p < 0.01]$. The interaction of both effects was not significant $[F(6,60) = 0.622, p = 0.712]$.

The mean dprime was 1.30 (sd=0.95) on the word trials and 1.15 (sd=1.00) on the nonword trials. This difference was not significant [$F(1, 10) = 4.153, p = 0.069$]. An effect of prime duration was found [$F(6, 60) = 11.791, p < 0.01$], but no interaction [$F(6, 60) = 0.378, p = 0.890$].

The mean response latency on the word prime trials was 842 ms (sd=247). On the nonword trials it was 819 ms (sd=255). This difference was not significant [$F(1, 10) = 4.327, p = 0.064$]. The effect of prime presentation time was significant [$F(6, 60) = 11.937, p < 0.01$]. No significant interaction was found [$F(6, 60) = 1.213, p = 0.321$].

Comparing groups 1-3[2]. The three groups did not differ significantly in their accuracy rates, [$F(2, 34) = 1.352, p = 0.272$] or dprime values [$F(2, 34) = 1.319, p = 0.281$]. Groups 1, 2 and 3 did not differ significantly in their reaction latencies either [$F(2, 34) = 1.216, p = 0.309$]. No significant interactions between the effect of Group and Prime Type were observed [$F(2, 34) < 1$].

Discussion

Experiment 1 evaluated the perceptibility of the primes across presentation durations ranging from 35 ms to 105 ms, using an e-detection task. As can be seen in Figures 1 and 2, for the workstation used, primes were next to invisible at 35 ms (dprime words = 0.28, dprime nonwords = 0.18) and were still not fully visible at 105 ms (dprime words = 2.11, dprime nonwords = 1.93). However, it is clear that the accuracy levels for the range of prime durations typically employed in masked priming experiments (50 - 67 ms) are well above chance.

We examined to what extent the accuracies and dprimes would differ as a function of the lexical status of the prime and the native language of the participants. There was a consistent, small trend towards better performance when the task involved English word primes than when it involved non-word primes. This difference hovered around the 0.05 significance threshold. However, in practical terms it was rather negligible. Looking at the dprimes, we find a difference of 0.14 in groups 1 and 3, and 0.23 in group 2 (remember that the difference was about 1.8 between the 35 ms and the 105 ms conditions). Furthermore, the difference was the same for native English speakers as for the two groups of bilinguals, indicating that the influence of word information on the probability of e-detection was very limited. Finally, the level of performance was very comparable for monolinguals and bilinguals (independent of whether their native language made use of the Roman alphabet or not). This again shows that within the proficiency range tested, the outcome of the e-detection task does not seem to depend much on linguistic status of the prime.

Together the results suggest that the task can be used both for native English speakers and participants with some knowledge of English (none of our bilingual participants were balanced bilinguals, although they, of course, mastered enough English to take classes in that language).

Experiment 2

In experiment 2 we tested whether the dprime values obtained in Experiment 1 would be comparable to those obtained in other laboratories, as has been tacitly assumed by most researchers. We repeated the e-detection task on the workstations used at Ghent University (Belgium), which has a well-established tradition of masked-priming experiments with verbal stimuli. The participants were students of the same university. They were Dutch-English bilinguals.

Method

Participants. Eleven Dutch-English bilinguals were recruited at the Faculty of Psychology of the Ghent University, Belgium. They participated for course requirements.

Material and procedure. The material and procedure were identical to Experiment 1. The on-screen instructions of the experiment were translated to Dutch. The computer that controlled the experiment was different from the computer used in the previous experiments. The experiment was run on an IBM compatible PC using a Phillips 17 Inch screen with the brightness and contrast settings normally used in this lab.

Results

A summary of the results of Experiment 2 can be found in Figure 4.

Insert Figure 4 about here

The mean accuracy level for the word primes was 0.77 (sd=0.15). For the non-word primes it was 0.75 (sd = 0.14). This difference reached significance $[F(1, 10) = 9.41, p = 0.011]$. The main effect of presentation time of the prime was also significant $[F(6, 60) = 28.08, p < 0.001]$, but not the interaction between the two variables $[F(6, 60) = 0.730, p = 0.627]$. The mean dprime was 1.82 (sd=1.10) for the word primes and 1.65 (sd=1.03) for the non-word primes. This difference was significant $[F(1, 10) = 14.696, p = 0.003]$. There was also a reliable effect of prime presentation time on the dprime $[F(6, 60) = 20.587, p < 0.001]$, but no interaction $[F(6, 60) = 0.521, p = 0.790]$.

The mean response latency was 758 ms (sd=177.5) in the word condition and 731 ms (sd=177.825) in the nonword condition. This difference did reach significance $[F(1, 10) = 5.929, p = 0.035]$. There was also a significant effect of presentation time $[F(6, 60) = 12.075, p < 0.01]$ and no interaction $[F(6, 60) = 0.441, p = 0.848]$. The participants of Experiment 2 were significantly more accurate in their responses than the participants of Experiment 1 if the accuracy was based on percentage correct

$[F(3,44) = 3.367, p = 0.027]$ and when it was based on dprime $[F(3,44) = 3.186, p = 0.033]$. The response latencies did not differ significantly $[F(3,44) = 1.143, p = 0.342]$.

Discussion Experiment 2

A comparison of the data of Experiments 1 and 2 indicates that the visibility of the primes was higher at the Ghent University laboratory of than at the Royal Holloway laboratory. Roughly, the visibility at each intensity in Ghent equalled that of one intensity up at Royal Holloway (i.e., the visibility at SOA = 46 ms in Ghent equals that of the visibility at SOA = 58 ms in Royal Holloway). See figure 5. This suggests that, everything else being the same, it would be easier to observe masked-priming effects at Ghent University than at Royal Holloway.

As indicated above, the difference in visibility could have many possible origins, related to the equipment, the lightning conditions, or individual differences between the two samples of participants. As for the latter, it is interesting to note that the Belgian participants (mean dprime = 1.74) showed an advantage over the native English RHUL students (mean dprime = 1.16), despite the fact that English was their second (or even third) language. As shown in Figure 5, this advantage was present over the complete range of conditions.

As in experiment 1, there was a small advantage for the word primes relative to the non-word primes (a difference in dprime of .17). Importantly, however, this difference was of the same size as the one reported in Experiment 1, indicating that it is does not depend on the proficiency level of the participants, at least not from a certain level on (psychology undergraduates who are fluent enough in English to read psychology texts).

Insert Figure 5 about here

Experiment 3

In Experiment 2 we compared different laboratories. However, the e-detection task can also be used to get an idea of the impact of different manipulations of the visibility of the primes. For instance, a technique sometimes used to increase the SOA without (supposedly) enhancing the visibility of the prime is to insert a postmask between the prime and the target. So, for instance, the premask (######) would be presented for 300 ms, the prime for 57 ms, followed by a postmask (######) for 100 ms, and only then the target. The insertion of the postmask between the prime and the target allows the prime to exert its influence for a longer time. However, does the insertion of a postmask also have implications for the visibility of the prime?

In the present experiment we used the e-detection task to verify the visibility of the primes in a study examining associative priming with acronyms (i.e., is it possible for British participants to prime the target word "television" with the masked acronym "BBC"?). In this study, we manipulated the SOA. In addition, we wanted to know whether the processing of acronyms was case dependent, as suggested by Seymour and Jack (1978), or whether it was possible to prime "television" with "bbc" or even "bBc". The former would suggest that acronyms are processed more like pictures than like words, whereas the latter would suggest that the letters of acronyms are first converted into abstract letter identifiers, as happens in visual word recognition (Bowers, 2000).

Method

Participants. Two groups of participants took part in experiment 3. Both groups consisted of 24 undergraduate students of Royal Holloway, University of London. The students took part in the experiment in exchange for course credit. All participants were native speakers of English.

Material. The experimental stimuli consisted of 96 prime-target pairs. Half of the primes were acronyms; the other half were words. All targets were words. For each target there was a related and an unrelated prime. The related primes could be displayed in upper case, in lower case, or in mixed case. The unrelated primes were always displayed in upper case (as we had no predictions concerning case differences for this type of primes). So, in all there were 8 prime conditions (see table 3).

Insert Table 3 about here

The acronyms were selected from an undergraduate student's research project in which students at Royal Holloway University of London, had been presented with a list of 170 acronyms. They were asked to write down the first associate that came to mind. Out of this list, the 48 acronyms with the most frequent associates were chosen. The average association strength was 71.9%. The acronym primes were 2 to 5 letters long and their associated targets were 3 to 12 letters long. The 48 word primes were selected from the Edinburgh Associative Thesaurus (Kiss, Armstrong, Milroy, & Piper, 1973). The word primes and targets were matched with the acronym primes and targets in association strength and in length. Four lists were created according to a Latin-square design, each including 96 prime-target pairs. Each participant was presented with one of the four lists. The filler stimuli consisted of 96 matched pairs of primes and non-word targets. Half of the filler primes were acronyms; the other half were words. The primes of the filler trials were presented in the same letter cases as those of the test trials (i.e., $\frac{1}{4}$ upper case, $\frac{1}{4}$ lower case, and $\frac{1}{4}$ mixed case). The filler stimuli had been made by starting from word trials similar to those used in the test trials, and then changing a letter of the target, so that this became a legal nonword. Each participant was presented with a total of 192 prime-target pairs. A practice session containing 20 prime-target pairs preceded the actual experiment. All stimuli were presented in black on a white background and printed in a bold Times New Roman font (12 pts). Although, Experiment 3 was run at RHUL, a different machine from the one in experiment 1 was used.

Procedure. Participants were tested individually. All stimuli were presented at the center of a 14 inch screen. On each trial, a premask was presented on the screen for 300 ms. The mask was made up of 14 "#" signs and had the same size and font as the prime and the target. Then the prime was displayed for 48 ms followed by the target, which stayed on the screen until the participant responded. Participants were asked to decide as quickly and as accurately as possible whether the string they saw was a real English word or a non-word by pressing the right and left shift key respectively. The participants were not informed about the presence of the primes. There were two different presentation conditions, depending on whether there was a postmask between the prime and the target. In group 2, but not in group 1, a postmask similar to the premask (but with a slightly bigger size of 13 pts) was presented for 36 ms between the prime and the target, extending the SOA in this condition to 84 ms without increasing the presentation time of the prime itself.

After the experiment, the e-detection task was completed by all participants. Material and procedure were the same as in Experiments 1 and 2, except that only the word primes were used. To match the e-detection task for group 2 with the viewing conditions in the priming experiment a backward mask made up of 6 "#" marks was presented for 36 ms after the prime. This mask had the same font but a bigger size (13 pts) as the forward mask.

Results

The results of Experiment 3 are summarized in figures 6,7 and 8.

Insert Figure 6 about here

Insert Figure 7 about here

Insert Figure 8 about here

Priming results, no post-mask (SOA = 48 ms). Four items were omitted from the analysis because the average percentage of errors in the lexical decision task on these items (74%) was too high. Outliers in the response latency were excluded from further analysis. Outliers (0.2%) were identified as trials in which the response latency was shorter than 200 ms or exceeded 1500 ms. Because we wanted to generalize the findings across participants and stimuli, we ran both F1 and F2 analyses. Reaction times of the correct responses and percentages of errors were submitted to Repeated Measure Analyses based on a 2 (Type: acronym and word) 4 (Relatedness: related upper, related lower, related mixed, and unrelated to the target) design.

The effect of prime type on the response accuracy was significant $[F1(1, 23) = 81.37, p < 0.01; F2(1, 360) = 9.55, p < 0.01]$: The percentage of errors was higher for target words preceded by words than for target words preceded by abbreviations. No other effects were significant.

There was a significant effect of prime relatedness on the response latencies in F1 but not in F2 [$F1(3, 21) = 3.08, p < 0.05; F2(3, 360) = 1.01, p = 0.38$]. Other effects were not significant. Planned comparisons showed that there was a significant difference between the related (upper, lower, and mixed) and the unrelated conditions for the word primes [$F1(1, 23) = 8.58, p < 0.01; F2(1, 360) = 5.23, p < 0.05$] but not for the acronym primes [$F1 < 1; F2 < 1$]. Responses were faster when word primes were related to the target than when they were unrelated. Related uppercase and related lowercase conditions did not differ significantly for the acronyms and for the words [$F1 < 1; F2 < 1$]. There was no difference either between the related uppercase and the related mixed case conditions for the acronyms [$F1 < 1; F2 < 1$] or for the words [$F1(1, 23) = 1.15, p = 0.29; F2 < 1$].

Priming results, post-mask (SOA = 84 ms). Analyses for group 2 were run in the same way as for group 1. Outliers were removed in the same way and the same 4 items were excluded from the analyses. The effect of prime type on accuracy was significant in the analysis by participants [$F1(1, 23) = 63.7, p < 0.01; F2(1, 360) = 3.04, p > 0.08$]. The percentage of errors was higher for target words preceded by words than for target words preceded by abbreviations. No other effects were significant. On response latencies there were significant effects of prime type [$F1(1, 23) = 11.19, p < 0.01; F2(1, 360) = 7.98, p < 0.01$] and prime relatedness [$F1(3, 21) = 6.25, p < 0.01; F2(3, 360) = 3.04, p < 0.05$]. Planned comparisons showed that the difference between the related (upper case, lower case, and mixed case) and the unrelated conditions was significant for the acronyms [$F1(1, 23) = 11.12, p < 0.01; F2(1, 360) = 4.91, p < 0.05$], indicating faster responses for primes related to the targets than for primes unrelated to the targets. There was also a significant difference between the related and the unrelated conditions for words in the analysis by participants but not in the item analysis [$F1(1, 23) = 7.62, p < 0.05; F2(1, 360) = 3.84, p > 0.05$]. Further analysis showed that there was no significant difference between related upper and related lowercase conditions for the acronyms and for the words [$F1 < 1; F2 < 1$]. Related uppercase and related mixed case conditions did not differ significantly either for the acronyms [$F1 < 1; F2 < 1$] nor for the words [$F1(1, 23) = 1.39, p > 0.25; F2 < 1$].

E-detection results, no post-mask. Trials in which the response latency deviated more than two standard deviations from the participant's mean reaction time were excluded from further analysis. The mean accuracy was 0.62 (sd=0.16) and depended on the prime duration [$F(6, 114) = 15.45, p < 0.01$]. The mean dprime was 0.77 and ranged from -0.07 at 35 ms to 1.43 at 105 ms [$F(6, 114) = 14.270, p < 0.01$]. The mean reaction time was 723 ms (sd=170.0) and was significantly influenced by the prime duration [$F(6, 114) = 5.04, p < 0.01$].

E-detection results, post-mask. Trials in which the response latency deviated more than two standard deviations from the respective participant's mean reaction time were excluded from further analysis. The mean accuracy was 0.74 (sd=0.17) and increased with prime duration [$F(6, 138) = 25.31, p < 0.01$]. The mean dprime was 1.62 and ranged from 0.65 at 35 ms + 36 ms postmask to 2.64 at 105 ms + 36 ms postmask [$F(6, 114) = 26.565, p < 0.01$]. The mean reaction time was 719 ms (sd=240.2) and decreased as a function of the SOA [$F(6, 138) = 8.61, p < 0.01$].

Effect of the post-mask on e-detection. The performance of group 1 and 2 on the e-detection task was compared.

The participants in the postmask condition responded more accurately [percentage correct: $F(2, 42) = 12.762, p < 0.001$; dprime: $F(1, 42) = 12.298, p = 0.001$]. However, they did not respond faster [$F(1, 42) = 0.003, p = 0.956$].

Discussion experiment 3

Experiment 3 compared the effects of associatively related acronym and word primes on the processing of target words. For the word primes, the effects were typical of those reported in the literature: There was significant priming at SOA = 48 ms and at SOA = 48 + 36 ms, and there was no effect of letter case (lower case primes, upper case primes, mixed case primes), in line with the hypothesis that visual word recognition is based on case-independent, abstract letter identifiers. The acronym primes provided us with a nice example of the added value the e-detection task can give. At first sight, the results are quite intriguing: Unlike word primes, acronyms do not result in a significant effect at SOA = 48 ms. However, at SOA = 48 + 36 ms, the priming effect is equivalent to that of the words. In addition, the priming effect is the same for the familiar upper case format (BBC) as for the less familiar lower case (bbc) and mixed case (bBc) formats, suggesting that the priming effect of acronyms is based on abstract letter identifiers as well.

The fact that there is no priming for acronyms at SOA = 48 ms could be taken as evidence for the claim that the information of an acronym needs more time to build up than the information of a word prime. However, the e-detection task informs us that the insertion of a 36 ms postmask between the prime and the target, not only increased the time in which the prime information could be built up, but also made the prime more visible. As a matter of fact, looking at figure 7 we can conclude that the insertion of a 36 ms postmask nearly coincided with the addition of 24 ms extra viewing time to the prime. It is therefore perfectly possible that priming effect of the acronyms depended on the visibility of the primes rather than on the SOA, as cautioned by Tzur and Frost (2007). The increase in dprime associated with the addition of the postmask was 0.85. This is about five times the difference in dprime we observed between word and non-word trials in experiments 1 & 2 (0.17). This too shows the size of the effect. The most important conclusion with respect to the present study, therefore, is that the addition of the e-detection task to a psycholinguistic experiment provides us with the information we need about the ways in which changes in the presentation timeline affect the visibility of the primes.

General Discussion

Psycholinguists making use of the masked priming technique thus far have happily ignored the fact that at short presentation durations the impact of a stimulus not only depends on the presentation duration, but on the total level of energy emitted by the stimulus and the degree of interference introduced by the stimulus presented after the prime. In general, they lack the equipment and the know-how to do low level physical measurements of stimulus intensities over (brief periods of) time and to correct for the level of ambient light and the distance of the participant to the screen. In addition, physical measurements do not take into account performance differences that may be present between various samples of participants.

On the other hand, psycholinguists have all the knowledge needed to run and analyze the e-detection task presented here (and inspired by the research of Finkbeiner et al., 2004). This allows them to compare and equate different work stations in their labs and to gauge the impact of changes in font, intensity, color, case, and so on. We have given two examples of how the application of the task can be used to compare conditions and, if needed, correct them.

The use of the e-detection task is further interesting, because we found the results to be little influenced by the language of the participants. In particular for those participants who have some knowledge of English (as is the case for many psychology undergraduates), we obtained convincing evidence that their performance is not lower than that of native English speakers (as a matter of fact, it tended to be slightly higher for our samples). Furthermore, there is little influence of whether the prime is an existing

English word or not (although there seemed to be a consistent trend for a slight word superiority effect). As briefly mentioned in the discussion of experiment 2, the use of the e-detection task is not limited to correcting differences in equipment. Also intrinsic differences between samples of participants in motivation and fatigue can be corrected for, because the e-detection task can easily be added to the experiment using the very same group of participants.

Finally, a look at the data indicates that researchers interested in unconscious processing may want to shift the SOA-range one or two steps downward. Although performance started to border chance accuracy at an SOA of 35 ms, in experiments we had dprimes above 0 (for the Ghent sample even larger than .5). The stimuli of the e-detection task are included in Appendix A, making it easy for the those who are interested to implement their own programme. In addition, the task will be made available as a DMDX script on the DMDX homepage for those who work with this software package.

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Appendix

Stimuli e-detection task

Insert Table A1 about here

Notes

[1] $Dprime = z(ProportionHits) - z(ProportionFalseAlarms)$. Hit proportions larger than $1 - (1/2n)$ were set to $1 - (1/2n)$. False Alarm proportions smaller than $1/2n$ were set to $1/2n$. In these corrections n was 24, being the number of trials per condition. See Macmillan & Creelman, 2005, Chapter 1.

[2] The analyses reported in this section were performed using SPSS statistical software (version 15.0) to allow for a correction of the repeated measure analysis using unbalanced groups based on Sum of Squares Type III.

Table 1

The first languages of the participants in group 2 & 3 of experiment 1.

Group 1		Group 2	
Language	Frequency	Language	Frequency
Dutch	1	Armenian	1
French	4	Cantonese	1
German	3	Mandarin Chinese	4
Polish	1	Greek	1
Spanish	3	Japanese	2
		Korean	2
	12		11

Table 2

Replacements of the ”e”s by other vowels in the nonword primes.

	Position					
Vowel	1	2	3	4	5	6
a	7	0	7	0	7	0
i	0	7	0	7	0	7
o	7	0	7	0	7	0
u	0	7	0	7	0	7

Table 3

The conditions in Experiment 3.

	Prime Conditions				Target
	Related Upper	Related Lower	Related Mixed	Unrelated	
Abbreviation	VCR	vcr	vCr	ABS	VIDEO
Word	MEN	men	mEn	NEW	WOMEN

Table A1

Stimuli e-detection task

Non Word Primes				Word Primes			
Prime does not contain e		Prime contains e		Prime does not contain e		Prime contains e	
Prime	Target	Prime	Target	Prime	Target	Prime	Target
affgxd	ABRUPT	ecpkzg	ACTING	strong	PISTOL	really	STANDS
hihjgc	ACQUIT	cekaso	ACTION	toward	SALAMI	twenty	BOARDS
kvomgf	AIRING	skeyyh	ACTUAL	fairly	BRANCH	rather	FIRING
cwkusz	ANIMUS	qziehb	ANALOG	amount	TAUGHT	moment	CUSTOM
otigap	ANORAK	pyofec	ANGINA	family	RATION	police	BAMBOO
ypjsmi	AROUND	xonspe	ASSIST	groups	CARING	enough	INSULT
odyhsf	ASTRAL	epvxhc	BANANA	paints	HUMANS	upheld	PATHOS
duikcf	BASICS	uezjqj	BANDIT	tracts	GRANTS	earthy	PARITY
raavbj	BORROW	avefhh	BARROW	truant	ORGANS	ridges	COURTS
ourilj	BOTTOM	vkrekl	BINARY	humbly	COLDLY	injure	AFFAIR
vnhqoy	BRAINY	mqzbeh	BITING	phobic	FACING	operas	FORMAL
vxhvhu	BRAZIL	gdckqe	SHINNY	thatch	COUNTY	legion	FABRIC
aqfvjo	BRIGHT	epkhdx	BOWING	points	IMPORT	minute	COUSIN
lipzyk	BURLAP	aeuqvb	BOXING	trying	LOUDLY	easily	STUDIO
vkoiip	BYPATH	msezrp	BRITON	bottom	THROWN	pretty	PARISH
mmnuyk	BYWORD	agrejy	CANARD	almost	COHORT	second	INTACT
qmhgaa	CANTOR	pfjxew	CANNON	simply	BRAINS	looked	PORTLY
vcydai	CORDON	bzsnje	CANTON	labour	STATIC	object	WILDLY
oidijl	DAFTLY	ewsuoq	CANYON	spoils	HARROW	edging	WAVING
fugxyx	DARKLY	reqond	CAUDAL	falcon	RAPIDS	tremor	TRUCKS

tranmn	DOMAIN	dweplx	CHORAL	wallow	WOUNDS	alleys	CALMLY
fyoikf	DURING	yyjelp	CITRON	bounty	RIBBON	outlet	ANIMAL
gbjxor	FAMOUS	vuaxek	CIVICS	swarms	BOOTHS	pearls	HATING
tadzbu	FLIGHT	mwoyze	CLAMMY	rancid	THINKS	awhile	FOSSIL
akdbkw	FRIGHT	evgqvn	CLINIC	growth	SUMMON	mother	SAVING
higknl	FUNGUS	newzqf	COBALT	spirit	LAUNCH	effort	BORING
jgoshh	GALLON	ibefqx	COLONY	saying	MUTINY	change	ANNUAL
mbruuo	GRIMLY	uwiekk	COMMON	colour	CIRCUS	theory	HANGAR
ovhcad	GRISLY	svxmen	COWBOY	bought	WADING	lovely	SWIFTS
puicai	GRUNDY	ascoue	PLOUGH	prison	VIRGIN	behind	CASING
otfvgs	HALLOW	eclsig	FALLOW	unborn	ALWAYS	benign	HOLLOW
dulkua	HAVANA	leihdj	FRIGID	vainly	WINDOW	motels	TRACKS
ztadxq	HUMBLY	gveclx	GRINGO	chubby	COMBAT	shears	STRING
bksikt	HUMBUG	qmhedy	GUNMAN	bazaar	WHILST	sparse	HABITS
krtcor	KIDNAP	jnxfeg	INDOOR	proton	KIMONO	egoism	SKILLS
zvmwgu	LABIAL	mynqye	INFANT	thorns	ODIOUS	tugged	BALLAD
azfgsp	LIGHTS	eqkhnk	INLAND	status	KINDLY	itself	UPHOLD
ditctg	LIKING	bexocx	INSIST	though	ROTARY	entire	SCOUTS
vaoora	LITMUS	diegcp	IRONIC	taking	RACIAL	reason	THUMBS
iazupb	LYRICS	clfesx	ITALIC	island	SYMBOL	useful	CAMPUS
nymfak	MALLOW	znkbel	JACKAL	attack	SLOUGH	called	GIBBON
rwkzsi	MAMMAL	cpvure	JULIUS	asking	SHROUD	couple	STRUCK
ozsnjz	MANTIS	expwbj	LARVAL	tailor	PARTLY	embryo	LAYMAN
wuidsk	MINING	weqras	LOVING	rascal	SPRINT	sermon	PARDON
yaajza	NUDITY	aieryo	MAGNUM	astral	PILLOW	combed	STITCH
cojiln	OBTAIN	usnekw	MAROON	rarity	FORGOT	queasy	HIDING

oltnor	ORISON	lquzey	MATRIC	sprays	PROFIT	supine	MIRROR
ffrwsu	ORPHAN	rwwzme	MATRIX	crotch	RHYTHM	digest	SPRING
auyvgv	PARING	ejdoqw	MILDLY	common	BLOODY	office	INJURY
uizoty	PATROL	melaos	FLOPPY	should	CHAINS	spread	CARBON
kboyss	PATRON	wdeutu	NARROW	ground	FOUGHT	person	COSMOS
ctzuls	PAWPAW	mcmeba	NORWAY	nobody	BRANDY	fields	GHOSTS
myvrao	PLURAL	dhipef	OPTION	living	SCURVY	wanted	THINGS
pbyqyi	PURIST	cgmqne	ORIGIN	public	FLORAL	eating	CRITIC
oqmusu	PUT UP	edwcgk	PACIFY	causal	THANKS	treats	FILIAL
puvnoo	RACIST	iejdhd	PAVING	inlaid	COLLAR	ascend	ARTIST
tiaaxb	RARITY	ydekxt	PLAINT	inflow	ATOMIC	delays	GOTHIC
kpriut	RAVING	gmcezq	POSSUM	muslin	THIGHS	easing	WAKING
dmsiov	RAVISH	ybwdew	PRISON	squint	OCCUPY	oblige	UNFAIR
lrlyyu	RISING	mzorce	PSALMS	charms	DOCTOR	flared	NATION
advgaj	ROBUST	eurgbx	PUBLIC	follow	RULING	sexual	WHOOPS
piihbi	SAMOAN	zedanp	RANSOM	crisis	MUTTON	record	GLOBAL
xioujr	SCURRY	saemyi	RARING	narrow	ALIGHT	design	FLYING
fbauiw	SINFUL	zuyegm	SANDAL	lights	FLIMSY	ending	ANYHOW
tdamag	SIRRAH	wxpces	SANITY	afford	PANTRY	employ	WORTHY
dudjbi	SKINNY	kvfsae	SIMPLY	rising	TRUTHS	editor	POTATO
ovjwnq	SNOTTY	eqjwqy	SODIUM	laughs	RACING	checks	LOSING
bupwsq	SPINAL	fefrvc	SQUASH	victim	COASTS	ghetto	CAUGHT
sxaydc	SPLINT	rbejhb	STANCH	cotton	HIKING	ideals	BUTTON
vpbisu	SPOOKY	znpehp	STRAND	visual	BRUTAL	novels	SCRIPT
ygcwog	STATUS	vqplex	SUMMIT	hoping	DINING	eighth	STOCKY
cccitu	STICKY	lkaale	SUNLIT	starts	VOTING	escort	MOSTLY

ajxxll	STRAIN	ednttk	SUPPLY	around	MONTHS	morose	BUYING
rijmnq	STRONG	qewarv	SWITCH	rights	POUNDS	torque	NOTION
ngoufh	TAKING	jbecfd	THINLY	guilty	WITHIN	arcade	SHADOW
otaufq	THIRST	haiehd	TRASHY	stairs	HIGHLY	virile	NIGHTS
mucpaz	TIDDLY	rwdmeu	TUMULT	vision	NORMAL	sifted	MARTIN
jokrsi	TITBIT	nlooye	TYCOON	factor	THIRTY	myself	SLIGHT
ochaji	TOUCAN	ecikzv	UNFOLD	firmly	SOCIAL	appear	SMOOTH
kuttaz	TROUGH	benibr	UNSOLD	fourth	GIVING	repaid	SIGNAL
xgakcm	UPLIFT	breuqi	UNWIND	autumn	MAKING	peanut	CRYING
ylviio	VACUUM	uqleju	UPROOT	hungry	CLOUDS	expand	CLAIMS
smdkou	WILLOW	sflves	VIOLIN	loving	BLACKS	belong	PUPILS
mbpwqu	WRIGHT	cbkwxe	SUBMIT	crowds	WHISKY	nearby	FINISH

Figure Captions

Figure 1. Response accuracy in Experiment 1 for the three groups of participants as a function of prime type (word/non word) and prime duration. Vertical bars denote 1 standard error.

Figure 2. Dprime values in Experiment 1 for the three groups of participants as a function of prime type (word/non word) and prime duration. Vertical bars denote 1 standard error.

Figure 3. Response latency in Experiment 1 for the three groups of participants as a function of prime type (word/non word) and prime duration. Vertical bars denote 1 standard error.

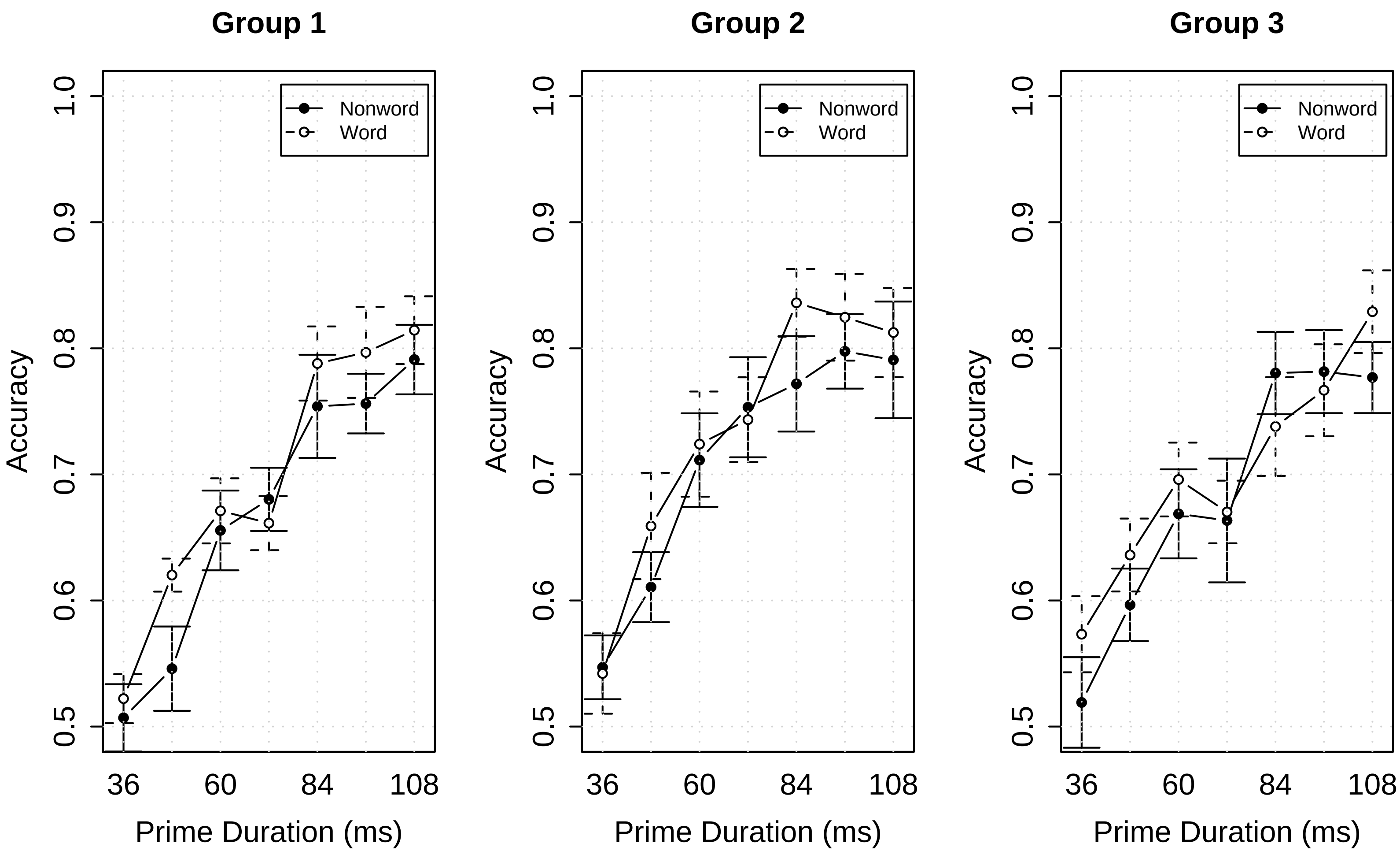
Figure 4. The results of Experiment 2. Vertical bars denote 1 standard error.

Figure 5. Dprimes of the students from Ghent University relative to those of the three groups of students tested at RHUL for the various conditions. It can be seen that the superior performance was present over the total range of SOAs tested. Vertical bars denote 1 standard error.

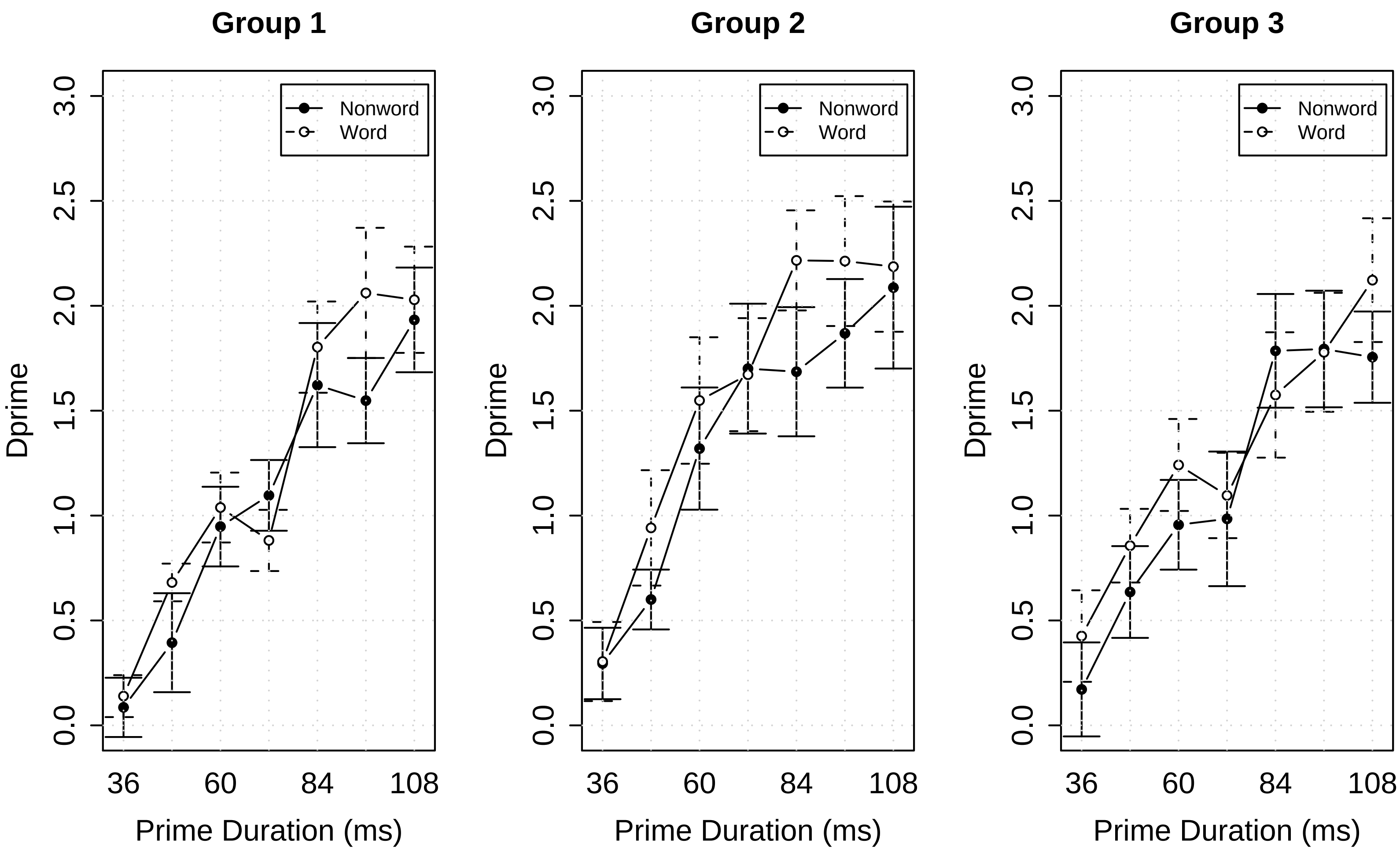
Figure 6. The mean response accuracy in the 4 conditions of experiment 3 as a function of the type of prime. Vertical bars denote 1 standard error.

Figure 7. The mean response latency in the 4 conditions of experiment 3 as a function of the type of prime. Vertical bars denote 1 standard error.

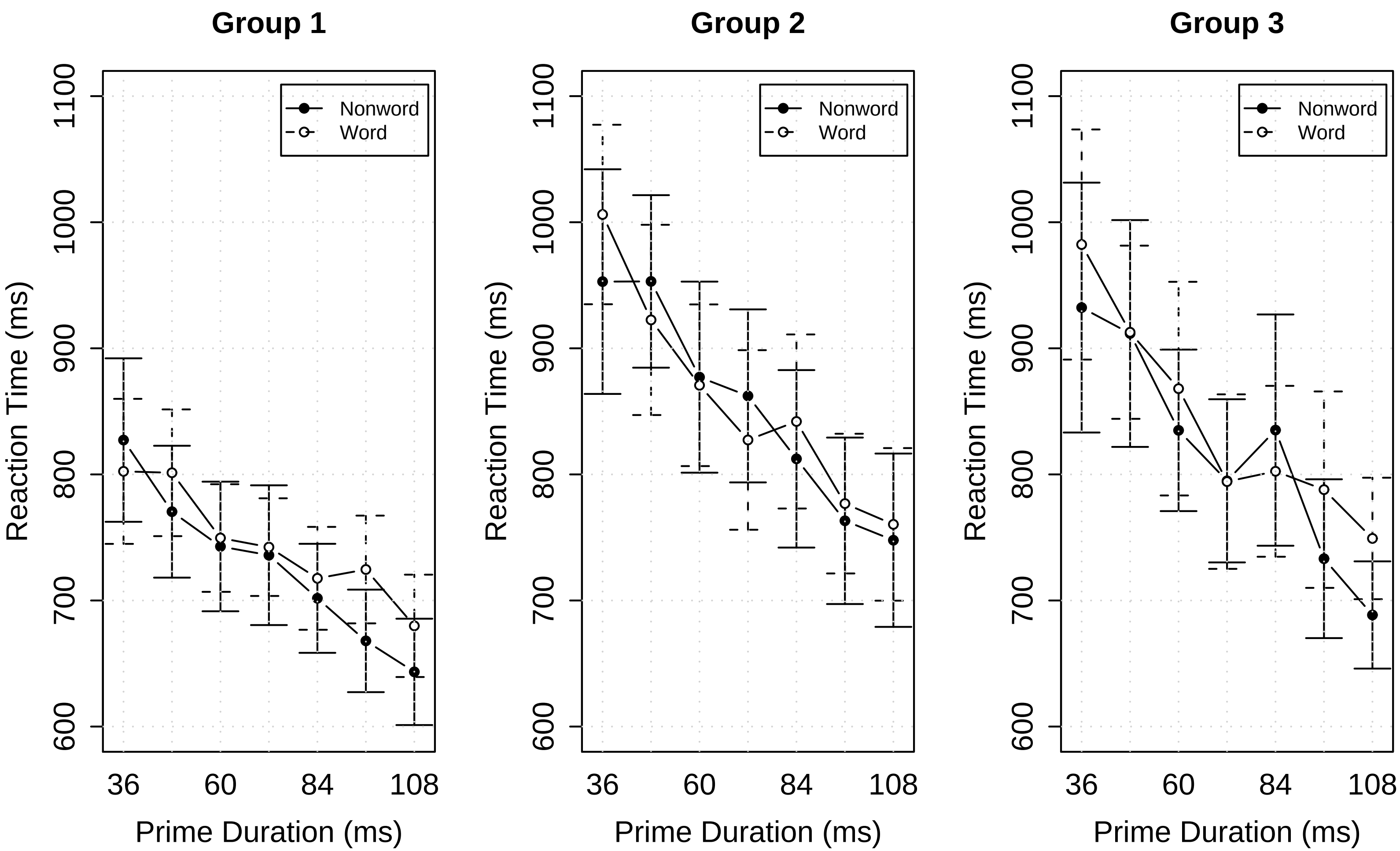
Figure 8. The results of the e-detection task in Experiment 3. Vertical bars denote 1 standard error.



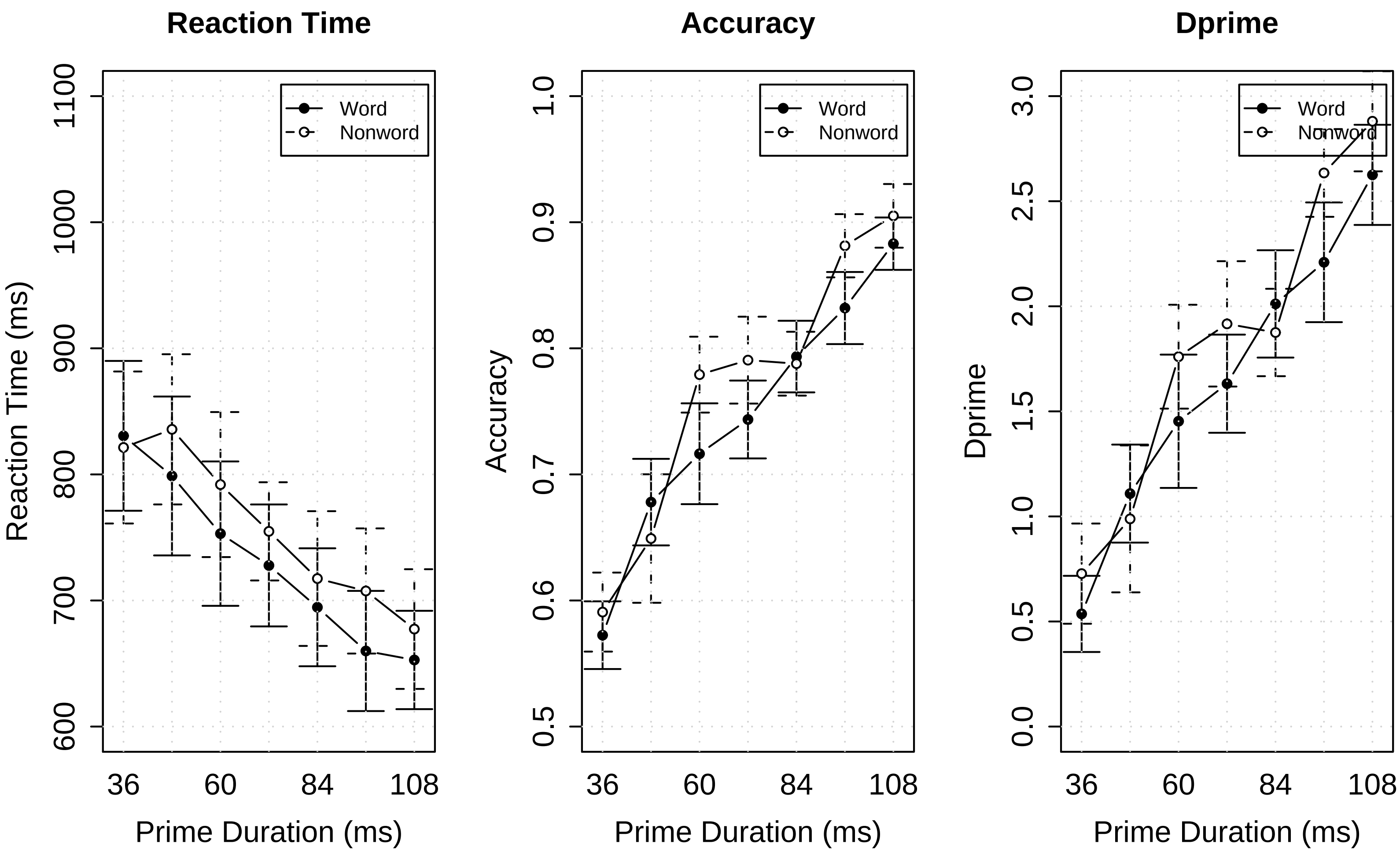
The e-detection task, Figure 1



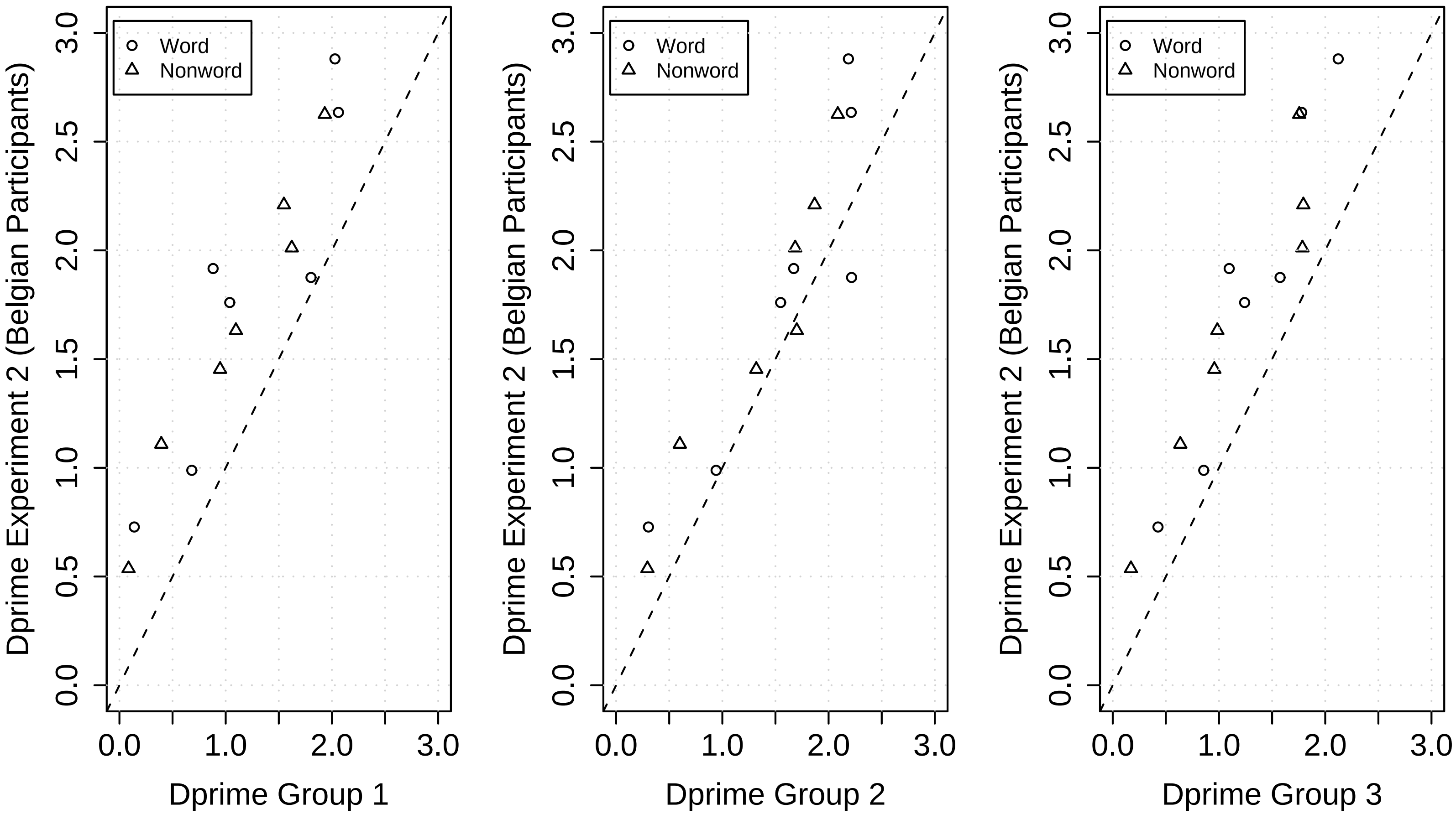
The e-detection task, Figure 2



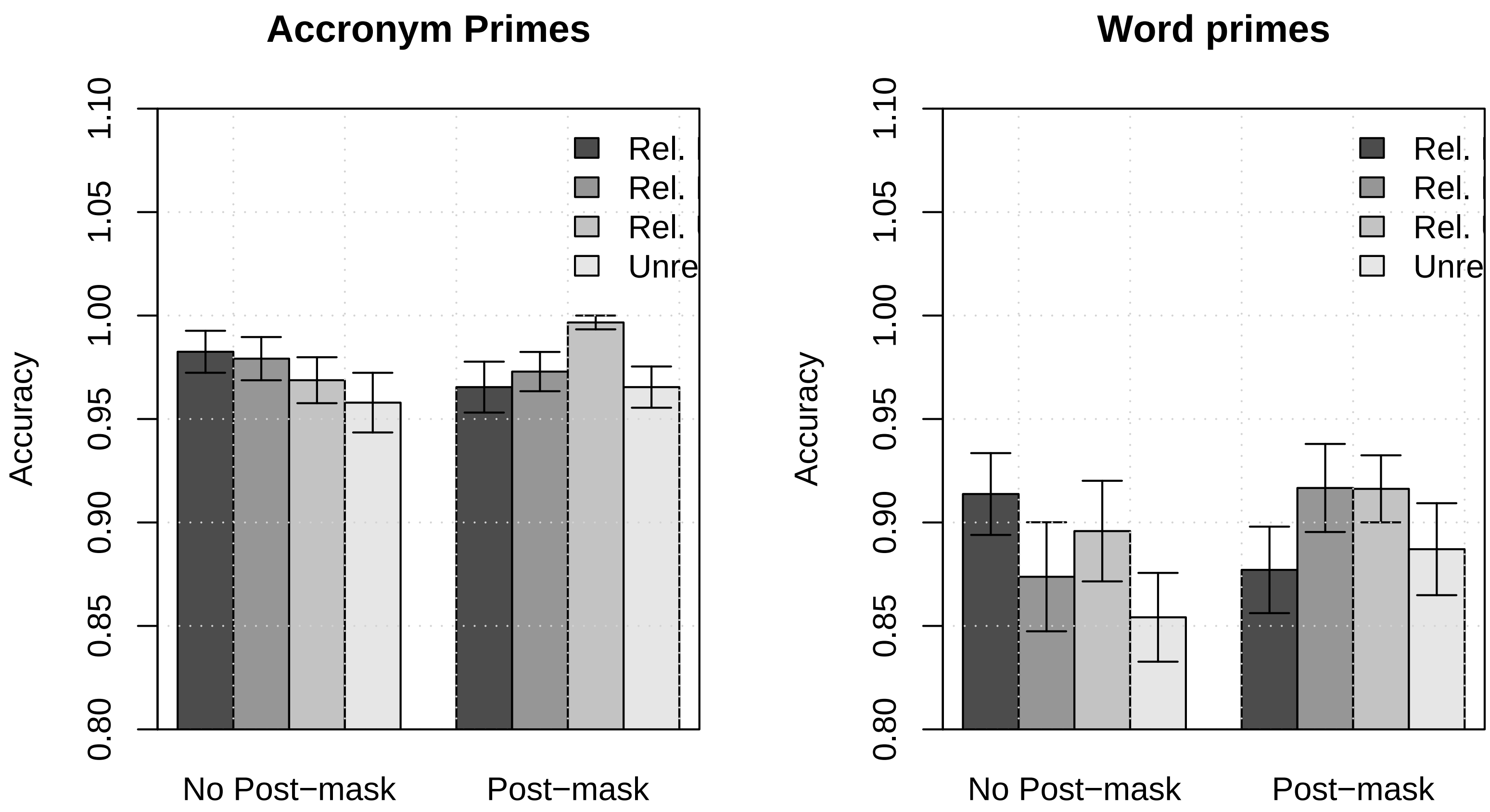
The e-detection task, Figure 3



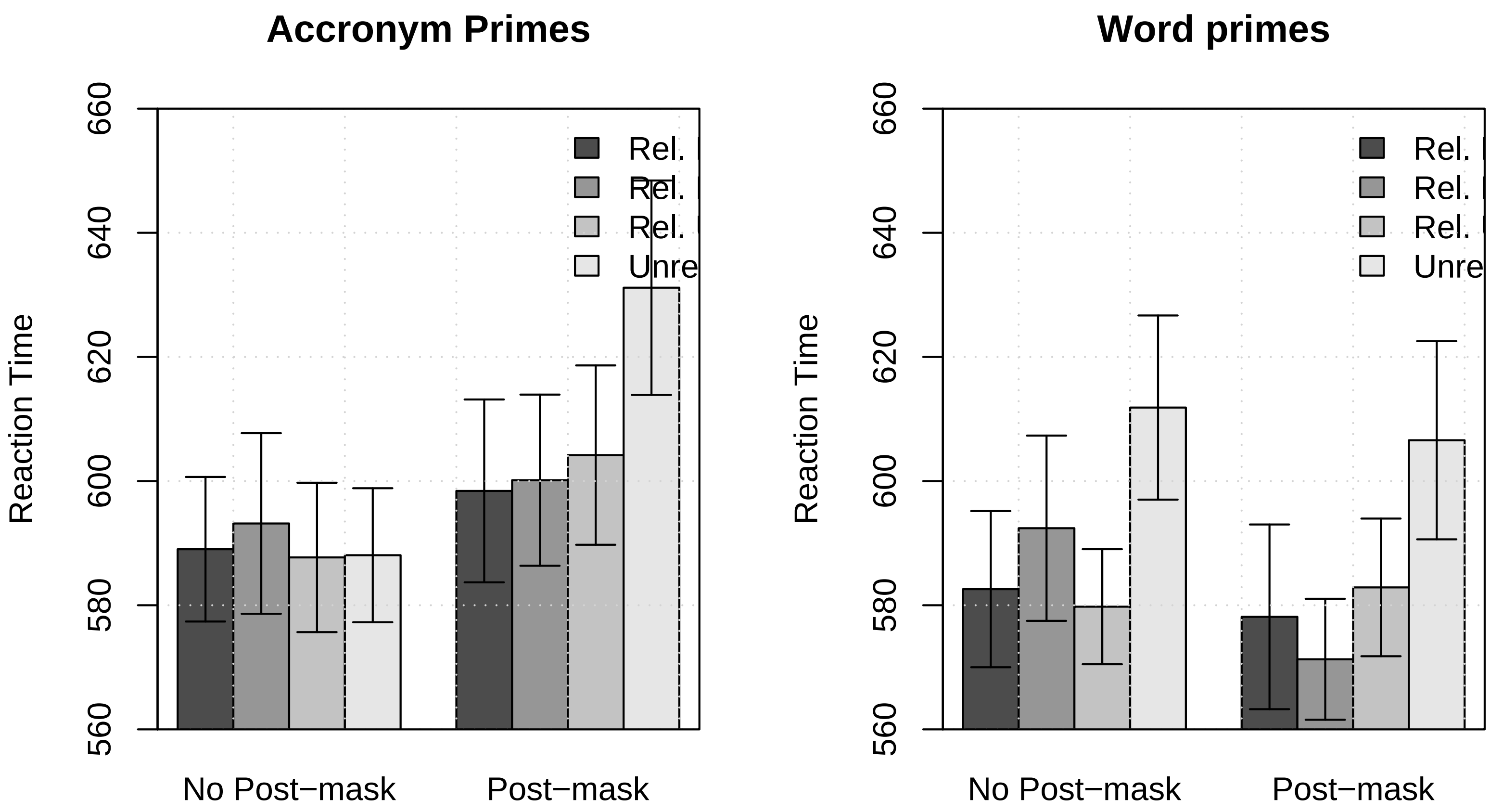
The e-detection task, Figure 4



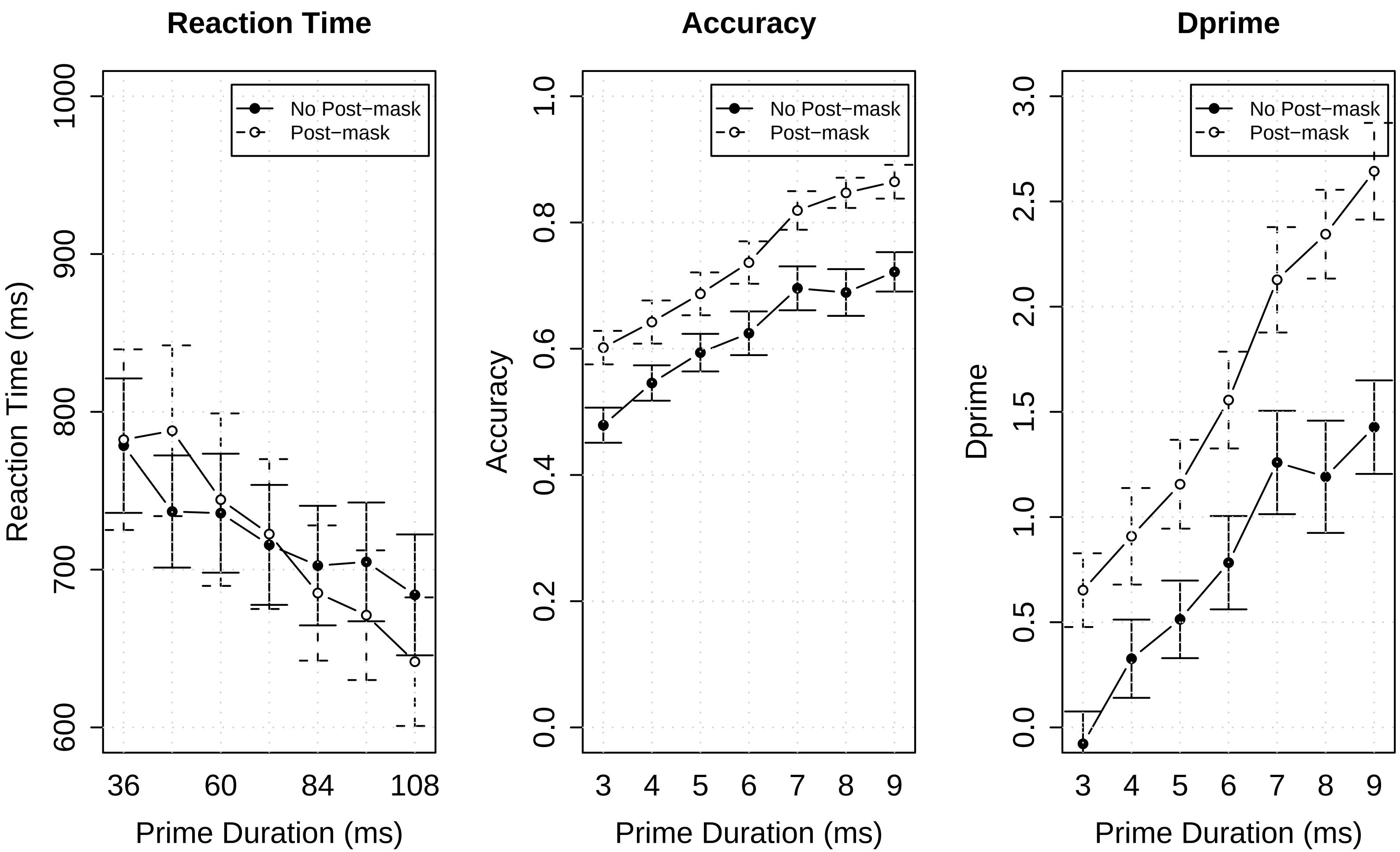
The e-detection task, Figure 5



The e-detection task, Figure 6



The e-detection task, Figure 7



The e-detection task, Figure 8