Lexical processing in Thai-English bilinguals

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This main focus of the research reported in this paper is upon the role that phonology has to play in the early stages of visual word recognition. However, it will be argued that in order to unambiguously examine the contribution that phonological processing has to make to lexical access, it is necessary to use a masked priming procedure with a particular subject group. Why these two features are necessary will be considered below.

Over the past quarter of a century there has been a continuing debate concerning the role of phonology in the identification of written words. That phonology has a role has been demonstrated in a number of experimental tasks: In nonword rejection times in lexical decision (Rubenstein, Lewis and Rubenstein, 1971), in sentence verification, (Baron, 1973), the Stroop task (Dennis & Newstead, 1981), and in proof reading (Gough & Cosky 1977). In each of these tasks the subject's performance indicated that they had phonologically processed the written foils (either by an increase in their correct rejection times or by an increase in their error rates).

On the other hand it has been argued that phonological recoding is not the only way to gain access to a word's lexical entry (Meyer, Schvaneveldt & Ruddy, 1974; Coltheart, 1978; Coltheart, Davelaar, Jonasson & Besner, 1977). These authors have suggested that lexical access can also proceed directly using the visual representation of the stimulus. In this regard it is pointed out that homophones exist in many languages. How could the meaning of the appropriate homophone be derived without recourse to how they are spelled? Further, in some languages such as English many words have irregular spellings (e.g., yacht); some means of ensuring that such words be pronounced properly appears necessarily to involve an orthographic analysis. Clearly this is the situation for languages like Chinese that use character-based rather than alphabetic writing systems.

In short, although the existence of phonological influences on reading are not denied what is questioned is whether such influences must affect the process of lexical access. That is, the automaticity of these phonological effects has been questioned. For example, McQuade (1981) demonstrated that the pseudohomophone effect in lexical decision does not always emerge but seems to be dependent on the proportion of pseudohomophones present in the experiment.

Recently, however, new evidence that phonological activation occurs automatically in visual word recognition has been reported. For instance, Van Orden (1987) has reported that subjects produce larger false positive error rates in a semantic categorisation task when they respond to stimulus foils that are homophonic to category exemplars (e g ROWS for the category A FLOWER) than when they respond to spelling control foils (e.g., ROBS). These results suggest that a phonological code has been derived from the letter sequence ROWS, contacting the lexical representation of ROSE. This phonological code then gives rise to interference in decision making.

However it is not clear that the semantic categorisation task is a suitable response measure with regard to making claims regarding access processes alone. It has been suggested that this task may be sensitive to more than just lexical access, requiring as it does access to word meaning, and not just to stored knowledge about the word form, (Forster, 1985; Verstaen, Humphreys, Olson and D'Ydewalle, 1995).

Other recent evidence supporting the view that phonology is automatically involved in word recognition comes from studies by Perfetti, Bell and Delaney (1988). These experiments are potentially more likely to index automatic phonological access to the lexicon as the response measure used (tachistoscopic word identification) requires at only the recovery of the visual form of the stimulus. In this procedure, subjects have to identify a briefly presented target word that has been masked by a letter string that is either phonologically related or not. Masking is reduced when target and mask have a phonological relationship.

However, while tachistoscopic identification in principle requires only detection of visual form, both Brysbaert and Praet (1992) and Verstaen, et al., (1995) have shown that phonological effects in backward masking may be strategy dependent. Such findings cast doubt on the utility of using such effects for arguments about the automaticity, or indeed even the primacy of phonological effects on word recognition.

The current set of experiments avoids these problems by using the masked priming technique developed by Forster and Davis (1984). In this procedure a sequence of visual stimuli are presented in rapid succession, each stimulus being superimposed on the previous one. The initial stimulus acts as a visual mask; the second as a prime, and the third as a target, which also acts as a backward mask.

The initial visual mask and the target (backward mask) are clearly visible; the prime is displayed relatively rapidly and the combined action of the forward and backward masks makes it unavailable for conscious report.

This masked priming procedure uses lexical decision as the response measure. This minimizes some above mentioned concerns regarding the nature of the response task and has been shown to be resistant to the proportionality effects typically found when related words are clearly presented (Von Baggo, 1990). Further this procedure is unaffected by a problem that possibly invalidates the masked priming technique of Evett and Humphreys (1981) and Perfetti et al. (1988) (see Davis & Forster, 1994).

Recent results using this techniques have provided evidence against the importance of phonological effects in reading (Davis, 1990; Davis, Iakovidis & Castles, submitted). These studies (in English) examined the effects of homophonic and pseudohomophonic primes on targets and showed that there was no benefit to processing for these "sound-the-same" primes when compared to graphemically matched controls.

The problem with accepting these findings unequivocally is that it is possible that potential phonological effects have been concealed by an opponent process operating at the orthographic level. Simply put, the phonological effects that arise when reading are cancelled out by opposing orthographic effects (see McClelland & Rumelhart, 1981).

One way to avoid such cross-activation between the orthographic and phonological processing systems would be to use primes and targets from languages that do not share orthographic systems. However, a basic consideration with this research strategy is whether a masked priming effect will actually be found across languages that have different writing systems. That is, although cross-language priming has been found in many studies, these have used languages that share orthographic scripts, e.g., Spanish-English (Sanchez-Casas, Davis & Garcia-Albea, 1992) and Dutch-English (de Groot & Nas, 1991) to date none have been published reporting data for languages that have radically different writing systems.

The first experiment then, will examine whether there are any cross-language masked priming effects with Thai/English bilinguals. In order to maximize the chances of finding a priming effect, Thai primes will be presented before English targets. This prime-target order was used, as Keatley, Spinks and de Gelder, (1994) have suggested that processing links are stronger from a person's first language (L1) to their second language (L2) than the other way around. Further, some of the primes used had both a form (phonological) and a semantic relationship to their targets (i.e., loan words). The reason for incorporating this feature into item selection was because it has been shown that such "cognate" translation pairs produce a stronger priming effect (Sanchez-Casas et al., 1992). A further set of prime-target pairs will also be used that are translation equivalents only (i.e., a noncognate set). This non-cognate set was included because in previous priming studies (using languages that share orthographies) the priming effect for these translations pairs has been marginal (de Groot & Nas, 1991; Sanchez-Casas, et al, 1992). As outlined above, it may be that a different outcome will result when primes and targets are written in different scripts, i.e, a meaning-only effect may be revealed.

Experiment 1

Method

Subjects

24 Thai-English bilingual subjects were selected on the basis of information about their language history obtained using a questionnaire.

Materials

Each item consisted of a sequence of three stimuli: a forward mask (a block of keyboard symbols), a prime (for English this was always presented in lower-case; for Thai it was 50% the height of the target) and a target (presented in upper-case letters for English). Targets words were chosen in order to form two sets, (one set based on cognate translations, the other on noncognate translations) with three different priming conditions within each set.

The cognate set: Thirty-six English words were selected as targets for the first three Experimental conditions. These words were chosen so that they could be paired with Thai "loan" word primes, i.e., Thai words, originating in English, that have their pronunciation close to their English equivalents.

For each of these targets three type of primes were used: An Identity condition in which the English prime was presented in lower-case. A Cognate condition using primes which were the Thai "loan" equivalents of the English words targets; both their pronunciation and meaning were thus closely related to the targets.

Finally, a Control condition, that used primes that were Thai words matched in number of letters and form to the cognate primes but unrelated in meaning and phonology to the English targets. Targets were constructed so that they were physically larger than the primes.

The noncognate set: A further 36 English words were selected to act as targets for a further three experimental conditions that made up the noncognate set. The first of these condition consisted of an Identity condition; target words preceded lower-case versions of themselves. The second condition of this set consisted of Noncognate translation pairs, primes that were the Thai translation equivalents of English targets, i.e., their meanings were closely related, but their phonologies were unrelated to the targets. The final condition consisted of a Control for this set of words, Thai word primes matched to the primes of the noncognate condition but unrelated in meaning and phonology to the English targets.

A set of 72 orthographically legal nonwords were generated, each similar in length and syllabic structure to one of the English words word targets. Prime/target conditions were constructed to mirror the word conditions, i.e., Identity, Translation and Control. As the targets were nonwords the translation and control conditions consisted simply of Thai word primes.

Three versions of the experiment were constructed so that each target would appear in each of the priming conditions, without being repeated within a version. A set of 14 practice items were constructed, each set preceded the appropriate version.

Procedure and data treatment

Subjects were tested singly, in one or other of the versions of the experiment. They were asked to make a lexical decision about the item presented in upper-case letters. Subjects indicated their decisions by pressing one of two response buttons, "word" responses being made with the preferred hand. No mention was made of the number of stimuli that would be presented on each trial. For each subject, the computer provided a different pseudo-random order of item presentation.

Items were presented in a computer-controlled video display in which the timing of the display was synchronised with the video raster (Forster & Forster, 1990). Each stimulus was centered in the viewing screen, superimposed on the one preceding. The display used a white P-4 phosphor, which has fast decay characteristics. Each item consisted of a sequence of three stimuli. The first, acted as a forward mask, consisted of a block of keyboard symbols, length-matched to the prime and target, which was displayed for 355 ms. This was immediately followed by a lower-case prime, displayed for 57 ms, which was in turn followed by an upper-case target displayed for 355 ms. Feedback about speed and accuracy was provided to each subject after each response in the appropriate test language.

Data corresponding to incorrect responses were discarded from the analysis. To moderate the influence of outliers, a cut-off value of two standard deviations above or below a subject's mean was set and latencies outside this range were trimmed to the cut-off. Any subject who made more than 15% errors was replaced.

Results

The mean reaction times and percent error rates for the cognate set are shown in Table 1.1. It can be seen that there is a priming effect for the both the within-language Identity condition and the cross-language Cognate condition. That there was an overall effect of prime type for this item set was confirmed by two analyses of variance, one for the subject data (collapsing over items) and one for the item data (collapsing over subjects). The factors in the analysis were Group (subject group in the subject analysis, item group in the item analysis) and Prime Type (Identical, Cognate translation, and Control). For latencies the effect of prime type was significant, F_1 (2,42) = 28.98, $p < 0.05$, F_2 (2,66) = 29.13 $p < 0.05$. However there were no prime type effects in the error data, F_1 (2,42) = 1.38, $p > 0.05$, F_2 (2,66) = 2.39 $p > 0.05$.

Table 1.1 about here

A series of two planned comparisons were conducted in order to determine if the Identity and the Cognate translation conditions differed from the Control condition. Both showed significant priming in the latencies data, F_1 (1,21) = 59.47, $p < 0.05$; F_2 (1,33) = 25.93, $p < 0.05$ for the Identity condition and F_1 (1,22) = 40.14, $p < 0.05$; F_2 (1,33) = 51.54, $p < 0.05$ for the Cognate translation condition. In the error data there was no priming for the Identity condition with both subject and item F's < 1. There was however a trend for a priming effect in errors for the Cognate translation condition, F_1 (1,21) = 2.17, $p > 0.05$; F_2 (1,33) = 5.77, $p < 0.05$.

Table 1.2 shows the mean reaction times and percent errors for the

noncognate set. As with the cognate set there was an overall effect of prime type for latencies, F_1 (2,42) = 9.57, $p < 0.05$, F_2 (2,66) = 7.75, $p < 0.05$ but not for errors, F_1 (2,42) = 2.24, $p > 0.05$, F_2 (2,66) = 3.04, $p > 0.05$.

Table 1.2 about here

Consistent with the pattern shown for the cognate translation set, there was a priming effect for the Identity condition: For latencies F_1 (1,21) = 18.88, $p < 0.05$; F_2 (1,33) = 7.88, $p < 0.05$, but no effect for errors with both subject and item F's < 1. Further there was a priming effect found for the Noncognate translation condition, both for latencies F_1 (1,21) = 8.63, $p < 0.05$; F_2 (1,33) = 18.3, $p < 0.05$ and for errors, F_1 (1,21) = 5.21, $p < 0.05$; F_2 (1,33) = 5.79, $p < 0.05$.

Discussion

A clear cross-language priming effect was found for both the Cognate and the Noncognate prime conditions. The finding of a reliable priming effect is important for several reasons. First, it demonstrates that masked priming can occur for primes and targets written in languages that have very different printed forms. Second, finding a robust noncognate priming effect supports the view that a wider range of priming effects will be revealed for primes and targets that are not likely to inhibit each other's orthographic processing. In this regard it should be noted that noncognate priming has not been reliably found with for languages that have the same scripts (Sanchez-Casas, et al., 1992; de Groot & Nas, 1991; Davis, Sanchez-Casas and Garcia-Albea, (submitted).

A straightforward interpretation of why this noncognate priming effect occurs across Thai and English can be made within an interactive activation framework (see McClelland & Rumelhart, 1981; Ferrand and Grainger, 1994). In such models, both orthographic and phonological units can activate word units in the mental lexicon. These in turn can interact with each other via both facilitatory and inhibitory connections. In languages that have the same orthographies (or within a single orthographic system) orthographic differences between a prime and its target may, via inhibitory connections, cancel out any facilitation due to a phonological match between them. However, this may not be the case for languages that have quite different scripts as there would appear to be no need to inhibit competition between the two orthographic processing systems (as there would be none). Given this, then, any shared features (either phonological or semantic) between a prime and its target would act as a source of response facilitation.

Before looking solely at phonological effects, a second experiment was carried out in order to examine whether the direction of prime/target translation might be an important factor in the production of a priming effect. There are two reasons why the issue of prime/target language is of interest. The first, is of some practical importance with regard to providing the optimal conditions for testing whether a phonological relationship between prime and target alone can produce a priming effect. The second, concerns whether Thai and English primes and targets will behave in the same way as those of previous studies.

The results of Keatly et al., (1994) suggest that in order to produce the largest priming effect the optimal prime/target ordering is from a first language (L1) prime to a second language (L2) target. However, in Kroll and Stewart's (1992) model of bilingual processing, the lexical links from L1 to L2 are weaker than those from L2 to L1. If the priming effect found in the previous experiment was in part due to what Kroll and Stewart have called lexical links, then the maximum amount of priming should be obtained by reversing the order of prime and target used in the previous experiment.

Experiment 2

Method

Subjects

A further 24 Thai-English bilingual subjects were selected on the basis of information about their language history obtained using a questionnaire.

Materials

As in the previous experiment targets were chosen in order to form two sets, (one set based on cognate translations, the other on noncognate translations) with three different priming conditions within each set.

The Cognate set: Thirty-six Thai words were selected as targets for the first three Experimental conditions. These were the "loan" words described in Experiment 1. The same type of prime conditions used in the first experiment were employed here. That is, an Identity condition, in which the Thai prime was the same as its target except reduced in height by 50%. A Cognate translation condition where the primes were the English equivalents of their Thai "loan" words targets. A final Control condition in which English word primes were matched in number of letters and word shape (pattern of ascenders, compacts and descenders) to the Cognate primes (above) but were unrelated in meaning and phonology to the Thai targets.

The English word primes were presented in lower-case letters with letter densities similar to that of the Thai letters. Targets were constructed so that they were physically larger than the primes.

The Noncognate set: Thirty-six additional Thai words were selected to act as targets for a further three experimental conditions. As before these consisted of an Identity condition, the same as described above. A Noncognate translation condition that consisted of Thai targets preceded by primes that were English translation equivalents (thus these primes and targets were related in meaning only). The last condition was a Control condition that consisted of English word primes matched in letter-number and basic shape to the Noncognate primes (above) but were unrelated in meaning and phonology to their Thai targets.

Seventy-two "Thai" nonwords were generated to act as foils, each of these were similar in length and syllabic structure to one of the Thai word targets. All were judged meaningless, pronounceable, and orthographically legal by a Thai native speaker. Prime/target conditions were constructed to mirror the word conditions, i.e., Identity, Translation and Control. As the targets were nonwords the translation and control conditions consisted simply of English word primes.

Three versions of the experiment were constructed so that each target would appear in each of the priming conditions, without being repeated within a version. A set of 14 practice items were constructed, each set preceded the appropriate version.

Procedure and data treatment

The procedure and date treatment used were the same as those employed in the previous experiment.

Results

Mean reaction times and percent error rates for the cognate set are shown in Table 2.1. In general it can be seen that the magnitude of priming is less than that found in the previous experiment. Indeed the overall effect of prime type for this item set was marginal. For latencies the effect of prime type was significant in the subject analysis, F_1 (2,42) = 3.31, $p < 0.05$, but not in the item analysis, F_2 (2,66) = 2.80, $p > 0.05$. However there was a robust effect of prime type in the error data, F_1 (2,42) = 13.24, $p < 0.05$, F_2 (2,66) = 19.95 $p < 0.05$.

Table 2.1 about here

A series of two planned comparisons were conducted in order to determine if the Identity and the Cognate translation conditions differed from the Control condition. Only the Identity condition showed a significant priming effect for latencies, F_1 (1,21) = 6.44, $p < 0.05$; F_2 (1,33) = 4.53, $p < 0.05$ and errors, F_1 (1,22) = 22.27, $p < 0.05$; F_2 (1,33) = 18.64 $p < 0.05$. Cognate translations did not produce a reliable priming effect in the latencies data, F_1 (1,22) = 2.67, $p > 0.05$; F_2 (1,33) = 2.23, $p > 0.05$ but did so for the error data, F_1 (1,22) = 8.27, $p < 0.05$; F_2 (1,33) = 8.48, $p < 0.05$.

Table 2.2 shows the mean reaction times and percent errors for the

noncognate set. For this set of words there was an overall effect of prime type for latencies, F_1 (2,42) = 17.71, $p < 0.05$, F_2 (2,66) = 13.71, $p < 0.05$ but this priming effect was only marginal in the error data, F_1 (2,42) = 3.07, $p > 0.05$, F_2 (2,66) = 3.17, $p < 0.05$.

Table 2.2 about here

Consistent with the pattern shown for the cognate translation set, there was a priming effect for the Identity condition: For latencies F_1 (1,21) = 26.30, $p < 0.05$; F_2 (1,33) = 28.52, with a priming effect for errors only by items, F_1 (1,21) = 3.93, $p > 0.05$; F_2 (1,33) = 4.26, $p < 0.05$. There was no priming effect found for the Noncognate translation condition for latencies with both subject and item F's < 1. There was a weak priming effect shown by the error data F_1 (1,21) = 4.93, $p > 0.05$; F_2 (1,33) = 4.40, $p < 0.05$.

Discussion

Unlike the results of the first experiment the cross-language priming effect in the current experiment was only marginal. This asymmetry in the size of effects as a function of the direction of translation is consistent with the results of Keatly et al., (1994). These authors argue that such an asymmetry in priming means that the semantic representation of translation equivalents cannot be one and the same, but must to some degree be separate.

There is, however, the possibility that the difference in the strength of the cross-language priming effect over the first two experiments is in some part due to differences in the efficiency of subject's orthographic processing of the Thai and

English rapidly displayed primes. In a recent study with English primes and Thai targets, (Scorgie, 1995) the size of the translation priming effect was found to strongly correlate with the subject's rated amount of reading experience in English. This finding is consistent with the suggestion that the orthographic processing of the English primes may be relatively slower than their processing of the Thai targets. If this were the case then, a response to a Thai target may be initiated before the English prime has been fully processed, obviously no priming could occur in this circumstance.

If the failure to find robust cross-language priming in the previous experiment was simple due to the Thai subjects not having sufficient time to process the English prime then a straight-forward prediction would be that increasing the Stimulus Onset Asynchrony (SOA) between prime and target would increase the priming effect. Experiment 3 then was conducted in order to determine if this was the case.

Experiment 3

Subjects

24 Thai-English bilingual subjects were selected on the basis of information about their language history obtained using a questionnaire.

Materials

The materials used in this experiment were the same as those used in Experiment 2 above.

Procedure

The procedure used in the current experiment was precisely the same as that which has been used in the previous two experiments except in regard to item timing. For this experiment only, after the primes were displayed for their standard duration, an additional 28 ms of blank screen was also presented.

Results

The mean reaction times and percent error rates for the cognate set are shown in Table 3.1. In contrast to the results of the previous experiment it can be seen that there is a clear priming effect for the both the within-language Identity condition and the cross-language Cognate condition. For the cognate set, there was an effect of prime type for the latency data, F_1 (2,42) = 12.58, $p < 0.05$, F_2 (2,66) = 12.95 $p < 0.05$. There was also a prime type effect in the error data for the subject analysis, F_1 (2,42) = 4.08, $p < 0.05$, but this was not secure by items, F_2 (2,66) = 2.66, $p > 0.05$.

Table 3.1 about here

Planned comparisons showed that there both the Identity and the Cognate conditions showed a priming effect. For the latency data, F_1 (1,21) = 27.03, $p < 0.05$; F_2 (1,33) = 20.83, $p < 0.05$ for the Identity condition and F_1 (1,22) = 10.02, $p < 0.05$; F_2 (1,33) = 9.85, $p < 0.05$ for the Cognate translation condition. In the error data there was no priming for the Identity condition with both subject and item F's < 1. There was, however, a trend for a priming effect in errors for the Cognate translation condition, F_1 (1,21) = 7.13, $p < 0.05$; F_2 (1,33) = 3.68, $p < 0.05$.

Table 3.2 shows the mean reaction times and percent errors for the

noncognate set. As with the cognate set there was an overall effect of prime type for latencies, F_1 (2,42) = 21.96, $p < 0.05$, F_2 (2,66) = 22.11, $p < 0.05$ but not for errors, both F's < 1.

Table 3.2 about here

Consistent with the pattern shown for the cognate translation set, there was a priming effect for the Identity condition: For latencies F_1 (1,21) = 32.98, $p < 0.05$; F_2 (1,33) = 46.21, but no effect for errors with both subject and item F's < 1. Further there was a priming effect found for the Noncognate translation condition, both for latencies F_1 (1,21) = 10.24, $p < 0.05$; F_2 (1,33) = 5.77, $p < 0.05$ but again no effect for errors with both subject and item F's < 1.

Discussion

It is possible that at least part of the difference in the size of the cross-language priming effects found in Experiment 1 and 2 was due to differences in subject's efficiency in the orthographic processing of the primes. Given this possibility, caution needs to be exercised in using the asymmetry in the size of the priming effects of Experiments 1 and 2 as necessarily an argument for differences in L1 and L2 lexical representations (c.f., Keatly et al., 1994).

Having shown that it is possible to get cross-language priming in either prime/target direction, the next experiment examines the topical issue of the role of phonology in the reading process; investigating whether primes that only share phonological aspects with their cross-language targets will prime.

Experiment 4

This experiment was designed to investigate the influence of the phonology of a written word (the prime) on the lexical access process of a closely following word (the target). In this regard it is important to consider how phonological information might be generated from a printed word. There are a number of alternatives; however a broad distinction can be made between pre-lexically assembled phonology (i.e., via GPC rules or larger spelling to sound correspondences, Kay, 1987) and lexically addressed phonology (i.e, previously stored and retrieved via orthographic description). A simple method of determining whether any phonological priming effect is due to assembled or addressed phonology is to use both homophone (word) and pseudohomophone (nonword) primes. If a priming effect is found with pseudohomophone primes it would suggest that the phonological influence was due to assembled pre-lexical phonology.

Subjects

24 Thai-English bilingual subjects were selected on the basis of information about their language history obtained using a questionnaire.

Materials

In this experiment targets were chosen in order to form two sets, (one set based on primes that are homophones to these targets, the other on primes that are pseudohomophones to these targets) with three different priming conditions within each set.

The homophone set: Thirty-six English words were selected as targets for the first three Experimental conditions. The first was an Identity condition, in which an English Target word was preceded by a lower-case version of itself. The second, consisted of Thai word primes that were homophonic to their English word targets but were unrelated in meaning. A final Control condition was constructed that consisted of Thai prime words that were unrelated in meaning and phonology to the Thai targets.

The pseudohomophone set: Thirty-six additional English words were selected to act as targets for a further three experimental conditions. As before these consisted of an Identity condition, as described above. A Pseudohomophone condition that consisted of English targets preceded by Thai nonword primes that sounded the same. The last condition was a Control condition that consisted of Thai primes that were unrelated in both meaning and phonology to their English targets.

Seventy-two English orthographically legal nonwords were generated to act as foils, each of these were similar in length and syllabic structure to one of the English word targets. Prime and target conditions were constructed to mirror the word conditions, i.e., Identity, Translation and Control. As the targets were nonwords the translation and control conditions consisted simply of Thai word primes.

Three versions of the experiment were constructed so that each target would appear in each of the priming conditions, without being repeated within a version. A set of 14 practice items were constructed, each set preceded the appropriate version.

Procedure

The procedure used in the current experiment was precisely the same as that which has been used in the first two experiments.

Results

The mean reaction times and percent error rates for the Homophone set are shown in Table 4.1. Curiously, although the within-language Identity and the cross-language Homophone conditions show the same amount of priming, the magnitude of this effect is not great. Indeed, there was no effect of prime type for the latency data in the subject analysis, F_1 (2,42) = 2.058, $p > 0.05$, although there was a significant prime type effect in the item analysis, F_2 (2,66) = 3.70, $p < 0.05$. There were no effects of prime type in the error data for either the subject, $F_1 < 1$, or item analysis, F_2 (2,66) = 1.01, $p > 0.05$.

Table 4.1 about here

Planned comparisons showed that the Identity priming effect was marginal for latencies, F_1 (1,21) = 2.18, $p > 0.05$; F_2 (1,33) = 4.43, $p < 0.05$ and absent for errors, $F_1 < 1$, F_2 (1,33) = 1.36, $p > 0.05$. Interestingly, priming in the Homophone condition was more secure in the latency data, F_1 (1,22) = 3.85, $p = 0.06$; F_2 (1,33) = 6.96, $p < 0.05$. In the error data there was no priming for this condition, F_1 (1,22) = 2.55, $p > 0.05$; F_2 (1,33) = 1.50, $p > 0.05$.

Table 4.2 shows the mean reaction times and percentage errors for the nonhomophonic set. For these items there was an overall effect of prime type for latencies, F_1 (2,42) = 11.58, $p < 0.05$, F_2 (2,66) = 7.81, $p < 0.05$ and for errors, F_1

(2,42) = 10.10, $p < 0.05$, F_2 (2,66) = 10.53, $p < 0.05$.

Table 4.2 about here

Planned comparisons confirmed an Identity priming effect for latencies F_1 (1,21) = 14.38, $p < 0.05$; F_2 (1,33) = 12.02, and for errors, F_1 (1,21) = 14.94, $p < 0.05$; F_2 (1,33) = 17.53. Further there was a priming effect found for the Nonhomophonic condition, both for latencies F_1 (1,21) = 18.61, $p < 0.05$; F_2 (1,33) = 8.84, $p < 0.05$ and for errors F_1 (1,21) = 12.28, $p < 0.05$; F_2 (1,33) = 9.86, $p < 0.05$.

Discussion

The results have shown that a large and reliable priming effect can be found from primes that have only a phonological relationship to their targets. Further, this effect appears not to be a lexically generated one, as nonword primes actually produced a slightly larger priming effect than the word primes. The implications that this result has for models of the word recognition process and of bilingual lexical representation will be discussed below.

General discussion

The results of these experiments have demonstrated that a masked priming effect can occur across languages that have very different written forms. Not only do these results suggest that the mental representations of each of a bilingual's languages are connected, but also that various stimulus characteristics interact in lexical processing. That is, the results of Experiments 1 and 3 show that both the semantic and phonological characteristics of a prime can influence a subsequent response to an immediately presented word target. This in turn suggests that this information acts to constrain word recognition, and that it does so rapidly and automatically.

There is, however, a possible problem with a fully interactive processing model where semantic, phonological and orthographic information all combine to constrain word recognition. If semantic and phonological information compete then this would appear to predict no priming effects for either the Noncognate primes in experiments 1 and 3 or the Homophone prime in the last experiment, (in these conditions there is either a phonological or a semantic mismatch between prime and target). However there was priming in these condition (although these were not as large or robust as the matching conditions). There is one interactive model that does not predict semantic or phonological inhibition. Colombo (1986) suggests that only information that is very similar competes. That is, the function of inhibition is to suppress near matches only, so when semantic or phonological information is quite different no inhibition takes place.

One final issue to be considered concerns whether the current findings can be generalized. Although the results of Experiment 4 clearly show that the phonological processing of a prime has an effect on the subsequent recognition response of a word target there may still be a question as to whether this effect is a general one that would occur for subjects of other linguistic backgrounds or whether it reflects a specific processing strategy of the current subjects. The reason that this may be of concern is that typically Thai orthography has a precise correspondence to its phonology, whereas in English this is not the case. Thus, the Thai subjects in Experiment 4 may be more sensitive to the phonological characteristics of a prime than, for example, a monolingual speaker of English. While this argument does not dismiss the finding that subjects rapidly and, probably, automatically phonologically recode the priming stimuli, it does raise the possibility that this may not be the case for all subjects.

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Table 1.1. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the cognate set.

Prime Type	Example	RT	%E
Identity	beer BEER	627	12.8
Cognate	เบียร์ BEER	616	10.1
Control	บัดกรี BEER	695	15.6

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 1.2. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the noncognate set.

Prime Type	Example	RT	%E
Identity	hat HAT	606	9.4
Noncognate	หมวก HAT	611	4.9
Control	ทหาร HAT	647	10.4

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 2.2. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the noncognate set.

Prime Type	Example	RT	%E
Identity	หมวก หมวก	555	6.3
Noncognate	hat หมวก	593	6.3
Control	bed หมวก	594	9.7

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 2.1. Mean reaction time (ms) and percent error rates to Thai word targets as a function of prime type for the cognate set.

Prime Type	Example	RT	%E
Identity	เบียร์ เบียร์	632	4.5
Cognate	beer เบียร์	642	10.4
Control	farm เบียร์	656	18.1

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 3.1. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the cognate set.

Prime Type	Example	RT	%E
Identity	เบียร์ เบียร์	574	6.6
Cognate	beer เบียร์	591	3.1
Control	farm เบียร์	622	7.3

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 3.2. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the noncognate set.

Prime Type	Example	RT	%E
Identity	หมวก หมวก	507	2.8
Noncognate	hat หมวก	536	4.2
Control	bed หมวก	556	3.1

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 4.1. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the homophone set.

Prime Type	Example	RT	%E
Identity	horn HORN	641	12.1
Homophone	หอน HORN	641	12.5
Control	หลัก HORN	663	15.6

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%

Table 4.2. Mean reaction time (ms) and percent error rates to English word targets as a function of prime type for the pseudohomophone set.

Prime Type	Example	RT	%E
Identity	feet FEET	638	10.1
Pseudohomophone	ฝีด FEET	640	11.8
Control	โกล FEET	683	20.8

Table note: It should be noted that targets were constructed to both wider and taller than primes and that Thai primes were reduced compared to Thai targets by 50%