EUROPEAN JOURNAL OF COGNITIVE PSYCHOLOGY, 1992, *4* (4) 273–292

The Bilingual Primed Lexical Decision Task: Cross-language Priming Disappears with Speeded Responses

Catharine Keatley and Beatrice de Gelder
Tilburg University, Tilburg, The Netherlands

Four cross-language primed lexical decision experiments were carried out to test models of cross-language priming. The first experiment varied the proportion of related pairs, but this manipulation did not affect the size of the priming effects. In Experiments 2 and 3, the subjects were asked to respond at a specific fast rate. This resulted in significant priming within languages, but priming in the cross-language conditions disappeared. The subjects in Experiment 4 were also asked to respond at a specific fast rate, but the stimuli in this experiment were translation equivalents. Cross-language priming occurred with the translations under the same conditions where it had disappeared with primary associates. These results suggest that cross-language priming between primary associates is due to a post-lexical meaning-integration process which the subjects can detach from the normal reading sequence if it slows their responses in relation to goal response rate.

INTRODUCTION

How are semantic representations of words organised in bilingual memory? Do they lie in a single, shared conceptual store (Potter, 1979; Potter, So, von Eckardt & Feldman, 1984; Snodgrass, 1984) or does the bilingual maintain distinct and independent symbol systems, complete with separate and independent conceptual representations? (Kolers, 1963; Macnamara, 1967; Paivio, 1986).

The shared model is most well-known today in the three-code, or hierarchical, model of bilingual memory (Potter et al., 1984; Snodgrass, 1984), which holds that words have two levels of representation, one lexical and one semantic. The lexical representations are assumed to be

We would like to thank the students and staff of the Center for Life and Learning at the University of Louvain and the students and staff of the Institut Superieure de Traduction et Interpretation for their help and cooperation in carrying out these experiments. We would also like to thank Dr. Mary Potter and two anonymous reviewers for their thoughtful comments on the paper.

stored separately while the semantic representations are shared and in an abstract form, such as propositional nodes (Anderson & Bower, 1973).

The most developed separate store model is the dual-coding model (Paivio, 1986; Paivio & Desrochers, 1980; Paivio & Lambert, 1981), which holds that semantic/lexical representations of the words in different languages are stored in separate, independent, but interconnected memory stores.

Others who find support for a separate store model prefer to draw general descriptions of separate, but connected, language systems and do not describe the system further (Grainger & Beauvillain, 1988; Kirsner et al., 1984; Meyer & Ruddy, 1974). Kolers and his colleagues (Durgunoglu & Roediger, 1987; Kolers & Gonzalez, 1980; Kolers & Roediger, 1984; Kolers & Smythe, 1984) argue that the means of acquisition of information, such as language, forms part and parcel of its representation, and so transfer across representations occurs more easily within languages than across languages.

Although research on bilingualism uses a number of different paradigms (for a history of the literature, see Keatley, 1992), this paper will focus on research which employs the primed lexical decision task (LDT). This task has been an important instrument in exploring memory organisation and lexical processing in general. A central question in this literature is what sort of processing is responsible for the cross-language priming effect? Does cross-language priming reflect patterns of automatic activation which are determined by the basic organisation of representations in memory, and does it therefore reflect a shared memory store? Does it reflect prelexical strategies employed by subjects to respond quickly? Or does it reflect post-lexical meaning-integration processes which occur after access of the target? These alternatives are discussed below.

The results of bilingual primed LDT experiments are far from uniform. Some have found overall cross-language priming effects and attribute them to automatic spreading activation across representations in a shared conceptual store (Chen & Ng, 1989; Schwanenflugel & Rey, 1986), as predicted by the hierarchical shared store model (Potter et al., 1984; Snodgrass, 1984). Others have found priming in the condition where the prime was in the first language (L1) and the target in the second language (L2), but little or no priming when the primes were in L2 and the targets in L1 (Altarriba, 1991; Jin, 1990; Keatley, Spinks & de Gelder, submitted).

Meyer and Ruddy (1974) found overall priming across languages accompanied by longer responses to cross-language pairs and Kirsner et al. (1984) found overall cross-language priming but greater priming effects within than across languages. The authors in both experiments felt they were not able to differentiate between a shared model or a separate but highly interconnected model of bilingual memory.

Other experiments employed manipulations designed to eliminate the effects of subject strategy and found that cross-language priming disappeared altogether. Grainger and Beauvillain (1988) used a small proportion of related pairs and found that when the stimulus onset asynchrony (SOA) was short (150 msec), cross-language priming disappeared. De Groot and Nas (1991) masked the primes and found, with non-cognates, that while priming occurred with primes and targets in L2, priming disappeared between L1 primes and L2 targets (priming did occurr across cross-language cognates in these experiments). The results of the experiments suggest that, with non-cognate words, cross-language priming effects are due to either subject strategy or to post-lexical access meaning-integration processes and not to spreading activation.

The explanation of cross-language priming based on pre-lexical strategic processing holds that the priming is due to prediction/translation strategies employed by subjects (Grainger & Beauvillain, 1988). Subjects may generate semantically related candidate words from the prime before the target is presented (Becker, 1979, 1980), focus attention on a specific area of memory (Neely, 1977) and/or translate the primes (de Groot & Nas, 1991). Monolingual experiments have demonstrated that the magnitude of priming increases with proportion of related pairs (de Groot, 1984; Den Heyer, Briand & Dannenberg, 1983; Neely, 1977; Tweedy, Lapinski & Schvaneveldt, 1977; Tweedy & Lapinski, 1981), but only if the SOA is sufficiently long to allow the controlled strategic processing to occur (de Groot, 1984; Den Heyer et al., 1983; Neely, 1977).

The explanation of cross-language priming based on post-lexical meaning-integration processing (de Groot & Nas, 1991) was developed in the context of monolingual experiments (de Groot, 1984). The model assumes that there is a decision mechanism which is responsible for translating the identification of a word (or nonword) into a yes/no response. After lexical access of the target, a message processor automatically initiates a coherence check to evaluate the relationship between the prime and the target. If the prime and target are related, a positive output in the message processor sets up a positive bias in the decision mechanism, thus facilitating a "yes" response on the LDT. If the prime and target are unrelated, a negative bias is established, inhibiting a "yes" response. De Groot added the suggestion that the process of post-lexical meaning integration may be sensitive to proportion manipulations.

A review of the bilingual-primed LDT studies suggests that there is a general relationship between proportion of related pairs and overall cross-language priming effects. The experiments which produced substantial priming in both language-order conditions tend to have proportions of related pairs over 0.5 (Chen & Ng, 1989; Kirsner et al., 1984; Schwanenflugel & Rey, 1986). Those with proportions below 0.5 (Altarriba, 1991;

Grainger & Beauvillain, 1988; Keatley et al., submitted, experiments 1 and 2) tend to produce little priming in the L2–L1 condition, or no cross-language priming at all. The exceptions were experiments 3 and 4 of de Groot and Nas (1991), where the proportion was 0.66, but the primes were masked; Meyer and Ruddy (1974), where a proportion of 0.33 was used and cross-language priming was found, but primes and targets were presented simultaneously (and thus there was no control over SOA or order of processing); and Jin (1990), who used a proportion of 0.66 but nevertheless found little priming in the L2–L1 condition. The overall pattern of sensitivity to proportion suggests that pre-lexical strategic processing and/or post-lexical meaning-integration processing may be responsible for the cross-language priming effect.

The relation of the pattern of priming to SOA also suggests that the process responsible for the effect is not only pre-lexical because the pre-lexical strategy explanation predicts that the longer the SOA the more priming should occur. However, SOA does not generally vary with amount of cross-language priming. At the extremes, Schwanenflugel and Rey (1986) found cross-language priming with a 100 msec SOA, and Keatley et al. (submitted, experiment 1) found much less priming from L1 to L2 with a 2000 msec SOA than with a 250 msec SOA, and no significant priming at all from L2 to L1 with either SOA. These two experiments used very different proportions of related word targets (1.0 and 0.25, respectively).

Experiment 1 was designed to test directly whether cross-language priming is sensitive to proportion of related pairs. The experiment used a 200 msec SOA between prime and target. It was assumed that, as in the monolingual experiments, this would rule out the possibility of pre-lexical strategy use. In addition, subjects received visual feedback about their response time after each trial. This was in order to establish a control condition for the next experiment where they were to be asked to monitor the speed of their responses.

EXPERIMENT 1

Method

Subjects. Altogether, 32 native French-speaking French–Dutch bilingual students studying to be professional translators participated. They were chosen on the basis of a detailed questionnaire which was administered to determine if they came from fully French-speaking families and had been educated primarily in French. All of them had studied Dutch since grade school.

Stimuli. The stimuli were those developed for the cross-language Dutch–French primed LDT experiments of Keatley et al. (submitted). A total of 96 French–Dutch translation equivalent primary associate pairs were developed through questionnaires completed by Belgian Dutch-speaking bilinguals. Translation equivalence was tested through back-translation; cross-language associative strength was checked by a panel of Belgian bilinguals. The words included were of middle to high frequency in both French (Savard & Richards, 1970) and Dutch (Uit den Boogaart, 1975) frequency counts. The mean length of the French words was 5.27 letters and that of the Dutch words 5.05 letters. Mean association strength of the French primary associate pairs was 40.13 and that of the Dutch ones 40.10. Unrelated pairs were formed by re-pairing primes and targets that were clearly not related. A total of 96 filler pairs was included, which generally matched the experimental pairs. In the high-proportion relatedness condition, filler targets were presented with related primes, yielding a 0.75 proportion of related word–target pairs. In the low-proportion relatedness condition, filler targets were all presented with unrelated primes, yielding a 0.25 proportion of related word–target pairs. Nonword–target pairs were constructed by replacing one letter from a real word with another letter which yielded an orthographically regular, pronounceable letter string that was not a word. Ninety-six nonword–targets were based on French words and 96 on Dutch words. Thus, in each of the four language-order conditions, the subjects saw 12 related word–target pairs and 12 unrelated word–target pairs. The subjects' responses to these targets constituted the data. They also saw 24 filler word–target pairs, related in the 0.75 proportion condition, and unrelated in the 0.25 proportion condition. Their responses to fillers were not included in the analyses. In addition, 48 nonword–target pairs were seen in each language-order condition.

List Construction. The 384 different prime–target pairs were divided into four blocks by language order of the prime and target (French–French, Dutch–Dutch, French–Dutch, Dutch–French). Their order of presentation was determined by a balanced square. Relatedness of the critical pairs (related *vs* unrelated) in each language-order condition was counterbalanced across subjects. The assignment of particular words to particular conditions was random, as was the order of presentation of items within a block.

Procedure and Apparatus. Each subject was tested individually using an Olivetti computer with a separate response button keyboard. The subjects, all of whom spoke some English, received instructions, both oral and written, in English, because we had noticed in earlier experiments that when instructions are given in a language used in the experiment, this seems to facilitate responses to that language at the beginning of the experiment. The instructions were repeated in French only if the subjects did not completely understand the English. Throughout the experiment, incidental conversation was carried out in English as much as possible. Before each of the four language-order conditions, the subjects were given 24 practice trials in the language order of the condition to follow.

The subjects initiated groups of 24 trials by pushing a button on the response panel. On each trial, a central fixation stimulus appeared approximately in the centre of the screen for 300 msec; it was blanked out for 50 msec and then the prime word appeared in the same place and remained on screen for 150 msec. The prime was replaced by a blank field for 50 msec, thus yielding an SOA of 200 msec. The target then appeared just below the space where the prime had been presented, and remained on the screen until the subject responded. After the subject's response, the reaction time (RT) was displayed at the bottom of the screen. It remained there for 1500 msec, which was the duration of the inter-stimulus interval. Then the RT feedback disappeared and the fixation stimulus for the next trial appeared. A rest period of at least 3 min occurred between each language-order block.

Design. The proportion of related pairs (high *vs* low) was the only between-subjects factor. The stimuli were presented in four language-order conditions (French prime—French target, Dutch prime—Dutch target, French prime—Dutch target, Dutch prime–French target). Relatedness (related *vs* unrelated), target language (French *vs* Dutch) and language mix—whether the prime and target were in the same or different languages (same *vs* different)—were within-subjects factors.

Results

Only correct responses to the 192 experimental word-targets were included in the analyses. Responses over 1400 msec were counted as errors, and excluded from the analyses. Errors accounted for 0.04 of the data.

The mean RTs for the related and unrelated conditions for each of the two proportion conditions, in each of the four language-order conditions, are displayed in Table 1, along with error rates for each cell. The RT data were subjected to analyses of variance (ANOVA) both by subjects and by items. All of the results reported below are significant at $P < 0.05$ or better unless otherwise indicated.

There was no main effect of proportion by subjects [$F1\ (1,30) > 1$], nor by items [$F2\ (1,190) = 1.15$] and this variable did not interact with any other variable. The main effect of relatedness was highly significant [$F1\ (1,30)$

TABLE 1
Experiment 1: Mean Reaction Times (msec) and Error Rates of Responses to Related and Unrelated Targets in the High- and Low-proportion Conditions

	Language Order			
Target	*Dutch–Dutch*	*French–Dutch*	*French–French*	*Dutch–French*
High proportion of related pairs				
Related	554 (0.04)	557 (0.04)	482 (0.05)	505 (0.02)
Unrelated	584 (0.07)	577 (0.11)	510 (0.05)	538 (0.05)
Priming	30	20	28	33
Low proportion of related pairs				
Related	542 (0.03)	548 (0.06)	496 (0.03)	512 (0.02)
Unrelated	568 (0.06)	585 (0.05)	525 (0.03)	533 (0.02)
Priming	26	37	29	21

= 37.16, MSe = 1,361; $F2$ (1,190) = 20.43, MSe = 11,194]. Overall, there was a 29 msec priming effect. The main effect of target language was significant [$F1$ (1,30) = 19.58, MSe = 8,771; $F2$ (1,90) = 44.20, MSe = 17,832], with responses to French words being 51 msec faster overall than to Dutch words. The main effect of language mix was significant by items [$F2$ (1,190) = 5.61, MSe = 10,812] but not by subjects [$F1$ (1,30) = 2.0, MSe = 4,168]. There were, however, no significant interactions. In particular, there were no interactions between relatedness and either target language or language mix. As can be seen in Table 1, the priming effects were essentially equal in all conditions.

Discussion

The equal priming effects found in this experiment indicate that the proportion manipulation did not affect priming. This result stands in contrast to the bilingual primed LDT experiments discussed above, and in contrast to monolingual experiments which varied proportion of related pairs to the same degree (and with a similar short SOA) and found significantly less priming with a low proportion (de Groot, 1984; Den Heyer et al., 1983; Tweedy & Lapinski, 1981).

One difference between this experiment and all of the others is that the subjects in this experiment received trial-by-trial visual feedback concerning their response times. It is possible this feedback may have diverted their attention from noticing the overall relatedness between primes and targets in either proportion condition. Another difference between this experiment and most of the bilingual experiments discussed above is that our subjects were more proficient than most of the subjects in the other studies in responding to words in L2 as compared to L1. Indeed, an observation we made, but which cannot be measured directly, was that the subjects in Experiment 1 were more relaxed during the experiment than subjects who have participated in other similar experiments we have conducted (Keatley et al., submitted, experiments 1 and 2). In these other experiments, cross-language priming did not occur equally in both language-order conditions; rather, it occurred when the primes were in L1 and the targets in L2, but not when the primes were in L2 and the targets in L1.

Of the three alternative explanations for the cross-language priming effect, the pre-lexical strategy explanation must be ruled out on the basis of the results of Experiment 1, since it rests on the assumption that cross-language priming will be determined by conditions of the experiment such as proportion of related pairs. The results of Experiment 1 are consistent with the classic hierarchical model of bilingual memory, which holds that cross-language priming is due to automatic spreading activation across shared conceptual representations (Potter et al., 1984). Another possibility, however, is that cross-language priming may be due to a post-lexical meaning integration process that is not sensitive to proportion (at least when the subjects are not stressed by the task). This explanation of cross-language priming is most consistent with a separate store model of bilingual memory.

If post-lexical meaning integration across separate language-specific memory stores is the source of cross-language priming, it could be hypothesised that this process is suppressed or discontinued by subjects when they feel pressed to respond quickly, relative to their normal response rate. This would cause cross-language priming to disappear. Within-language priming should still occur under the same stressed conditions because it is assumed to be due, at least partially, to automatic spreading activation within the separate stores. When subjects are relaxed, as in the present experiment, post-lexical meaning integration processing occurs because it is a part of the normal sequence of procedures that make up the reading process. Under the relaxed conditions, cross-language priming effects would be equally strong in both language-order conditions, as was found to be the case in Experiment 1.

How great an effort the subjects make to respond quickly, and how difficult the task is for them (based on their relative proficiency in L2), are variables that may be important in determining patterns of cross-language priming. However, these are aspects of experiments that are difficult to determine from experimental reports and data. Variables such as stress and effort have not been studied before in the context of priming.

The next experiment was designed to determine whether increased pressure to respond quickly on the primed LDT would result in a reduction or the absence of cross-language priming, as predicted by the above account of the effect based on a post-lexical meaning-integration explanation. Alternatively, it could simply result in faster responses overall, as predicted by the spreading activation hypothesis of the hierarchical model (Potter et al., 1984), or in an absence of priming in the L2–L1 language order condition.

In order to encourage the subjects to feel pressured to respond quickly, and yet to produce a minimum change in actual response rate, they were asked to respond at a particular rate, which was actually well within the normal range for their group. In Experiment 1, the overall mean RT to targets was 538 msec; in Experiment 2, we asked the subjects—taken from the same population—to respond at a rate between 500 and 600 msec, but as close to 500 msec as possible. As in Experiment 1, the subjects received feedback as to how fast they had responded after each trial. Only the 0.25 proportion condition was included in Experiment 2 because the proportion manipulation had not influenced the priming effects in Experiment 1.

EXPERIMENT 2

Method

Subjects. Altogether, 16 subjects were selected for this experiment, all of them from the same population as the subjects in Experiment 1, and on the basis of the same questionnaire.

Stimuli. The stimuli used and the lists were identical to those of the low proportion condition in Experiment 1.

Procedure. The procedure of Experiment 1 was followed except that the subjects were asked to respond with a RT between 500 and 600 msec, but as close to 500 msec as possible. During practice sessions, they were urged to respond faster if necessary. During the experimental session, the experimenter did not comment on the subjects' speed, but they could monitor it using the visual feedback that appeared after each trial.

Design. The experiment included the following within-subjects factors: target language (Dutch *vs* French), relatedness (related *vs* unrelated) and language mix (same *vs* different).

Results

As in Experiment 1, responses slower than 1400 msec were treated as errors and excluded from the analyses. Errors accounted for 0.06 of the data. Analyses of variance were carried out both across subjects and across

TABLE 2
Experiment 2: Mean Reaction Times (msec) and Error Rates of Responses to Related and Unrelated Targets in the Four Language-order Conditions

	Language Order			
Target	*Dutch–Dutch*	*French–Dutch*	*French–French*	*Dutch–French*
Related	506 (0.05)	520 (0.05)	469 (0.03)	510 (0.05)
Unrelated	528 (0.11)	526 (0.07)	492 (0.07)	508 (0.08)
Priming	22	6	23	−2

items. Effects were counted as significant at $P < 0.05$ or better, unless otherwise mentioned.

The mean RTs and proportion of errors in the four different language-order conditions for related and unrelated pairs are displayed in Table 2. The main effect of relatedness was highly significant by subjects [$F1$ (1,15) = 5.16, MSe = 891], but not by items [$F2$ (1,95) = 0.14, MSe = 17,621]. There was no main effect of target language by subjects [$F1$ (1,15) = 3.42, MSe = 199,975], but it was significant by items [$F2$ (1,95) = 10.67, MSe = 162,561]. Language mix also produced a significant main effect by items [$F2$ (1,95) = 7.35, MSe = 10,120], but not by subjects [$F1$ (1,15) = 1.77, MSe = 5,189]—as was also the case in Experiment 1. There was a significant interaction between language mix and relatedness by subjects [$F1$ (1,15) = 6.70, MSe = 519], but not by items [$F2$ (1,95) = 0.22, MSe = 13,272]. As can be seen from Table 2, there were only small priming effects in the cross-language conditions [which were unreliable on an analysis of simple effects: $F1$ (1,15) < 1, MSe = 1,601], whereas the priming effects of 22 and 23 msec for the within-language conditions were reliable [$F1$ (1,15) = 13.19, MSe = 1,218].

A meta-analysis of the data of the low proportion condition of Experiment 1 and those of Experiment 2 was carried out. We will only discuss the most relevant outcomes of that analysis here. The factor experiment (1, unstressed; 2, stressed) was significant [$F1$ (1,30) = 4.79, MSe = 62,718], indicating that the 32 msec faster overall response rate in Experiment 2 was significantly different from the overall response rate in Experiment 1 (low proportion condition). The interaction between experiment, relatedness and language mix, which would reflect the differences in the priming patterns in the two experiments, did not reach significance [$F1$ (1,30) = 2.58]. However, because of the theoretical importance of the differences in priming in particular language-order conditions across the two experiments, and the specificity of the predictions, specific comparisons were carried out over the error of the two experiments combined (MSe =

1,343). The most important comparisons were in the cross-language conditions.

In Experiment 1 (low proportion), priming was significant in the cross-language conditions French–Dutch [$t(30) = 4.0$, $P < 0.01$] and Dutch–French [$t(30) = 2.29$, $P < 0.05$]. But in Experiment 2, the between-language priming was not significant in either condition [French–Dutch: $t(30) = 0.65$; Dutch–French: $t(30) = 0.33$]. The comparisons confirmed the results of the two experiments analysed separately: When subjects were asked to respond at a particular fast rate, the cross-language priming disappeared.

Discussion

In Experiment 2, the subjects were encouraged to respond quickly. The main finding was that there were reliable within-language priming effects in the subjects analysis but, in contrast to Experiment 1, no cross-language priming effects. This pattern of results suggests that post-lexical access meaning-integration processing is the source of cross-language priming when it occurs. It thus also suggests that the meanings of words expressed in different languages are represented separately.

One problem with our analyses, however, is that on the items analysis there was no interaction between language mix and priming, and no main effect of priming. It therefore seemed desirable to run yet another experiment to find out how robust the observed effects are. The only difference between Experiment 3 and Experiment 2 was in the subject groups tested. The subjects in Experiment 3 were native Dutch-speaking, Dutch–French bilinguals. They were selected from a population of students from which we had already drawn subjects, using the same criteria, for a previous experiment (Keatley et al., submitted, experiment 2). The previous experiment had employed the same stimuli and design, except the subjects had not been asked to respond at a particular rate and they had not received trial-by-trial feedback as to their rate of response. In this earlier experiment, the mean response rate was 545 msec, a rate quite similar to the 538 msec mean response rate in Experiment 1 of this study. Since these rates of response were similar, the instructions for speeded responding remained unchanged.

EXPERIMENT 3

Method

Subjects. Altogether, 16 native Dutch-speaking Dutch–French bilingual subjects were selected from the Centre of Language and Learning at the University of Louvain. They were screened by use of a language history questionnaire, plus tests of speed and comprehension in French. All of the subjects who participated came from Dutch-speaking families and first learned to read in Dutch. They were all able to read in French at a rate within one standard deviation from the French reading speed of native French-speaking university students with normal comprehension. In all other respects, Experiment 3 mirrored Experiment 2.

Results

As in Experiments 1 and 2, scores exceeding 1400 msec and scores associated with errors were excluded from the analyses. Together these accounted for 0.09 of the scores. Analyses of variance were carried out over subjects and over items. All the results reported below are significant at $P < 0.05$ or better, unless otherwise indicated.

The mean RTs for related and unrelated targets in each language-order condition with accompanying error rates are displayed in Table 3. The main effect of relatedness was significant by subjects and by items [$F1$ (1,15) = 32.57, MSe = 509; $F2$ (1,95) = 7.27, MSe = 11,718], indicating the 23 msec overall priming effect was significant. The main effect of target language was also significant by subjects and items [$F1$ (1,15) = 99.49, MSe = 1,992; $F2$ (1,95) = 96.0, MSe = 11,051], with a 79 msec advantage for Dutch (L1) targets. Language mix in this experiment did not produce a significant main effect ($F1$ = 1.02; $F2$ = 2.01). However, there was a significant interaction between relatedness and language mix by subjects and this time also by items [$F1$ (1,15) = 5.18, MSe = 1,107; $F2$ (1,95) = 4.37, MSe = 5,587]. An analysis of simple effects indicated that priming was significant in the same-language conditions [$F1$ (1,15) = 17.18, MSe = 2,434], but unreliable in the different-language conditions [$F1$ (1,15) = 3.52]. Although the within-language priming effect in the French–French condition was greater than in the Dutch–Dutch condition, this difference was not significant on a *post-hoc* comparison of the priming effects.

TABLE 3
Experiment 3: Mean Reaction Times (msec) and Error Rates of Responses to Related and Unrelated Targets in the Four Language-order Conditions

	Language Order			
Target	*Dutch–Dutch*	*French–Dutch*	*French–French*	*Dutch–French*
Related	436 (0.04)	446 (0.07)	493 (0.08)	529 (0.11)
Unrelated	456 (0.06)	454 (0.04)	545 (0.12)	540 (0.15)
Priming	20	8	52	11

A meta-analysis of Experiment 2 and Experiment 3 was carried out. The specific language-order conditions were replaced with L1 and L2 designations in order to analyse the scores together, i.e. the Dutch–Dutch condition in Experiment 2 was assigned L2–L2, whereas in Experiment 3 it was assigned L1–L1. Only the most relevant outcomes of the analysis will be discussed here. Overall RTs in the experiments did not differ significantly: the main effect of experiment did not reach significance [$F1$ (1,30) = 2.30]. Relatedness produced a main effect [$F1$ (1,30) = 27.60, MSe = 19,321]. Although the effect of language mix was not significant [$F1$ (1,30) = 2.78], it interacted with relatedness [$F1$ (1,30) = 11.16, MSe = 9,072]. *Post-hoc* Neuman-Keuls tests demonstrated a significant overall difference (29 msec) between responses to related and unrelated targets in the same-language conditions (MSe = 1,284, $P < 0.01$). The difference between related and unrelated targets in the cross-language conditions (6 msec) did not reach significance. This meta-analysis thus confirmed that when subjects are asked to respond at a specific fast rate on the LDT, priming occurs in within-language conditions but not in cross-language conditions.

Discussion

The results of Experiment 3 are incompatible with a shared model of bilingual memory organisation, but consistent with a separate-store model. A separate-store model could account for cross-language priming effects in the non-speeded experiments by attributing them to normal meaning-integration processes that occur after the access of the target.

A problem for the classic separate-store model of bilingual memory organisation, however, is that cross-language priming across *translation equivalent* prime–target pairs appears to be a robust phenomenon that has been demonstrated in a number of studies (Altarriba, 1992; Chen & Ng, 1989; Jin, 1990; Keatley et al., submitted). If this priming is similar to within-language priming, then a model which assumes completely separate stores must be inaccurate. However, if it can be demonstrated that this priming effect for translation equivalents also disappears when subjects are pressed to respond quickly, this would suggest that memory organisation is separated by language. The effect obtained under normal, unpressed circumstances could then also be attributed to post-lexical meaning-integration processes occurring across separate memory modules.

Translation equivalent priming is characterised by asymmetry in all the experiments listed above, with more priming occurring from L1 to L2 than from L2 to L1. In these experiments, asymmetry is also a characteristic of cross-language primary associate priming, which suggests that the cross-language translation priming might disappear with speeded responses, as associative priming did in Experiments 2 and 3. However, de Groot and

Nas (1991) found that when primes were masked and associative priming between non-cognates disappeared, priming across non-cognate translation equivalents persisted. This suggests that translation equivalent priming was due to the same process as within-language priming.

Experiment 4 tested whether translation equivalent priming would persist or disappear when subjects are pressed to respond quickly. The experimental pairs all consisted of translation equivalents and not of primary associates. The subjects were the same as those who took part in Experiment 3. The experimental design was identical to that of Experiment 3 except that different stimuli were used and only the two cross-language language-order conditions were included.

Experiment 4 was actually carried out right after Experiment 3. In each experimental session, which included both Experiment 3 and then Experiment 4, the subjects were told only that they would see six blocks of prime–target pairs. No comment was made about the relationships between the primes and targets.

EXPERIMENT 4

Method

Stimuli. The crucial stimuli were 48 prime–target pairs consisting of translation equivalents expressed either with the French translation as the prime and the Dutch as the target (CHEVAL–PAARD), or in the reverse order (PAARD–CHEVAL). All words were 3–8 letters long, and of medium to high frequency in French (Savard & Richards, 1970) and Dutch (Uit den Boogaart, 1975). Half of the pairs consisted of concrete words that named an object and half consisted of words that named abstract concepts. Unrelated pairs were created by re-pairing primes and targets that were clearly not related in any way. Twenty-four unrelated filler pairs in the French prime–Dutch target order and 24 different pairs in the reverse order were constructed using words which followed the same length and frequency restrictions as the crucial pairs. Also, 48 nonword targets in both language-order conditions were constructed and paired with unrelated filler primes. Nonword targets were constructed as in the other experiments. Twenty-four practice pairs preceded both language-order conditions.

The list construction and counterbalancing procedures used in Experiment 3 were repeated in Experiment 4. There were two blocks of stimuli: one with Dutch–French stimulus pairs and one with French–Dutch pairs. There were 96 trials in each of the two language-order blocks: 12 with related experimental targets, 12 with unrelated experimental targets, 24 unrelated word–target filler pairs, and 48 nonword–target pairs. Each subject saw a target only once, with translation equivalence and language-order counterbalanced across the subjects.

Design. The factors were target language (French *vs* Dutch) and translation equivalence (translation *vs* unrelated).

Results

The mean RTs and error rates of subjects' responses in Experiment 4 are displayed in Table 4. Again, RTs longer than 1400 msec were treated as errors and all errors were excluded from the analyses. They accounted for 0.11 of the data. Analyses were carried out over subjects and over items. All the effects reported below were significant at 0.05 or better, unless otherwise mentioned.

Translation equivalence produced a significant priming effect [$F1$ (1,15) = 6.81, MSe = 1,883; $F2$ (1,95) = 5.79, MSe = 5,327]. Translation targets were responded to on average 20 msec faster than unrelated targets. Language-order also produced a significant main effect [$F1$ (1,15) = 34.91, MSe = 1,699; $F2$ (1,95) = 31.70, MSe = 6,127], indicating that the 61 msec shorter mean RT in the French–Dutch condition than in the Dutch–French condition was significant. Although priming found in the Dutch–French condition was greater than that found in the French–Dutch condition, language-order and translation equivalence did not produce a significant interaction ($F1$ = 2.46; $F2$ = 1.23).

TABLE 4
Experiment 4: Mean Reaction Times (msec) and Error Rates of Responses to Translation and Unrelated Targets in Two Language-order Conditions

	Language Order	
Target	*French–Dutch*	*Dutch–French*
Translation	446 (0.02)	493 (0.07)
Unrelated	460 (0.02)	535 (0.11)
Priming	14	42

Discussion

Priming thus occurred across translation equivalent words, whereas under identical conditions and with the same subjects, cross-language priming did not occur with primary associate pairs. This suggests that priming across translation equivalents is caused by a process that is akin to the process responsible for priming across associates within languages, such as spreading activation. However, since there was no significant cross-language priming in Experiment 3, where word associates were used as primes and targets, it appears that the process responsible for translation equivalent priming does not spread activation to related words in different language stores, as would be predicted by the spreading activation model. The priming occurring across translation equivalents, however, challenges a completely separate model of bilingual memory organisation and suggests that the organisation of representations is determined by principles that are more complex than only language-specific boundaries.

GENERAL DISCUSSION

Four cross-language primed LDT experiments were conducted in order to test hypotheses about the processes underlying cross-language priming. In Experiment 1, within- and cross-language priming occurred for targets associated with the primes, and there were no effects of varying the proportion of related pairs in the experimental list. This demonstrated that the processes responsible for within- and cross-language priming were not guided by a controlled strategy sensitive to context occurring either pre- or post-lexically. In Experiments 2 and 3, the subjects, presented with the same materials, were asked to respond at a given fast rate. While significant priming effects occurred for within-language associated pairs, priming disappeared in the cross-language conditions. It was concluded that the subjects had discontinued a meaning-integration process that occurs after the access of the target. The remaining priming effects in both within-language conditions were attributed to automatic spreading activation occurring within separate language-specific memory stores. The model of separate stores based on language specificity, however, was contradicted by the results of Experiment 4, which demonstrated that when primes and targets were translation equivalents, cross-language priming persisted, even though, as in Experiments 2 and 3, the subjects were asked to respond at a fast rate. This result suggests that the principles which determine bilingual memory organisation are more complex than simply language specificity.

Models of word identification which include a post-lexical meaning-integration process (Forster, 1979; 1981; de Groot, 1984; Seidenberg, Waters, Sanders & Langer, 1984; Stanovich & West, 1983; West & Stanovich, 1982) hold that this process is a basic part of normal reading. It is considered to be a discrete process which forms part of a sequence of processes employed by the skilled reader to decode word meanings.

Logan (1979; 1981; 1985) proposed that skilled activity, such as reading, may be made up of components (such as perceptual analysis of stimuli, lexical search, meaning integration, etc.) that are organised in a particular way to perform a particular task. While the individual components may be more or less automatic in their functioning, the overall organisation is more subject to conscious control.

This general model of automaticity and skill may be applied to the results of the experiments reported above. The subject who participates in the primed LDT has already in his or her memory a sequence of processes, including meaning integration, which are normally employed to decode words when reading. When asked to respond especially quickly and given a means to monitor speed (with a low proportion of related pairs), they find that the meaning-integration process, which occurs after lexical access of the target, slows their response rate. The subjects respond to this by employing controlled attentional processing, which requires effort and attention, to interrupt the normal reading sequence and restructure it so that meaning integration does not occur before the lexical decision. (The suggestion that this is a controlled, effortful, attentional process is reflected in the comments, and complaints, of subjects when they are trying to respond quickly.) As a result of dropping the meaning-integration process from the sequence of processes leading to lexical decision, cross-language priming disappears and within-language priming may be reduced. Some within-language priming, however, persists, presumably because it is the result of automatic spreading activation within a language-specific memory store, a process which occurs as an integral part of one of the processes that leads to target recognition.

The implication of these results for models of bilingual memory is to support the general hypothesis that the representations of the meanings of words expressed in different languages are separate and discrete. This conclusion is consistent with the general separate-store hypothesis (Kolers, 1963; Paivio, 1986). It is not, however, consistent with a model where the representations of words are neatly divided into linguistically determined modules. This is because priming between translation equivalents persisted in the stressed condition as it did with within-language primary associates.

De Groot and Nas (1991) concluded from their masked prime experiments that there are lexical links between representations of translation equivalent words. The research presented in this paper presents converging evidence that translation equivalents are directly linked in memory. However, activation does not reach cross-language primary associate representations in the other language store along this route. The larger implication for bilingual memory organisation is that it is not determined by linguistic groupings alone, but by principles that are more complex and which may cross language boundaries.

An alternative explanation for the disappearance of priming when the subjects were pressed to respond quickly, that cannot be entirely ruled out, is that at a surface level the subjects filtered out the primes in the cross-language conditions so that they were never available to semantic processes.

There are several reasons, however, for questioning this alternative hypothesis. An experimenter sat with each subject throughout the experiment and verified that they looked directly at the primes. Is it possible to look at the primes and not process them? The fact that de Groot and Nas (1991) found within-language priming effects when the primes were masked and the subjects were unaware of their nature suggests not. Also, the results of Experiment 4, which employed translation equivalent pairs and produced cross-language priming (under exactly the same conditions as the cross-language primary associate pairs), suggest that the subjects did not screen out the cross-language primes. Further, in a different series of cross-language primed LDT experiments, Keatley et al. (submitted, experiment 1) asked highly proficient Chinese–English bilinguals to repeat the name of the prime from time to time in order to check whether they were screening out the primes. Priming in this study was asymmetrical, with significant priming occurring from L1 to L2, but not from L2 to L1. But the recall scores were equally large in both conditions. As a result, we concluded that a perceptual filtering could not account for the lack of priming in the L2 to L1 condition, but rather the explanation must lie at a deeper level of processing.

In sum, the experiments reported in this paper support the hypothesis that cross-language priming is the result of a post-lexical meaning-integration process. Logan's model of skilled performance and automaticity was employed to explain how subjects are able to stop normal meaning-integration processing in order to respond faster on the LDT. The finding that priming disappears in the cross-language conditions when subjects are pressed to respond quickly, while it persists in within-language conditions, supports a generally separate-store model of bilingual memory. Since priming also persists across translation equivalents, the principles that determine the organisation of representations appear to be more complex than simple language-specific boundaries.

REFERENCES

Altarriba, J. (1991). Is there automatic semantic priming across a bilingual's two languages? Paper presented to the *Third Annual Meeting of the American Psychological Society*, Washington, D.C., June.

Altarriba, J. (1992). The representation of translation equivalents in bilingual memory. In R. Harris (Ed.), *Cognitive processing in bilinguals*, pp. 157–174. Amsterdam: Elsevier.

Anderson, J.R. & Bower, G.H. (1973). *Human associative memory*. Washington, D.C.: V.H. Winston.

Becker, C.A. (1979). Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *3*, 252–259.

Becker, C.A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition*, 8, 493–512.

Chen, H.-C. & Ng, M.-L. (1989). Semantic facilitation and translation priming effects in Chinese–English bilinguals. *Memory and Cognition*, *17*, 454–462.

Den Heyer, K., Briand, K. & Dannenberg, G. (1983). Strategic factors in a lexical-decision task: Evidence for automatic and attention-driven processes. *Memory and Cognition*, *11*, 374–381.

Durgunoğlu, A.Y. & Roediger, H.L. (1987). Test differences in accessing bilingual memory. *Journal of Memory and Language*, *26*, 377–391.

Forster, K.I. (1979). Levels of processing and the structure of the language processor. In W.E. Cooper & E. Walker (Eds), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*, pp. 27–85. Hillsdale, N.J.: Lawrence Erlbaum Associates Inc.

Forster, K.I. (1981). Priming and the effects of sentence and lexical contexts on naming time: Evidence for autonomous lexical processing. *Quarterly Journal of Experimental Psychology*, *33A*, 465–495.

Grainger, J. & Beauvillain, C. (1988). Associative priming in bilinguals: Some limits of interlingual facilitation effects. *Canadian Journal of Psychology*, *42*, 261–273.

Groot, A.M.B. de (1984). Primed lexical decision: Combined effects of the proportion of related prime–target pairs and the stimulus onset asynchrony of prime and target. *Quarterly Journal of Experimental Psychology*, *36A*, 253–280.

Groot, A.M.B. de & Nas, G.L.J. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language*, *30*, 90–123.

Jin, Y.-S. (1990). Effects of concreteness on cross-language priming of lexical decision. *Perceptual and Motor Skills*, *70*, 1139–1154.

Keatley, C.W. (1992). History of bilingualism research in cognitive psychology. In R. Harris (Ed.), *Cognitive processing in bilinguals*, pp. 15–50. Amsterdam: Elsevier.

Keatley, C.W., Spinks, J. & de Gelder, B. (submitted). Asymmetrical semantic facilitation between languages: Evidence for separate representational systems in bilingual memory.

Kirsner, K., Smith, M., Lockhart, R., King, M. & Jain, M. (1984). The bilingual lexicon: Language specific units in an integrated network. *Journal of Verbal Learning and Verbal Behavior*, *23*, 519–539.

Kolers, P.A. (1963). Interlingual word associations. *Journal of Verbal Learning and Verbal Behavior*, *2*, 291–300.

Kolers, P.A. & Gonzalez, E. (1980). Memory for words, synonyms and translations. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 53–65.

Kolers, P.A. & Roediger, H.L. (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior*, *23*, 425–449.

Kolers, P.A. & Smythe, W.E. (1984). Symbol manipulation: Alternatives to the computational view of mind. *Journal of Verbal Learning and Verbal Behavior*, *23*, 289–314.

Logan, G.D. (1979). On the use of concurrent memory load to measure attention and automaticity. *Journal of Experimental Psychology: Human Perception and Performance*, *5*, 189–207.

Logan, G.D. (1981). Attention, automaticity, and the ability to stop a speeded choice response. In J. Long & A. Baddeley (Eds) *Attention and performance IX*. New York: Academic Press.

Logan, G.D. (1985). Skill and automaticity: Relations, implications, and future directions. *Canadian Journal of Psychology*, *2*, 367–386.
Macnamara, J. (1967). The linguistic independence of bilinguals. *Journal of Verbal Learning and Verbal Behavior*, *6*, 729–736.
Meyer, D.E. & Ruddy, M.G. (1974). Bilingual word-recognition: Organization and retrieval of alternative lexical codes. Paper presented to the *Eastern Psychological Association*, Philadelphia (April).
Neely, J.H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, *106*, 226–254.
Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford: Oxford University Press.
Paivio, A. & Desrochers, A. (1980). A dual-coding approach to bilingual memory. *Canadian Journal of Psychology*, *34*, 388–399.
Paivio, A. & Lambert, W.E. (1981). Dual-coding and bilingual memory. *Journal of Verbal Learning and Verbal Behavior*, *20*, 532–539.
Potter, M.C. (1979). Mundane symbolism: The relations among objects, names, and ideas. In N.R. Smith & M.B. Franklin (Eds), *Symbolic functioning in childhood*, pp. 41–65. Hillsdale, N.J.: Lawrence Erlbaum Associates Inc.
Potter, M.C., So, K.-F., von Eckardt, B. & Feldman, L.B. (1984). Lexical and conceptual representation in beginning and proficient bilinguals. *Journal of Verbal Learning and Verbal Behavior*, *23*, 23–38.
Savard, J.G. & Richards, J. (1970). *Les indices d'utilité du vocabulaire fondamental français*. Quebec: Les Presses de l'Université Laval.
Schwanenflugel, P. & Rey, M. (1986). Interlingual semantic facilitation: Evidence for a common representational system in the bilingual lexicon. *Journal of Memory and Language*, *25*, 605–618.
Seidenberg, M.S., Waters, G.S., Sanders, M. & Langer, P. (1984). Pre- and postlexical loci of contextual effects on word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *15*, 88–97.
Snodgrass, J.G. (1984). Concepts and their surface representations. *Journal of Verbal Learning and Verbal Behavior*, *23*, 3–22.
Stanovich, K.E. & West, R.F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General*, *112*, 1–36.
Tweedy, J.R. & Lapinski, R.H. (1981). Facilitating word recognition: Evidence for strategic and automatic factors. *Quarterly Journal of Experimental Psychology*, *33A*, 51–59.
Tweedy, J.R., Lapinski, R.H. & Schvaneveldt, R.W. (1977). Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory and Cognition*, *5*, 84–89.
Uit den Boogaart, P.C. (1975). *Woordfrequenties in Geschreven en Gesproken Nederlands*. Utrecht: Oosthoek, Scheltema and Holkema.
West, R.F. & Stanovich, K.E. (1982). Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *8*, 385–399.