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Transfer of refractory states across languages in a global aphasic patient

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ABSTRACT

We report new data on the nature of category-specific deficits, and the transfer of refractory behaviour across languages, in a pre-morbidly fluent bilingual (English-French) patient. Previous studies (Forde & Humphreys, 1995, in press) have shown that the present patient, JM, shows a category-specific breakdown in auditory-written word matching tasks, along with impaired (refractory) performance when stimuli are tested repeatedly. In the present paper we show that there is a similar pattern of category-specific breakdown in French as well as English, and that there is symmetric transfer of the refractory state from one language to the other. We discuss the implications of the findings for understanding bilingual language representations and for understanding the nature of the functional deficit in JM and similar patients.

INTRODUCTION

Semantic and lexical representation in bilinguals

A major issue in understanding language representation in bilinguals is whether the two languages are stored independently, or whether they are mediated through common representations. In its strictest terms, a separate representation account would hold that bilinguals have two independent language systems, including separate lexical and semantic knowledge stores ; also, information from one language system need not be readily available to the other (Kirsner, Brown, Abrol, Chandra, & Sharma, 1980 ; Kolers, 1963 ; Figure 1a). In contrast to this, several theorists have argued that there exist only separate lexical representations for the words in each language, but there is a common semantic representation for translation equivalent words (e.g., Caramazza & Brones, 1980 ; Kroll & Stewart, 1994 ; Paradis, 1981 ; Potter, So, Von Eckardt, & Feldamn, 1984 ; Figure 1b).

Word representation in bilinguals has frequently been assessed using priming procedures. For instance, in lexical decision tasks short-term semantic priming has been demonstrated across languages, consistent with a shared-representation account (e.g., Chen & Ng, 1989 ; Dufour & Kroll, 1995 ; Frenck & Pynte, 1987 ; Grainger & Beauvillain, 1988 ; Kirsner, Smith, Lockhart, King, & Jain, 1984 ; Meyer & Ruddy, 1974 ; Scarborough, Gerard, & Cortese, 1984 ; Schwanenflugel & Rey, 1986 ; Tzelgov & Eben-Ezra, 1992 ; Williams, 1994). However, recent studies that have carefully controlled the characteristics of the relations between languages have yielded rather inconsistent results (see Altarriba, 1990; Tzelgov & Eben-Ezra, 1992; Williams, 1994, for results in favor of the 'shared conceptual representations hypothesis', and de Groot & Nas, 1991; Keatley, & de Gelder, 1992; Keatley, Spinks, & de Gelder, 1994, for results in favor of the 'separate conceptual representations hypothesis'). In particular, some researchers have found asymmetric priming effects : priming may occur from primes in the bilingual's first language (L1) to targets in the second language (L2), but there may be little or no priming in the reverse case (see Dufour & Kroll, 1995, Keatley & de Gelder, 1992, and Williams, 1994, for a discussion). This suggests that

conceptual links are stronger in the direction from L1 to L2, perhaps because the words of a second language acquired later in life will be learned in terms of their translation equivalent in L1. It follows that cross-language connections between lexical and conceptual memory are asymmetrical. Similar effects have been found for translation tasks (de Groot, Dannenburg, & Van Hell, 1994; Dufour & Kroll, 1995; Kroll & Sholl, 1992; Kroll & Stewart, 1994). It takes longer to translate from L1 to L2 than vice versa. Kroll and Sholl (1992) suggest that as learners become more proficient in a second language, they shift to a strategy in which words in the second language are understood directly rather than by accessing the first language. Greater fluency would entail greater reliance on conceptual mediation.

Even in models supposing a common conceptual representation for translation equivalents in bilinguals, differences in either the ease or the 'route' to access conceptual knowledge may occur, so accounting for these asymmetries in priming and translating tasks. For example, in one view (the 'word association model' ; Figure 2a), there may be no direct connection between the lexical representation of words in the bilingual's second language (L2) and associated conceptual representations. L2 words can only access their concepts indirectly, via the lexical representations of their translations in the bilingual's first language (L1). Alternatively, there may be direct connections from lexical representations of L2 words to both their translation equivalents (L1 lexical representations) and their conceptual representations (the 'asymmetrical model' ; Figure 2b). However, the relative strengths of these connections may differ across bilinguals. For instance, in fluent bilinguals, the connections may be equally strong from lexical representations for L1 and L2 to the common conceptual representations. In less fluent bilinguals, however, the connections may be weighted asymmetrically, so that connections to conceptual representations from the lexicon for L2 may be less strong than those from the lexicon for L1. In the latter case, the direction of translation will affect performance (Kroll & Stewart, 1994 ; see also Dufour & Kroll, 1995).

The word translation task

The word translation task has been used as a means of obtaining information on the organization of knowledge in bilingual memory of normal subjects (e.g., Chen & Leung,

1989; de Groot, 1992a; Kroll & Curley, 1988; Potter et al., 1984). This task consists of asking a French-English bilingual subject (for instance) to translate into English the French word "ARBRE". This word translation task could take place via the direct connection between the lexical representations of the translation equivalents (Route T1 on Figure 2a), or indirectly, via an amodal conceptual representation shared by the two translation equivalents (Route T2: T2a plus T2b ; Figure 2b). In recent research these two hypothesis have been examined by comparing word translation times with those for picture naming in the second language. If translation comes through route T1, it may take less time than picture naming in the second language, because the route to the response would be shorter ; in picture naming access to the conceptual representation may not be bypassed. Such a result would be equivalent to the finding that words are named faster than pictures even in monolingual subjects (Potter & Faulconer, 1975). In contrast, if route T2 is used in translation, word translation and picture naming should take equally long, since conceptual knowledge must be contacted in both cases. The data indicate that fluent bilinguals use route T2, whereas less proficient adult bilinguals take route T1 (Chen & Leung, 1989; Kroll & Curley, 1988). This suggests that T1 connections exist, but are bypassed by fluent bilinguals during word translation (see de Groot, 1992a; Dufour & Kroll, 1995).

Neuropsychology and bilingualism

Additional evidence on the nature of language representation in bilinguals comes from studies of bilingual subjects who have suffered brain lesions. Evidence for some degree of independent language representation in bilinguals is provided by cases such as AD, a French/Arabic bilingual aphasic discussed by Paradis, Goldblum, and Abidi (1982). Following a head injury AD suffered a period of total aphasia and could speak only a few words of Arabic. However, on returning to France it was noted that she sometimes named objects in one language spontaneously, whilst on other occasions naming only operated in the other language. In addition, on days when AD could use one language spontaneously she was unable to translate into that language from the other language, even though she could translate

from the active language into the other. This evidence for nonparallel recovery of multiple languages is consistent with there being some separation of the languages in the brain.

Other evidence for the separate representation of languages in bilinguals derives from studies of electrical brain stimulation. Ojemann and Whitaker (1978) stimulated electrically different sites in the brains of two bilinguals undergoing treatment for intractable epilepsy. During stimulation the patients were asked to name objects shown to them on slides. Ojemann and Whitaker found a number of cortical sites where both languages were disturbed by stimulation, and sites where one language was disturbed more than the other. They concluded that there are sites common to both languages and sites specific for each language. In addition they suggested that the patient's second language was represented in a wider area of cortex than the first. This is consistent with there being some pruning of pathways such as T1 (Figure 2a) as learning progresses.

One problem with prior neuropsychological studies of bilinguals, however, is that investigators have not tied-down in detail the functional loci of the shared and independent language functions. Hence the question of whether there is a common set of conceptual representations along with independent lexica has not been addressed. In the present study, we report a detailed single case analysis of a bilingual aphasic subject, JM, in which we attempt to localize the functional locus of his shared language functions. Previous work with JM indicates that, when tested in English, he showed the characteristics of what has been termed 'category specific access dysphasia' (see McNeil, Cipolotti, & Warrington, 1994). Of most relevance to the present study, JM's performance deteriorated when there was repeated testing of stimuli (i.e., there is refractory behaviour); and as outlined below, there are grounds for arguing that this deterioration was specific to when access to conceptual information was required by the task. Here we assess whether, once a refractory state has been created in one language, there is a spread of that state to other languages, as would be expected if there are common conceptual representations across the languages of fluent bilinguals.

'Category specific access dysphasia'

Warrington, McCarthy and colleagues (e.g., McNeil et al., 1994 ; Warrington & McCarthy, 1983, 1987) have reported case studies of patients with 'category specific access dysphasia'. These patients were all globally aphasic and so were tested using simple matching-to-sample tasks (e.g., point to a designated word amongst a set of 6 targets). In each case the patients were found to show : (i) inconsistent performance when tested on the same items across time ; (ii) a deterioration in performance when items were repeated, especially when there was a relatively brief interval between the last response and the next stimulus presentation (e.g., with a 2 sec interval) ; (iii) no effect of the frequency of the words tested ; and (iv) worse performance on items from some categories rather than others. Patients MED (McNeil et al., 1994) and YOT (Warrington & McCarthy, 1987) were particularly impaired at auditory word-written word matching with non-famous proper names (girls' names and boys' names) compared to famous proper names (countries and famous people), and they were worse when they had to discriminate between stimuli from within the same category in the matching task. Warrington and McCarthy (1983, 1987) proposed that, in some cases, there was temporary inhibition of access to conceptual knowledge, making performance worse with repeated testing particularly for items within a category (perhaps because access is then required to the same part of the conceptual system, or because there is a spread of inhibition between related concepts).

Forde and Humphreys (1995) reported a matching pattern of performance in patient JM. Also, in tests assessing access to explicit phonological information from written words and pictures JM performed very poorly, typically scoring at chance level on rhyme and homophone judgements. Forde and Humphreys suggested that, in a patient with poor explicit access to phonology, auditory word-written word and auditory word-picture matching may be based on activated conceptual representations. Also, contrary to the idea that there is an impairment of access procedures (along with intact conceptual representations) in such patients, they argued that conceptual representations themselves are temporarily inhibited so that refractory behaviour results. Consistent with this last proposal, Forde and Humphreys

showed that there was a spread of the refractory state to new items that were semantically related to previously tested stimuli.

In an extension of this last study, Forde and Humphreys (in press) provided additional evidence that the locus of JM's deficit was in stored conceptual representations. Tasks that required access only to pre-semantic representations, such as lexical decision (with words), object decision and the matching of object across unusual viewpoints (with objects) were performed relatively well, and lexical decision and unusual view-matching did not become refractory (even though the same items did become refractory when tested in auditory-written word and picture matching under equivalent circumstances). In contrast, tasks explicitly requiring access to semantic knowledge, even when contained in a single modality of testing, deteriorated with repeated testing (e.g., when associatively related items had to be matched). Perhaps most telling, there was transfer of the refractory state across presentation modalities. Thus, the effect of inducing a refractory state with picture targets generalized to the same stimuli presented as words, and vice versa. Since different presentation modalities were involved, it is difficult to account for this last result in terms of refractory access procedures into an intact conceptual system, since the access procedures should be modality-specific (note 1). However, the data are consistent with JM's conceptual knowledge becoming refractory with repeated testing, with the same knowledge being affected irrespective of the modality of the input.

The present study

Prior to suffering a stroke, JM had been fluent in seven languages (English, French, German, Italian, Spanish, Dutch and Russian). Though a native speaker of English, he had been educated at the Sorbonne in Paris and had written a postgraduate thesis in French. He and his wife had both taught French for many years and latterly they lived in France for six months of each year. These bilingual skills, combined with the previous work locating the locus of JM's refractory behaviour within the conceptual knowledge system, provided a unique opportunity for us to assess the nature of language representations in a fluent bilingual. In particular, if the conceptual representations of L1 and L2 are the same for the fluent

bilingual, we can expect there to be a complete transfer of the refractory state across languages. Thus initial probing of words in one language should lead to impaired performance on the first presentation of the matching words in a second language. Also, if access to conceptual knowledge is equally efficient in both languages, this transfer should be symmetric (from L1 to L2, and vice versa). Finally, if the conceptual representations are the same, and there is evidence of a category-specific deficit in accessing conceptual knowledge, the nature of the category-specific deficit will be the same across languages. These predictions were tested with JM in auditory word-written word matching tasks in French and English. Note that, if we find evidence for equivalent category-specific deficits in both languages, and for a complete transfer of the refractory state across languages, this would also go against an account of refractory behaviour in terms of impaired access routes to intact conceptual knowledge, since the access routes to conceptual knowledge are typically thought to be language-specific (see Figure 1). Hence the present study is relevant too for understanding the nature of the deficit in so-called ‘category-specific access dysphasia’.

CASE REPORT

JM, a 72 year old man, was formerly head of languages at a grammar school. He suffered a left hemisphere stroke on the 12th of February 1992, which led initially to right sided hemiparesis although motor control over his leg improved to the level that he was able to walk. A CAT scan (see Forde & Humphreys, 1995) showed a large hypodense area in the left temporo-parietal region. After the stroke JM was globally aphasic. He had no spoken output and minimal written output (for some single letters but not for words). When asked to write single letters to dictation he scored 15/26 and 13/26 but he failed to write any single word correctly. His spoken output was reduced to a single repetitive utterance ('da, da'). His general intellectual performance was average for his age (27/60 on the Standard Progressive Raven's Matrices). His auditory digit span was measured using a digit matching test (test 13 in the PALPA test battery; Kay, Lesser, & Coltheart, 1992), giving a score of 4, and he could

point to up to three objects in correct serial order when given their names auditorily. On line cancellation, there were no signs of unilateral neglect.

JM had relatively good access to stored lexical knowledge from vision and from audition. He scored 55/60 (92%) on visual lexical decision and 51/60 (85%) on auditory lexical decision, taken from PALPA (Kay et al., 1992), pointing either to a letter W (for a word) or a letter N (for a nonword) placed in front of him. With pictures he scored 32/32 (100%) on object decision, taken from BORB (Riddoch & Humphreys, 1993).

In contrast, JM had minimal access to output phonology and little apparent internal phonology. He scored 10/26 and 9/26 on pointing to named letters, and 6/20 on pointing to a named nonword surrounded by other nonwords sharing letters but not pronunciations (e.g., vib, vit, vab). This was not due to poor audition; JM performed relatively well at auditory lexical decision (see above), and from a name he could point to one of 3 pictures which were semantically dissimilar but whose names differed by one phoneme (e.g. goat, coat, goal). However, on the written-word rhyme matching task from PALPA (test 15), his performance was : 12/15 on rhyming words with similar spelling (town-gown), 12/15 on non-rhyming spelling pattern controls (food-blood), 11/15 for rhyming words with dissimilar spelling (ghost-roast), 12/15 on non-rhyming spelling pattern controls (bond-hand). Overall his performance (42/60; 70% correct) was significantly impaired relative to one age matched control (58/60 ; Fisher exact probability, $p < .005$). On homophone matching (PALPA test 28), he scored 34/60 (57%) correct (12/20 with regular, 12/20 with exception words and 8/20 with nonwords) ; this level of performance does not differ from chance (control level, 57/60). JM also could not assemble phonology from nonwords. He scored 8/20 when asked to point to which of 3 nonwords had the same name as an object (e.g., nale, zalt, orse). He scored 6/22 (27% correct) on judging the number of syllables in words (words could have either 1, 2 or 3 syllables), chance level of performance. Asked to match pictures according to whether their names rhymed, he scored 10/34 (29% correct) (he had to point to 2 out of 4 pictures that had rhyming names). In a name rhyme-decision task, requiring discrimination between two pictures, he scored 30/70 (43%) correct. When given the picture names auditorily he scored 54/70 (77%) correct, which was better than when he had to access the picture names internally

(Chi square (1)=15.74, $p < .001$). This last result indicates that JM understood the task, but he was still impaired at both versions of the task (non-brain damaged age-matched controls are at ceiling). JM even failed to judge whether the names of 2 pictures began with the same initial letter (7/33 (21%) correct ; this is below chance, primarily because JM tended to judge that stimuli did not have the same initial letter).

Preliminary tests on semantic memory indicated that JM had some problems even when items were not repeated. He scored 47/52 (90%), 38/52 (73%) and 44/52 (85%) for pictures, written words and auditory words on the Pyramids and Palm Trees test (Howard & Orchard-Lisle, 1984). These scores are below control level (minimum 49/52 correct) for all modalities, although performance tended to be worse with written words. On a picture-word matching test requiring discrimination between semantically related target and distractor items (from PALPA; Kay et al., 1992) JM scored 39/40 (98%) and 31/40 (78%) with auditory word and written word-picture matching ; performance was better with auditory words (Fisher exact probability = 0.007).

These preliminary tests indicated a dissociation between JM's ability to access different types of stored knowledge. On-line access to stored lexical and structural knowledge was relatively good (judged from lexical and object decision performance), access to output phonology was poor (whether accessed from pictures or printed words). In addition JM showed some difficulties in making semantic judgements. The experiments reported in the present study were conducted from January 1995 to July 1995; JM's performance throughout this time remained stable, but he died suddenly the 6th of August 1995.

EXPERIMENTAL INVESTIGATIONS

Section A: Effects of category within and between languages

JM was typically presented with 6 printed words in a random spatial order and asked to point to the word that matched the name given (visually or auditorily) by the experimenter (see Forde & Humphreys, 1995). Names were given in a pseudo-random temporal order. Once

all 6 words had been prompted, the test was initially repeated after the experimenter gathered the printed words together and re-randomized their positions.

In Section A we examined whether JM showed a similar pattern of performance when tested with auditory-written word matching in French as he did in English, and in particular whether performance varied in the same way across different stimulus categories. In Experiment 1, both the auditory and the written names were presented in French. In Experiment 2, the auditory word was in English and the written words in French.

Experiment 1: Effects of category with French words.

Method.

The method was the same as in Forde and Humphreys (1995; Experiment 6). JM was required to match a French spoken word to one of 6 written French words. The words on each trial were all exemplars from the same category, and one trial was completed when all the words in the category had been tested once (in pseudo-random order). The trial was then repeated a second time, using a different temporal order of testing and spatial layout for the written words. The 28 English categories used by Forde and Humphreys (1995) were translated into French (see Table 1 and Appendix 1). The interval between each response and the next stimulus was kept at approximately 2 sec (here and throughout the present paper), since prior work showed that JM exhibited refractory behaviour at that presentation rate (Forde & Humphreys, 1995).

Results and Discussion.

The scores for each category on each presentation for words are illustrated in Table 1. For comparison, the scores obtained in English by Forde and Humphreys (1995) with the same patient are shown in brackets.

<Insert TABLE 1 about here>

JM scored 97/168 (57.7% correct) on the first presentation of French words (P1), and 78/168 (46.4% correct) on the repeated presentation of words (P2). His performance was

significantly worse on the repeated than on the first presentation of the words (One-tailed Sign Test, $N=18$, $x=2$, $p<.001$).

JM showed better matching for some categories of stimulus than for others (see Table 1). In particular, for words, and across the different category exemplars, he was relatively good at matching clothes, transport, occupations, residences and instruments (48/60; 80% correct) and somewhat worse at matching geographical features, fruits, vegetables, colours and kitchen items (21/60; 35% correct). JM also demonstrated an interesting dissociation within the general category of proper names. He was particularly good with famous names, cities and countries (29/36; 80% correct) and very impaired with girls' names, boys' names and surnames (15/36; 42% correct). This pattern of performance is similar to that shown by JM in English (Forde & Humphreys, 1995), and there was a reliable linear relationship across the categories between JM's performance in English and in French ($F(1,26)=10$, $p<.005$).

The preliminary tests with JM indicated a deficit in accessing phonology from both pictures and printed stimuli. With printed stimuli, the problem was common to words and nonwords, suggesting that both the lexical and non-lexical route to phonology was impaired (see Morton & Patterson, 1980). Since neither of these two routes can be easily utilized, JM may be forced to match printed words to auditory words on the basis of common conceptual representations. The finding that JM's performance deteriorated when testing was repeated is consistent with him having problems in gaining access to conceptual information after it has been initially activated. It is interesting in this respect that this pattern of performance obtained in French closely mirrors that obtained in English (see Table 1). A similar pattern of deficit across different categories suggests a common underlying impairment in French and English, rather than a deficit which is specific to the access route to semantics from these two languages. Experiment 2 further tests this hypothesis by requiring JM to match words across languages (from English to French).

Experiment 2: Effects of category in English-French matching.

Method.

Exactly the same method as in Experiment 1 was used, except that JM was required to match an English spoken word to one of 6 written French words. 25 of the 28 English categories used by Forde and Humphreys (1995) were tested (see Table 1 and Appendix 1) (it was not possible to have French-English differences for cities, famous names and surnames).

Results and Discussion.

The scores for each category on each presentation are illustrated in Table 1.

JM scored 99/150 (66% correct) on the first presentation of words (P1), and 80/150 (53.3% correct) on the repeated presentation of words (P2). His performance was significantly worse on the repeated than on the first presentation of the words (One-tailed Sign Test, $N=15$, $x=3$, $p<.018$).

JM again showed better matching for some categories of stimulus than for others (see Table 1). In particular, for words, and across the different category exemplars, he was relatively good at matching sport, transport, occupations, residences and instruments (49/60; 82% correct) and somewhat worse at matching geographical features, fruits, vegetables, colours and kitchen items (27/60; 45% correct). There was again a reliable linear relationship across categories between his earlier performance on English (Forde & Humphreys, 1995) and his present performance on matching English to French words ($F(1,23)=10$, $p<.005$).

The results from Experiments 1 and 2 indicate close similarities between JM's ability to carry out auditory-written word matching in English, French and from English to French. In each case, he performs worse when the tests are repeated, and he tends to perform worse with the same categories across languages. Forde and Humphreys (in press) have strongly argued for JM's deficit being at the conceptual level because: (i) it occurs on within-modality associative matching tasks, and (ii) it transfers across modalities. The similarity of performance across languages here suggests in turn that, for JM, English and French share conceptual representations.

The categories that JM tends to find difficult, such as non-famous nouns and colours, are those with relatively sparse conceptual representations, and, where conceptual representations exist (e.g., male or female name) they tend to be shared across many exemplars. It is possible that such items may in any case be difficult to match using conceptual knowledge, irrespective of whether his conceptual knowledge is additionally impaired. We suggest that JM has to perform auditory-written word matches using conceptual knowledge because he is impaired at derived phonological information from print (see the Preliminary Investigations).

Cognate/Noncognate status: Post-hoc analyses

A word characteristic attended to in some bilingual studies is the cognate status of translation equivalents. The question is whether the translations are similar both in sound and in spelling (similar for cognates, dissimilar for noncognates) and what effects this factor may have (de Groot, 1992b; 1993; de Groot & Nas, 1991; Sanchez-Casas, Davis, & Garcia-Albea, 1992; Taylor, 1978). Using the translation task, de Groot (1992b) found that cognates (e.g., English carrot and French carotte) were translated faster, more often, and more correctly than noncognates (e.g., English grape and French raisin). The translation direction in de Groot (1992b) study was from the native language to the subjects' second language, as in the present study. Sanchez-Casas et al. (1992) observed the same effects of cognate status in word translation. de Groot and Nas (1991) also looked at the effect of cognate status on repetition priming. The translation priming effect observed was larger for cognates than for noncognates although statistically the effect was equally large for the two types of words. de Groot and Nas (1991) concluded from these and other data (see also de Groot, 1993) that (1) in bilingual memory cognate translations share a conceptual representation, and (2) that noncognate translations are represented in language-specific conceptual nodes.

Given that the materials used in Experiment 2 contained a large number of words that are cognates in English and French (50 words out of 150 are cognates, 33.3% of the stimuli), we performed post-hoc analyses of the data to determine (1) whether there was any effect of the cognate status of the words, and (2) to determine whether the refractory pattern overall

holds for noncognates alone and cognates alone. The scores for each category on each presentation and for cognates and noncognates are illustrated in Table 1 Bis.

<Insert TABLE 1 Bis about here>

Overall, JM was better for cognates (77% correct) than for noncognates (51% correct), thus confirming the results of de Groot (1992b) and Sanchez-Casas et al. (1992).

Concerning the refractory pattern, for cognates (C), JM scored 42/50(84%) on the first presentation of words (P1), and 35/50 (70%) on the repeated presentation of words (P2). His performance was significantly worse on the repeated than on the first presentation of the words (One-tailed Sign Test, $N=9$, $x=2$, $p=.09$). For noncognates (NC), JM scored 57/100 (57%) on the first presentation of words (P1), and 45/100 (45%) on the repeated presentation of words (P2). Again, his performance was significantly worse on the repeated than on the first presentation of the words (One-tailed Sign Test, $N=16$, $x=4$, $p<.038$).

The results of these post-hoc analyses clearly show (1) an effect of cognate status (+21%), and (2) that the refractory pattern holds for noncognates alone (-12%) as well as for cognates alone (-14%). These fine-grained analyses of the stimulus materials used in the present study do not support the view that the storage format for cognates differs from that of noncognates (de Groot, 1992b, 1993). The suggestion of shared representations for cognates and separate representations for non-cognates is not supported by the present data.

Section B: The spread of refractoriness across languages

In Section B, we provided a further test of (a) whether JM's impairment is at a conceptual level, and (b) whether conceptual information is shared across languages, by assessing whether refractoriness induced by one language can transfer to a second language. In Experiment 3 JM first performed French-French auditory word-written word matches before being tested on English-English matches (Experiment 3A), or he performed English-English matches before being tested on French-French matches (Experiment 3B). In Experiment 3, all the words on a trial belonged to the same category. In Experiment 4, the same procedure was used except that, on the language-switch trial the words changed category as well as language. Experiment 4 tested whether any deleterious effect of repetition in

Experiment 3 was because the category members were maintained across trials, and not because of more general fatigue on JM's part as testing was continued. In Experiment 3A we ask whether performance is impaired on English words presented for the first time if they had earlier been probed in French, and in Experiment 3B we assess whether performance is impaired on French words if they had earlier been probed in English.

Experiment 3: Transfer within categories across languages.

Method.

The method was similar to that in Experiments 1 and 2. In Experiment 3A, JM was initially required to match a French spoken word to one of 6 written French words. The words on each trial were all exemplars from the same category, and one trial was completed when all the 6 words had been tested once (in pseudo-random order). The trial was then repeated a second time in French, using a different temporal order of testing and spatial layout for the written words. Finally, the trial was repeated a third time, but this time JM was required to match an English spoken word to one of 6 written English words from the same semantic categories. In Experiment 3B, JM was initially required to match an English spoken word to one of 6 written English words. The words on each trial were all exemplars from the same category, and one trial was completed when all the words in the category had been tested once (in pseudo-random order). The trial was then repeated a second time in English, using a different temporal order of testing and spatial layout for the written words. Finally, the trial was repeated a third time, but this time JM was required to match a French spoken word to one of 6 written French words from the same semantic categories. For both Experiments 3A and 3B, 12 of the 28 English categories used by Forde and Humphreys (1995) were translated into French and tested (see Table 2 and Appendix 1).

Results and Discussion.

The scores for each category on each presentation for words are illustrated in Table 2.

<Insert TABLE 2 about here>

Experiment 3A.

JM scored 46/72 (63% correct) on the first presentation of French words, and 33/72 (46% correct) on their repeated presentation. His performance was significantly worse on the repeated than on the first presentation of the words (French-French condition: One-tailed Sign Test, $N=9$, $x=1$, $p<.002$). On the third presentation (in English), JM scored 24/72 (34% correct). Again, his performance was significantly worse on the third than on the second presentation, even with a change of language presentation (from French to English: One-tailed Sign Test, $N=9$, $x=2$, $p=.09$).

Experiment 3B.

JM scored 44/72 (61% correct) on the first presentation of English words, and 36/72 (50% correct) on their repeated presentation. His performance was significantly worse on the repeated than on the first presentation of the words (English-English condition: One-tailed Sign Test, $N=12$, $x=2$, $p<.019$). On the third presentation of words (in French), JM scored 23/72 (32% correct). Again, his performance was significantly worse on the third than on the second presentation of the words, even with a change of language presentation (from English to French: One-tailed Sign Test, $N=11$, $x=2$, $p<.033$).

In both Experiment 3A and Experiment 3B, JM showed clear refractory behaviour, performing worse on trials 2 and 3 relative to trial 1. Moreover performance was particularly poor on trial 3 even though the language used on this trial differed from the earlier two trials. This transfer of refractory state was also symmetrical across languages. In Experiment 4 we tested whether this apparent refractory behaviour was either because items were repeated across 3 trials at a fast presentation rate, or because there was a switch in language on trial 3. On trial 3, the words changed categories as well as languages here. In prior work, refractory behaviour has been shown to decrease when words change category (Forde & Humphreys, 1995; Warrington & McCarthy, 1987). If general fatigue, or the language switch per se, is not responsible for the effect of repetition here, JM's performance may improve on trial 3, even up to the level observed on trial 1.

Experiment 4: Transfer across categories and languages.

Method.

The method was the same as in Experiments 3A and 3B except that in the third presentation, the semantic categories were different from the previous ones (the same categories were used across the experiment, but the categories on trial 3 were randomly related to those on trials 1 and 2). In Experiment 4A JM first carried out auditory-written word matching in French on trials 1 and 2, and then in English, on trial 3. In Experiment 4B he carried out matching in English on trials 1 and 2 followed by French on trial 3.

Results and Discussion.

The scores for each category on each presentation for words are illustrated in Table 3.

<Insert TABLE 3 about here>

Experiment 4A.

JM scored 41/72 (57% correct) on the first presentation of French words, and 24/72 (33% correct) on the repeated presentation of French words. His performance was significantly worse on the repeated than on the first presentation of the words (French-French condition: One-tailed Sign Test, $N=12$, $x=0$, $p<.001$). On the third presentation (in English), but with the switched category, JM scored 40/72 (55% correct). This time his performance was significantly better on the third than on the second presentation (One-tailed Sign Test, $N=11$, $x=1$, $p<.006$), and it did not differ relative to the first trial (One-tailed Sign Test, $N=4$, $x=1$, $p=.312$).

Experiment 4B.

JM scored 39/72 (54% correct) on the first presentation of English words, and 21/72 (29% correct) on the repeated presentation of English words. His performance was significantly worse on the repeated than on the first presentation of the words (English-English condition: One-tailed Sign Test, $N=11$, $x=0$, $p<.001$). On the third presentation of words (in French), with the switched category, JM scored 38/72 (52% correct). His performance was significantly better on the third than on the second presentation of the words

(One-tailed Sign Test, $N=9$, $x=0$, $p<.002$), and performance on the third trial did not differ from that on the first trial (One-tailed Sign Test, $N=9$, $x=4$, $p=.500$).

In contrast to Experiment 3, JM showed no evidence here of refractory behaviour on trial 3, even though there was still a switch of language on that trial. Thus neither the serial position of the test, nor the language switch is sufficient ; what is important is that the same set of items, from the same category, are presented repeatedly (as in Experiment 3).

GENERAL DISCUSSION

Overall, the present study shows that JM showed a very similar pattern of auditory word-written word matching in English and French. Experiments 1 and 2 demonstrated that the categories that JM found either difficult or easy to match were largely the same irrespective of whether the words were in English (Forde & Humphreys, 1995), French (Experiment 1) or had to be matched across languages (Experiment 2). This suggests that performance in French and English was influenced by a common factor.

In previous studies with JM, Forde and Humphreys (in press) demonstrated that refractoriness spread across modalities, from pictures to words (and vice versa). In Experiment 3 here we have shown that refractoriness can also spread across languages, from English to French and from French to English. Given the fact that we provided evidence that refractoriness not only occurs within the languages activated initially by words, but can spread across languages, the most parsimonious explanation of these results is that the locus of the refractoriness is within a common conceptual store (Potter et al., 1984; Riddoch, Humphreys, Coltheart, & Funnell, 1988) which is accessed by English and French alike. It is difficult to account for the effects of both the spreading refractoriness and the common pattern across categories if the locus of the impairment was in either language specific lexical or conceptual stores, in separate access routes to a common conceptual stores or in separate access routes to separate language specific conceptual stores.

Implications for bilingualism

Pre-morbidly JM was a fluent bilingual speaker and reader of English and French. After his stroke there is evidence that access to conceptual knowledge from written English words was impaired (see the Preliminary Investigations), and that conceptual representations became refractory across repeated testing. For example, Forde and Humphreys (1995, in press) have shown that for JM : (a) lexical access is relatively good and does not become refractory (e.g., on visual lexical decision tasks) ; (b) tasks become refractory if they require access to associative knowledge even from stimuli presented within a single modality ; (c) there is a transfer of the refractory state across items from the same category ; (d) there is transfer of the refractory state across the same items presented in different modalities. These results isolate the refractory state within the conceptual system. Given that, our findings that (a) there is similar category-specificity in the deficits across languages, and (b) there is symmetric transfer of the refractory state across languages, indicate that, for JM, there are shared conceptual representations for English and French words. Indeed, since the transfer of the refractory state across languages was symmetric, the data also suggest that the connections into the conceptual system from L1 to L2 are equally efficient. Linked to this last point, Forde and Humphreys (in press) found that the transfer of the refractory state from words to pictures tended to be weaker than that from pictures to words. This may be because pictures have privileged access to conceptual knowledge (Caramazza, Hillis, Rapp, & Romani, 1990 ; Potter & Faulconer, 1975), so making them less vulnerable to the refractory state. If there were similar privileged access to conceptual knowledge for L1 (English), we would also expect the transfer of the refractory state to be greater from English to French than from French to English. There was no evidence for this (Experiment 3). For fluent bilinguals, at least, there can be direct and equally efficient access to the conceptual system from both languages.

Implications for so-called category-specific access dysphasia

McNeil et al. (1994) proposed that there exists a neuropsychological syndrome of ‘category-specific access dysphasia’, in which there is impaired (refractory) access into

conceptual knowledge. JM shares many of the characteristics of this syndrome with other patients, including showing detrimental effects of stimulus repetition, effects of presentation rate, inconsistency across items over time, and effects of semantic distance (worse performance when discrimination is required between items from the same category). We have extended these previous results here by showing that, in a bilingual patient with these symptoms, there are qualitatively similar patterns of deficit across languages and symmetric transfer of the refractory state induced by repeated testing. To the extent that access routes to conceptual knowledge are independent for different languages (see Figure 1), our data suggest that, in such patients, it is not the access routes per se which become refractory but rather the conceptual system ; there are similar category-specific deficits and transfer of the refractory state because common, language-independent conceptual representations are involved. From the present data it remains unclear whether the refractory state is caused by prolonged inhibition of representations after their initial activation or from competition caused by prolonged activation of semantically related representations. Future work must address the issue of what causes such refractory states to occur.

FOOTNOTES

1- For the same reason it is also difficult to account for the results if there were deficits in modality-specific conceptual systems, since separate systems should become refractory with different modalities of presentation (cf. Warrington & McCarthy, 1994).

AUTHORS NOTES

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TABLE 1

Number of correct responses on auditory-written word match in Experiments 1 and 2. Scores for French-French matches are shown on the first line, scores for English-French matches (when conducted) are shown below . In brackets are the data from Forde and Humphreys (1995) for English-English matches.

| | Written Word | | |
|-----------------|--------------|------|--------|
| | P1 | P2 | t |
| <u>Category</u> | | | |
| Famous names | 6(6) | 6(6) | 12(12) |
| | - | - | -- |
| Transport | 5(6) | 4(5) | 9(11) |
| | 5 | 4 | 9 |
| Animals | 3(6) | 4(6) | 7(12) |
| | 5 | 5 | 10 |
| Sport | 4(6) | 4(6) | 8(12) |
| | 6 | 6 | 12 |
| Occupations | 5(6) | 5(5) | 10(11) |
| | 5 | 5 | 10 |
| Countries | 6(6) | 6(6) | 12(12) |
| | 6 | 5 | 11 |
| Cities | 3(5) | 2(6) | 5(11) |
| | - | - | -- |
| Clothes | 4(6) | 4(4) | 8(10) |
| | 0 | 3 | 3 |
| Office Items | 3(6) | 1(6) | 4(12) |
| | 5 | 2 | 7 |
| Residences | 4(4) | 6(5) | 10(9) |
| | 4 | 4 | 8 |
| Weather | 3(6) | 2(4) | 5(10) |
| | 4 | 4 | 8 |
| Emotions | 3(6) | 3(3) | 6(9) |
| | 3 | 2 | 5 |
| Subjects | 3(4) | 3(3) | 6(7) |
| | 6 | 5 | 11 |
| Fruits | 3(5) | 2(5) | 5(10) |
| | 3 | 4 | 7 |

| Written Word | | | |
|--------------|----|----|---|
| | P1 | P2 | t |

Category

| | | | |
|---------------|-----------|-----------|--------------|
| Body Parts | 1(4) 4 | 1(4) 3 | 2(8) 7 |
| Instruments | 6(5) 5 | 5(6) 5 | 11(11) 10 |
| Colours | 3(3) 1 | 2(3) 1 | 5(6) 2 |
| Geographical | 4(5) 5 | 3(2) 0 | 7(7) 5 |
| Kitchen Items | 1(2) 3 | 0(4) 2 | 1(6) 5 |
| Materials | 2(3) 3 | 2(3) 3 | 4(6) 6 |
| Boys' names | 3(2) 3 | 0(3) 3 | 3(5) 6 |
| Vegetables | 2(3) 5 | 2(4) 3 | 4(7) 8 |
| Furniture | 2(4) 5 | 1(0) 1 | 3(4) 6 |
| Units of time | 4(3) 4 | 3(3) 1 | 7(6) 5 |
| Parts of room | 3(2) 3 | 1(6) 2 | 4(8) 5 |
| Surnames | 4(1) - | 3(1) - | 7(2) -- |
| Girls' names | 3(2) 3 | 2(1) 4 | 5(3) 7 |
| Flowers | 4(4) 3 | 1(2) 3 | 5(6) 6 |

| Written Word | | |
|--------------|----|----|
| | P1 | P2 |

Means

| | | |
|-----------------|---------------|----------------|
| English-English | 121/168(72%) | 112/168(66.6%) |
| French-French | 97/168(57.7%) | 78/168(46.4%) |
| English-French | 99/150*(66%) | 80/150*(53.3%) |

Note: Maximum score=6. P1 is the first presentation of those items, P2 is the second. t refers to the total correct. The numbers into brackets refer to the English-English matching task used with the same items (Forde & Humphreys, 1995). The results on the second line correspond to the English-French matching task.

* 3 categories (Famous names, Cities, and Surnames) have not been tested.

TABLE 2

Number of correct responses on auditory-written word match (French-French-English/English-English-French- Same Categories) in Experiment 3.

| | Written Word | | | | | |
|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | E | E | F | F | F | E |
| | P1 | P2 | P3 | P1 | P2 | P3 |
| <u>Category</u> | | | | | | |
| Transport | 4 | 3 | 5 | 4 | 4 | 3 |
| Animals | 4 | 3 | 2 | 3 | 3 | 2 |
| Occupations | 5 | 6 | 3 | 6 | 5 | 4 |
| Clothes | 4 | 2 | 2 | 3 | 1 | 3 |
| Weather | 4 | 2 | 0 | 3 | 4 | 0 |
| Fruits | 4 | 3 | 2 | 5 | 3 | 2 |
| Body Parts | 4 | 3 | 2 | 3 | 2 | 2 |
| Vegetables | 1 | 2 | 3 | 3 | 1 | 1 |
| Colours | 3 | 1 | 0 | 3 | 3 | 1 |
| Furniture | 3 | 5 | 3 | 3 | 1 | 2 |
| Residences | 4 | 3 | 1 | 4 | 3 | 3 |
| Geographical | 2 | 1 | 0 | 3 | 3 | 1 |
| TOTAL (n=72) | 44 (61%) | 36 (50%) | 23 (32%) | 46 (63%) | 33 (46%) | 24 (34%) |

TABLE 3

Number of correct responses on auditory-written word match (French-French-English/English-English-French- Two first categories are the same, the last one is different) in Experiment 4.

| | Written Word | | | | | |
|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | E | E | F | F | F | E |
| | P1 | P2 | P3 | P1 | P2 | P3 |
| <u>Category</u> | | | | | | |
| Transport | 3 | 2 | 2 | 4 | 3 | 4 |
| Animals | 5 | 4 | 4 | 4 | 2 | 4 |
| Occupations | 5 | 4 | 3 | 5 | 4 | 3 |
| Clothes | 4 | 1 | 3 | 3 | 1 | 3 |
| Weather | 3 | 1 | 3 | 3 | 2 | 3 |
| Fruits | 3 | 1 | 3 | 4 | 2 | 3 |
| Body Parts | 2 | 1 | 1 | 3 | 2 | 3 |
| Vegetables | 3 | 2 | 5 | 3 | 2 | 2 |
| Colours | 2 | 1 | 3 | 3 | 1 | 3 |
| Furniture | 2 | 2 | 3 | 3 | 1 | 3 |
| Residences | 3 | 0 | 3 | 3 | 2 | 3 |
| Geographical | 4 | 2 | 5 | 3 | 2 | 4 |
| TOTAL (n=72) | 39 (54%) | 21 (29%) | 38 (52%) | 41 (57%) | 24 (33%) | 40 (55%) |

APPENDIX 1: STIMULI FOR EXPERIMENTS 1 and 2

Fruits (Fruits)

| | | | | | |
|-------------------|--------------------|--------------------|--------------------|-----------------|------------------|
| Grape (Raisin) | Banana (Banane) | Orange (Orange) | Cherry (Cerise) | Pear (Poire) | Apple (Pomme) |
|-------------------|--------------------|--------------------|--------------------|-----------------|------------------|

Clothes (Vêtements)

| | | | | | |
|-------------------|-----------------|------------------------|--------------------|-----------------------|--------------------|
| Jacket (Veste) | Skirt (Jupe) | Socks (Chaussettes) | Cap (Casquette) | Blouse (Chemisier) | Scarf (Echarpe) |
|-------------------|-----------------|------------------------|--------------------|-----------------------|--------------------|

Animals (Animaux)

| | | | | | |
|-------------------|------------------|---------------|----------------|----------------|-----------------|
| Horse (Cheval) | Tiger (Tigre) | Cat (Chat) | Cow (Vache) | Dog (Chien) | Pig (Cochon) |
|-------------------|------------------|---------------|----------------|----------------|-----------------|

Materials (Matériaux)

| | | | | | |
|-----------------|-------------------|----------------|------------------|---------------------|----------------|
| Wool (Laine) | Cotton (Coton) | Linen (Lin) | Nylon (Nylon) | Velvet (Velours) | Silk (Soie) |
|-----------------|-------------------|----------------|------------------|---------------------|----------------|

Colours (Couleurs)

| | | | | | |
|----------------|-------------------|--------------------|-----------------|-------------------|----------------|
| Blue (Bleu) | Yellow (Jaune) | Purple (Violet) | Green (Vert) | Brown (Marron) | Red (Rouge) |
|----------------|-------------------|--------------------|-----------------|-------------------|----------------|

Geographical (Topographie)

| | | | | | |
|------------------------|--------------------|------------------|---------------|--------------------|--------------------|
| Mountain (Montagne) | River (Rivière) | Cave (Grotte) | Lake (Lac) | Valley (Vallée) | Cliff (Falaise) |
|------------------------|--------------------|------------------|---------------|--------------------|--------------------|

Furniture (Meubles)

| | | | | | |
|------------------|----------------|-------------------|--------------|-----------------|---------------------|
| Table (Table) | Rug (Tapis) | Chair (Chaise) | Bed (Lit) | Bench (Banc) | Stool (Tabouret) |
|------------------|----------------|-------------------|--------------|-----------------|---------------------|

Body Parts (Parties du corps)

| | | | | | |
|------------------|-------------------|----------------|---------------|---------------|----------------|
| Elbow (Coude) | Mouth (Bouche) | Foot (Pied) | Nose (Nez) | Eye (Oeil) | Arms (Bras) |
|------------------|-------------------|----------------|---------------|---------------|----------------|

Vegetable (Légumes)

| | | | | | |
|---------------------|-------------------|--------------------|---------------------|-----------------------|-------------------|
| Carrot (Carotte) | Onion (Oignon) | Tomato (Tomate) | Lettuce (Laitue) | Peas (Petits-pois) | Turnip (Navet) |
|---------------------|-------------------|--------------------|---------------------|-----------------------|-------------------|

Occupations (Métiers)

| | | | | | |
|-----------------------|-------------------------|-----------------------|---------------------|-------------------------|-----------------------|
| Nurse (Infirmière) | Teacher (Professeur) | Dentist (Dentiste) | Doctor (Docteur) | Engineer (Ingénieur) | Baker (Boulangier) |
|-----------------------|-------------------------|-----------------------|---------------------|-------------------------|-----------------------|

Transport (Transports)

| | | | | | |
|----------------------|----------------------|------------------|------------------|------------------|--------------|
| Aeroplane (Avion) | Van (Camionnette) | Car (Voiture) | Train (Train) | Ship (Bateau) | Bus (Bus) |
|----------------------|----------------------|------------------|------------------|------------------|--------------|

Residences (Résidences)

| | | | | | |
|------------------------|--------------------|-------------------|-------------------|-----------------|------------------|
| Cottage (Chaumière) | Palace (Palais) | Cabin (Cabane) | House (Maison) | Tent (Tente) | Hotel (Hôtel) |
|------------------------|--------------------|-------------------|-------------------|-----------------|------------------|

Weather (Temps)

| | | | | | |
|-----------------|--------------------|----------------|-------------------------|-----------------|----------------------|
| Snow (Neige) | Gale (Tonnerre) | Wind (Vent) | Drought (Sécheresse) | Rain (Pluie) | Thunder (Tempête) |
|-----------------|--------------------|----------------|-------------------------|-----------------|----------------------|

Flowers (Fleurs)

| | | | | | |
|-----------------------|-------------------|----------------|----------------------|--------------------|-----------------------|
| Daisy (Paquerette) | Tulip (Tulipe) | Rose (Rose) | Violet (Violette) | Crocus (Crocus) | Poppy (Coquelicot) |
|-----------------------|-------------------|----------------|----------------------|--------------------|-----------------------|

Kitchen Items (Ustensiles de cuisine)

| | | | | | |
|----------------------|--------------------|---------------------|---------------|----------------|--------------------|
| Saucer (Soucoupe) | Pan (Casserole) | Spoon (Cuillère) | Bowl (Bol) | Dish (Plat) | Knife (Couteau) |
|----------------------|--------------------|---------------------|---------------|----------------|--------------------|

Office Items (Objets de bureaux)

| | | | | | |
|-------------------------|-------------------|----------------|-----------------|-----------------|-----------------------|
| Envelope (Enveloppe) | Brush (Brosse) | Pen (Stylo) | Coin (Pièce) | Book (Livre) | Scissors (Ciseaux) |
|-------------------------|-------------------|----------------|-----------------|-----------------|-----------------------|

Countries (Pays)

| | | | | | |
|------------------------|--------------------|--------------------|-------------------------|--------------------|-------------------|
| Germany (Allemagne) | Russia (Russie) | Canada (Canada) | England (Angleterre) | France (France) | Italy (Italie) |
|------------------------|--------------------|--------------------|-------------------------|--------------------|-------------------|

Cities (Villes)

| | | | | | |
|------------------------|--------------------|-----------------|--------------------|------------------------|------------------|
| Dublin (Strasbourg) | Glasgow (Paris) | Hull (Brest) | Cardiff (Lille) | Bristol (Marseille) | London (Lyon) |
|------------------------|--------------------|-----------------|--------------------|------------------------|------------------|

Famous Names (Personnes célèbres)

| | | | | | |
|--------------------------|--------------------|------------------------|----------------------|----------------------|--------------------|
| Churchill (Churchill) | Hitler (Hitler) | Napoleon (Napoléon) | Picasso (Picasso) | Dickens (Dickens) | Mozart (Mozart) |
|--------------------------|--------------------|------------------------|----------------------|----------------------|--------------------|

Girls' names (Prénoms de filles)

| | | | | | |
|----------------|--------------------|-------------------|------------------|--------------------------|-----------------|
| Anne (Anne) | Susan (Suzanne) | Sally (Sylvie) | Jane (Janine) | Elizabeth (Elisabeth) | Mary (Marie) |
|----------------|--------------------|-------------------|------------------|--------------------------|-----------------|

Boys' names (Prénoms de garçons)

| | | | | | |
|------------------|-------------------|----------------------|----------------|----------------------|-----------------|
| David (David) | Peter (Pierre) | Richard (Richard) | John (Jean) | Steven (Stéphane) | Tom (Thomas) |
|------------------|-------------------|----------------------|----------------|----------------------|-----------------|

Surnames (Noms de famille)

| | | | | | |
|-------------------|-----------------------|-----------------------|--------------------|--------------------|---------------------|
| Jones (Durand) | Thompson (Lambert) | Williams (Mercier) | Baxter (Dupont) | Smith (Ferrand) | Jackson (Maurel) |
|-------------------|-----------------------|-----------------------|--------------------|--------------------|---------------------|

Subjects (Matières)

| | | | | | |
|-----------------------|---------------------------|-----------------------|-----------------------|------------------|------------------------|
| History (Histoire) | Geography (Géographie) | Chemistry (Chimie) | Biology (Biologie) | Maths (Maths) | Physics (Physiques) |
|-----------------------|---------------------------|-----------------------|-----------------------|------------------|------------------------|

Sport (Sports)

| | | | | | |
|------------------|----------------|------------------------|------------------------|-----------------|--------------------|
| Boxing (Boxe) | Golf (Golf) | Swimming (Natation) | Football (Football) | Skiing (Ski) | Tennis (Tennis) |
|------------------|----------------|------------------------|------------------------|-----------------|--------------------|

Parts of a room (Parties d'une pièce)

| | | | | | |
|----------------------|-----------------|---------------|---------------------|----------------|----------------|
| Ceiling (Plafond) | Door (Porte) | Wall (Mur) | Window (Fenêtre) | Roof (Toit) | Floor (Sol) |
|----------------------|-----------------|---------------|---------------------|----------------|----------------|

Emotions (Emotions)

| | | | | | |
|--------------------|--------------------|-------------------|---------------------|---------------------|-----------------|
| Happy (Heureux) | Tired (Fatigué) | Greedy (Avide) | Afraid (Effrayé) | Angry (Coléreux) | Sad (Triste) |
|--------------------|--------------------|-------------------|---------------------|---------------------|-----------------|

Units of time (Unités de temps)

| | | | | | |
|---------------|--------------------|-----------------|---------------------|-----------------|-----------------|
| Day (Jour) | Minute (Minute) | Month (Mois) | Second (Seconde) | Year (Année) | Hour (Heure) |
|---------------|--------------------|-----------------|---------------------|-----------------|-----------------|

Instruments (Instruments de musique)

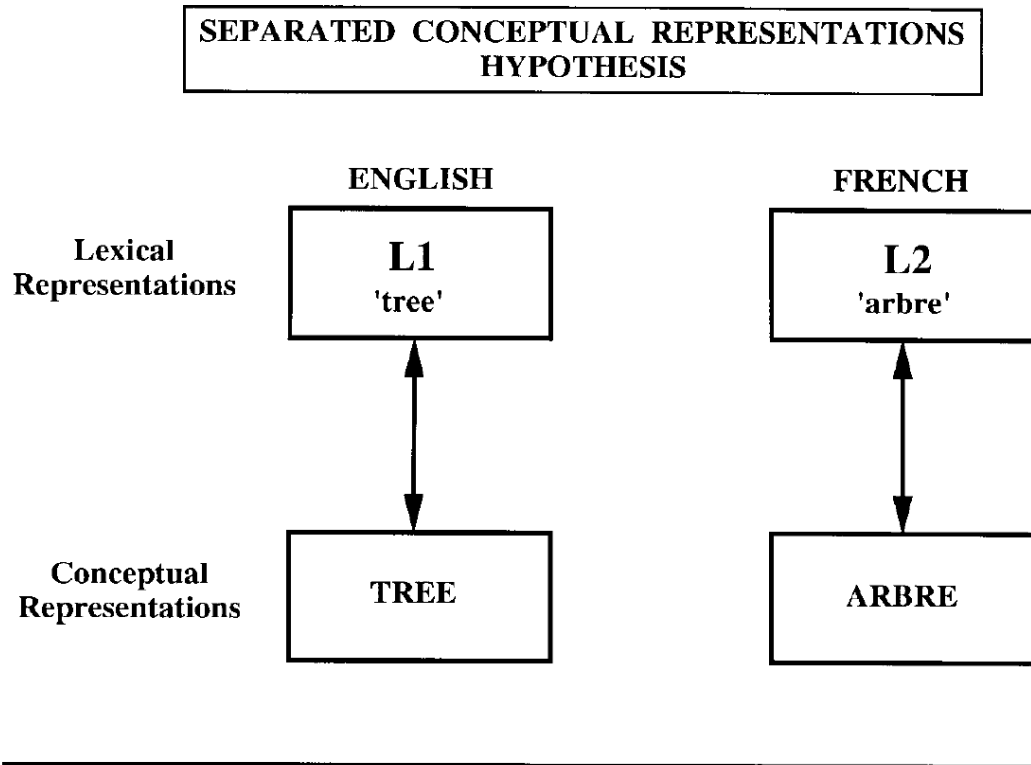
| | | | | | |
|------------------|-------------------|------------------|------------------------|---------------------|--------------------|
| Piano (Piano) | Drum (Tambour) | Flute (Flûte) | Trumpet (Trompette) | Guitar (Guitare) | Violin (Violon) |
|------------------|-------------------|------------------|------------------------|---------------------|--------------------|

FIGURE LEGENDS

Figure 1. The separated and shared conceptual representations hypothesis.

Figure 2. Two models of bilingual memory: a, the word association model; b, the asymmetrical model.

a



b

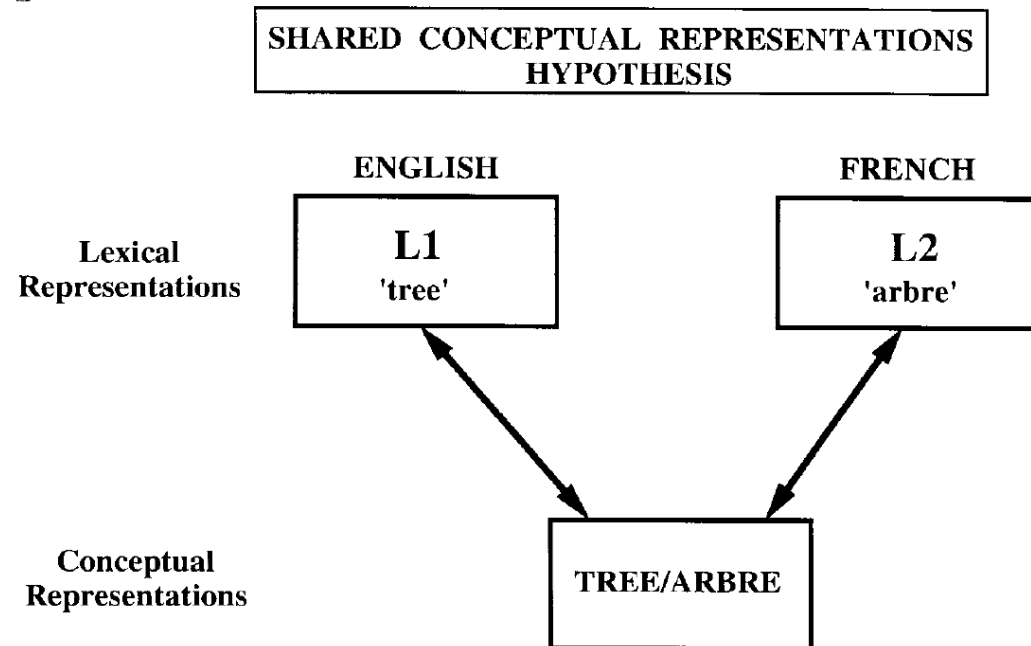


Figure 1. The separated (a) and shared (b) conceptual representations hypothesis.

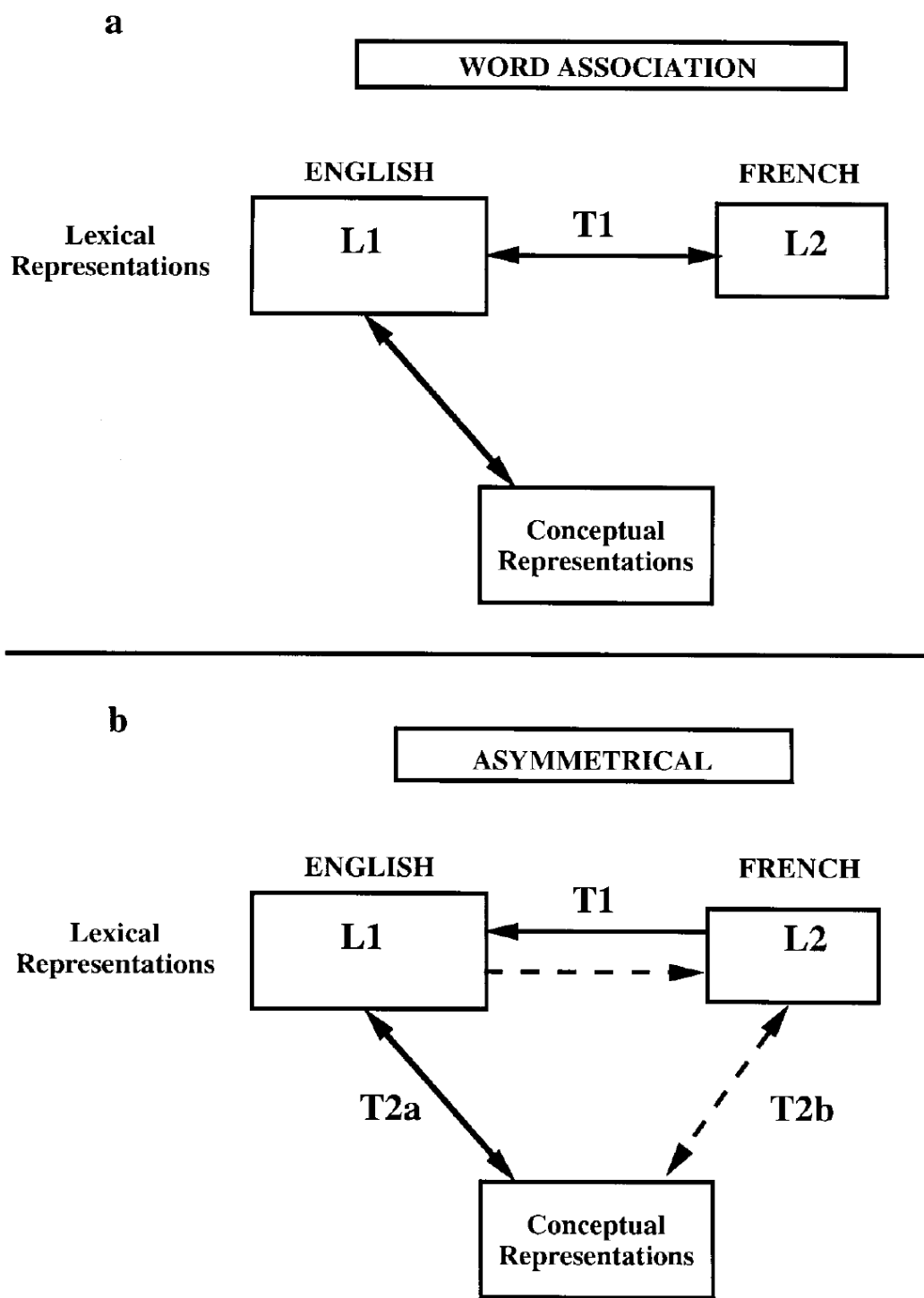


Figure 2. Two models of bilingual memory: (a) the word association model; (b) the asymmetrical model.