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The Nature of Cross-Language Activation in Late Chinese-English Bilinguals : A Behavioural and Event-Related Potential Investigation

Wu, Yanjing

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THE NATURE OF CROSS-LANGUAGE ACTIVATION IN LATE CHINESE-ENGLISH BILINGUALS: A BEHAVIOURAL AND EVENT-RELATED POTENTIAL INVESTIGATION

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YAN JING WU

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ABSTRACT

The present thesis explores the cognitive operations underlying word recognition and production of late bilingual adults in their second language (L2). Experimental psychology and electrophysiology have made a case for the activation of the first language (L1) when bilingual individuals process words in L2. Evidence for cross-language activation has shaped current models of bilingual lexical processing and influenced our conception of the bilingual lexicon. However, previous studies have made extensive use of interlingual lexical stimuli (e.g., cognates, interlingual homographs) and/or translation equivalents to compare L1 and L2 processing in bilingual individuals. Experiments mixing stimuli from two languages create an artificial context which may differ significantly from real-life situations and bias behavioural performances toward a language-nonselective processing pattern. In the present thesis we tested bilingual participants reading, listening to, and producing words exclusively in their L2. In the first experiment series, Chinese-English bilinguals read and listened to pairs of English words, half of which shared a character repetition in their Chinese translations. Evidence of event-related potentials (ERPs) showed that Chinese translations were accessed automatically and unconsciously. In the second experiment series, the same paradigm was used except that phonological and orthographic repetitions in Chinese translations were independently tested. Significant priming was found for phonological but not orthographic repetitions, independently of the input modality (visual or auditory), demonstrating that cross-language activation is mediated by phonology. In the third experiment series, speech production was studied using a covert picture naming paradigm involving rhyming decisions. Here again, L1 access was detected but it was delayed in comparison to L2 access as well as more conscious in comparison to reading and listening in L2. Moreover, cross-language activation in picture naming was asymmetric, featuring strong influences of L1 on L2, but no effect of L2 on L1. Findings of the thesis shed new light on the dynamic nature of bilingual language processing, as well as constraints affecting cross-language activation. Implications for current models of bilingual lexical access are discussed.

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Introduction and Overview

It is widely acknowledged that over half of the world population uses more than one language (Bhatia & Ritchie, 2004b; Crystal, 1987; Grosjean, 1982; Hoffmann, 1991). Although bilingualism is a multidisciplinary topic, its practical (e.g., educational and societal) applications have traditionally attracted more attention than its theoretical accounts (Romaine, 1989). The three studies reported in this PhD thesis join the young but rapidly growing theoretical field of bilingualism by investigating a key issue at the core of any bilingual theory and model: the nature of the bilingual mental lexicon. The research methodology adopted here is inspired by the rigor of experimental cognitive psychology; it tests fundamental hypotheses deriving from psycholinguistic theory and capitalises on a state-of-the-art observational technique in neuroscience, namely event-related potentials (ERPs).

The concept of mental lexicon is central in the study of bilingual language processing because, as Schreuder et al. (1993) pointed out, it "bridges between form and meaning". How do bilingual individuals understand words written and spoken in the second language (L2)? Does knowledge in their first language (L1) become available (or "activated") during semantic access? What mechanisms, if any, do bilinguals use to filter out the unwanted language during comprehension and select the intended language during production? The present studies attempt to contribute new evidence to answer these questions.

The first chapter provides an overview of psycholinguistic studies of monolingual and bilingual word recognition and production. Bilingual research in the past decade or so is marked by the consistent finding of cross-language interactions: when words in L2 are being processed, in both comprehension and production tasks, corresponding information in L1 is activated in parallel. Models of bilingual language representations and processing that have been proposed to account for this phenomenon are then reviewed. The chapter closes with a discussion on the limitations of the psycholinguistic approach and its experimental paradigms, and introduces outstanding questions regarding the nature of cross-language interactions in bilingual individuals.

The second chapter introduces the technique and theoretical background of ERPs, and its application to the study of language processing. A number of ERP studies on bilingual word recognition and production are then selectively reviewed in the third chapter. The high temporal resolution of ERPs is particularly suited to the study of cognitive activities like reading and listening which occur very rapidly in real time. However, although ERP experiments involving bilingual participants can be dated back to the beginning of the 90s, many studies have been empirical in nature and only a few have been systematically guided by predictions of psycholinguistic models.

The fourth chapter outlines generic methodological parameters that we have used throughout my doctoral studies. The first study[1] (chapter 5) investigated cross-language interactions in Chinese-English bilinguals using a stringent unconscious repetition priming paradigm and ERPs. We further studied the nature of cross-language interactions in Chinese-English bilinguals by manipulating orthographic and phonological priming independently. In the third study (chapter 7), we used a picture-naming paradigm in Chinese-English bilinguals to characterize the level of L1 activation during L2 word production. In chapter 8, the general discussion, findings of the three studies are discussed in the context of the psycholinguistic

[1] The first study and a previous version of it have given rise to a couple of publication (Thierry and Wu, 2004; Thierry and Wu, 2007) which will be discussed more extensively in the discussion section.

literature and recent ERP studies. Overall, this thesis provides in-depth analysis of cross-language interactions during reading, listening, and speaking, in bilingual individuals who use two very different languages (Chinese and English), which differ both in terms of their sound form and written form. Moreover, findings from this research also shed light on general cognitive principles of language processing that cannot be shed based on studies of monolingual individuals.

Psycholinguistic Aspects of Bilingualism

Most theories of bilingual lexicons have taken fundamental concepts from those theories that describe language processing in monolinguals. Therefore, it is necessary to briefly introduce language processing models in monolinguals, and methodologies and terminologies that have been adopted in bilingualism research. The three models reviewed below concern reading, listening, and speaking, respectively. All three models have been influential in the field of language and inspirational to the study of bilingualism.

1. 1. Classic models of language processing

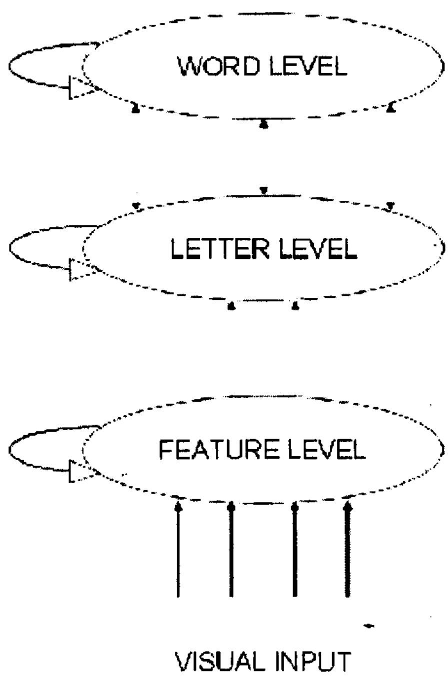

Figure 1-1. Interactive Activation Model of visual word recognition (McClelland & Rumelhart, 1981)

The Interactive Activation Model (Fig. 1-1) is a connectionist model of visual word recognition. It assumes that word information is stored at three levels (i.e., visual feature, letter, and word level). Within each level, the activation of one unit leads to inhibition of competing units (lateral inhibition) and, at the same time, facilitates activation of corresponding units at the next level. At the word level, the unit that receives the highest facilitation gets activated. A later modification of the IAM model features a threshold of activation at the word level which depends on lexical frequency; high-frequency words have lower threshold and vice versa (Grainger & Segui, 1990; Jacobs & Grainger, 1992). Evidence in support of this assumption is derived from studies using lexical decision tasks (LDT; i.e., deciding whether a string of letters forms a word - the limitations of this type of task will be discussed in chapter 4). Indeed, Grainger (1988) found that low-frequency words such as "blur", which have a high-frequency orthographical neighbour (blue), are recognised slower than words without orthographical neighbours. This effect was explained as the result of a competition between the target word and high-frequency orthographic neighbours at the word-level of representation.

The Trace Model of speech perception (Fig. 1-2) resembles the structure and assumptions behind the interactive model of visual word recognition (McClelland, 1991; McClelland & Elman, 1986). Auditory features (e.g., place of articulation, voicing) are connected to phonemes (basic elements of auditory word forms) which are connected, in turn, to whole word representations (sound of words). Similarly to the case of IAM, nodes at the same level have inhibitory connections and the recognition of a word is determined by the activation level of word representations when the threshold of activation is reached.

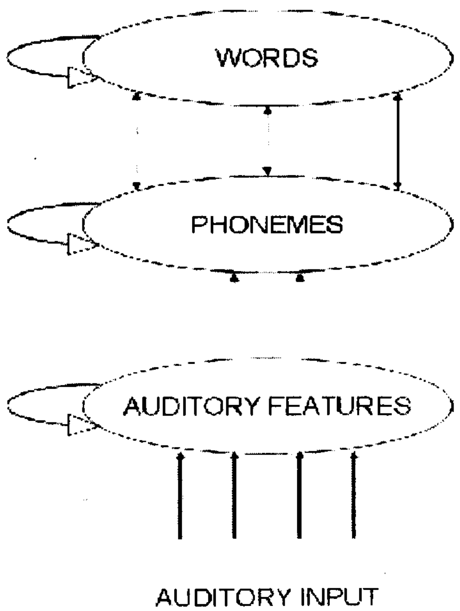

Figure 1-2. The Trace Model of speech perception (McClelland & Elman, 1986)

Note that a key assumption behind the interactive activation model and the trace model is that top-down processes (driven by the individual's knowledge and expectations) are involved in addition to bottom-up processes (triggered by the stimulus itself). Bilingual models also include top-down mechanisms to account for word comprehension in bilingual individuals. However, studies reported in this thesis only look into the processes of single word recognition and production by bilinguals, which minimizes the importance of top-down processing. Therefore, literature relating to top-down regulation will not be discussed in detail.

The Word-form Encoding by Activation and Verification (WEAVER++, Fig. 1-3) model conceived by Levelt and colleagues (1999) focuses on the mechanism behind single spoken word production. The fundamental assumptions of WEAVER++ are consistent with early ideas of Levelt (1989): discrete processing levels are connected to one another only by excitatory links. Activation proceeds in a strictly forward direction during word production (from meaning to sound, this is known as the feed-forward theory). There is also a self-monitoring mechanism constantly checking the speaker's overt and internal speech. Although the characteristics and exact time course of each of these processing stages have been a matter of constant debate, most researchers agree with the general organisation of word production.

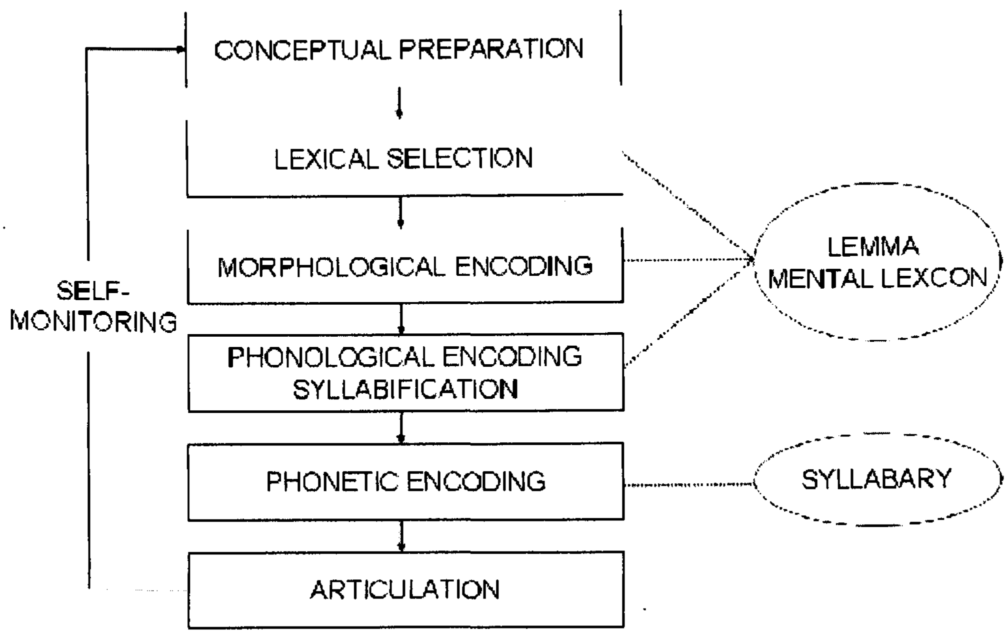

Figure 1-3. The WEAVER++ computational model (Levelt et al., 1999)

The Word-form Encoding by Activation and Verification (WEAVER++, Fig. 1-3) model conceived by Levelt and colleagues (1999) focuses on the mechanism behind single spoken word production. The fundamental assumptions of WEAVER++ are consistent with early ideas of Levelt (1989): discrete processing levels are connected to one another only by excitatory links. Activation proceeds in a strictly forward direction during word production (from meaning to sound, this is known as the feed-forward theory). There is also a self-monitoring mechanism constantly

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1. 2. Bilingual word recognition

In recent years, psycholinguistic research has taken two main perspectives regarding the issue of bilingual lexical access and cross-language interactions. The processing perspective, as characterised by the Bilingual Interactive Activation (BIA) and the BIA+model, examines how L2 word recognition is influenced by the activation of and competition from form relatives in L1 (Dijkstra & Van Heuven, 1998; Dijkstra et al., 1998; Van Heuven et al., 1998). On the other hand, the Revised Hierarchical Model (RHM) takes a developmental perspective and focuses on cross-language interactions via translation equivalents of the two languages (Kroll & Stewart, 1994). These two particular models are reviewed here because (a) they have been shown to account for a great variety of bilingual phenomena, (b) taken together, the two approaches provide a complete account of bilingualism as observed in proficient late L2 learners, which is the type of participant tested in the present studies, and (c) these models are the most relevant to my research because they focus on the process of word identification itself rather than secondary factors such as task demands and context effects (see also Dijkstra & Van Heuven, 2002; Green, 1998).

As can be seen in Figure 1-4, the BIA model is a bilingual extension of the interactive model of visual word recognition. Both models share the lower two layers of feature and letter representations. The word level of BIA includes lexical knowledge of both bilinguals' L1 and L2, in the case illustrated here, Dutch and English. Interestingly, the two languages are segregated within the word level. At the top of this network, there is an additional layer of language nodes, representing language-specific information (e.g., grammar, syntax). The BIA model is consistent with the interactive model in assuming that high-frequency words have a lower threshold of activation than low-frequency words and vice versa. The flow of activation from lower levels to higher levels by means of facilitation and inhibition is also comparable between the two models.

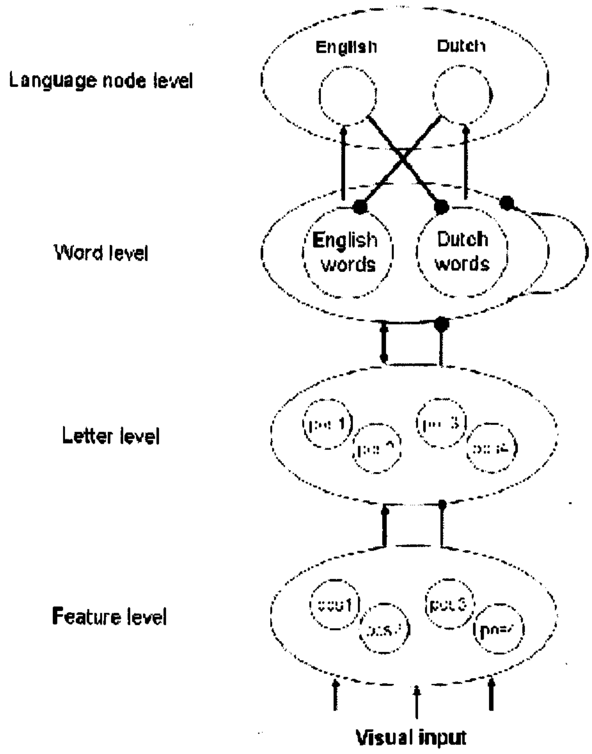

Figure 1-4. The Bilingual Interactive Activation model (Dijkstra & Van Heuven, 1998)

Arguably, the most important component of the BIA model is the word level of representation where the model begins to differ from its monolingual equivalent. It is assumed that word nodes from the two languages are connected to one another by inhibitory links. This means that words that are activated inhibit other words regardless of the language they belong to. Therefore, the assumption is made of an integrated lexicon for the two languages of bilingual individuals. Also, since the bilingual lexicon is assumed to be highly integrated, the letter-to-word connection is not language-specific (language non-selective access). Another important assumption of the BIA model is that, in the case of unbalanced bilinguals, L2 proficiency is reflected by means of resting-level activation of words. Consistent with the concept of frequency-dependent threshold, less proficient L2 readers require higher level of facilitation to activate words in their L2 as compared to words in their L1.

The concept of language node is another special characteristic of the BIA model. First, it serves as a language tag which, during the word identification process, is activated by correspondent words to indicate which language they belong to. Second, BIA assumes that an activated language node feeds back to the word level by lowering the activation threshold of all word nodes in that language and inhibiting those of the other language. In particular, this top-down effect of language nodes can account for context priming effects where the competition at the word level is biased.

The two most studied hypotheses of the BIA model are the assumption of lexical non-selective access and of the language nodes as top-down control mechanisms within a complex linguistic context. Given that this thesis is concerned with single word processing, the following review focuses more on empirical findings regarding the first than the second issue.

Previous studies have exploited the existence of cognates and interlingual homographs to examine whether lexical information from both L1 and L2 is activated during word recognition in one of the two languages. Cognates are words that are identical in terms of orthography (i.e., spelling) and overlap largely in L1 and L2 in terms of meaning (i.e., *café* in English and French). By contrast, interlingual homographs are L1 and L2 words that share the same orthography but have distinct meanings in the two languages (i.e., *brand* -'fire' in Dutch). These are also called interlexical homographs or false friends. Often, the experimental strategy is to present cognates or interlingual homographs in a LDT inter-mixed with control words that do not share any lexical or semantic properties in L1 and L2. If lexical access is language-selective, words that have cross-language relations should be processed in the same way as words that occur only in one language. On the other hand, if lexical access is language non-selective, these critical words might be read in different ways to control words due to their interlingual status. Such potential differences have been hypothesized to affect bilingual performance in terms of latency and/or accuracy.

Gerard (1989) tested Spanish-English bilinguals with cognates and interlingual homographs in a monolingual context (LDT in Spanish or English). Lexical frequency was manipulated independently of word category. The authors found that reaction time (RT) to cognates and interlingual homographs correlated with their frequency in the target language, but not in the other language. For example, when the word "red" was presented in the English LDT, it was responded to with the same speed as words that have the same frequency in Spanish. In the Spanish condition, however, the word *red* yielded much longer time reaction times, which was consistent with its relative lexical rareness (*red* means 'network' in Spanish). The reverse pattern was also observed for words that have a high frequency in Spanish but low frequency in English (e.g., *fin*, - 'aim' in Spanish). These results suggested that, in contrast to the prediction of the language non-selective hypothesis, bilingual participants were able to selectively access the meaning of interlingual words in the appropriate language. A couple of more recent studies have confirmed the null results of interlingual homographs with another bilingual combination (Dutch-English) under comparable experimental conditions (De Groot et al., 2000; Dijkstra et al., 1998).

Nonetheless, there is an extensive body of evidence in favour of the language non-selective access hypothesis. First, cognates have been shown to reduce RT during LDT in both L1 and L2 (Dijkstra et al., 1998; Lemhofer & Dijkstra, 2004; Van Hell & Dijkstra, 2002). Second, despite the absence of interlingual homograph effect in several studies, subtle designs tapping semantic processing have successfully detected co-activations of meanings in the two languages. For instance, Beauvillain et al. (1987) tested French-English bilinguals in a LDT using English words preceded by French words which, in the critical trials, were interlingual homographs related in meaning with the English target word (e.g., *coin - money*, *coin* meaning 'corner' in French). Although participants were told that the French prime was irrelevant, they spontaneously accessed the English meaning of the interlingual homograph prime as shown by significantly reduced RT in the related condition. Furthermore, the same results were found in a translation priming paradigm. For example, in an English LDT, the word *brand* was followed by the word 'fire', which is the translation into English of the Dutch word *brand*. Dutch-English bilinguals showed a small but reliable reduction of RT, suggesting that the interlingual homograph was initially processed in a language non-selective fashion whereby meanings in both L1 and L2 had been accessed (De Moor, 1998; Van Heste, 1999).

Other evidence in favour of the language non-selective hypothesis comes from experiments manipulating orthographic neighbourhood. An orthographic neighbour is a word which differs from the target word by one letter (Coltheart et al., 1997). For example, 'look' and 'cool' are both neighbours of 'cook'. As mentioned earlier, monolingual word recognition is sensitive to the number of orthographical neighbours (neighbourhood density effect) and their frequencies (neighbourhood frequency effect). These effects have been explained as the result of a competition among lexical candidates at the word-level. The logic follows that, if bilinguals have an integrated lexicon where access to L1 and L2 is parallel, neighbourhood effects should be language non-selective. Indeed, several studies have shown that the number of orthographic neighbours in the nontarget language systematically affect RT during LDT in the target language. For instance, Dutch-English participants have more difficulty recognizing English words with many Dutch neighbours than those which have few or no Dutch neighbours (Grainger & Dijkstra, 1992; Van Heuven et al., 1998).

To summarise, two decades of research capitalising on the existence of orthographic overlaps between languages (e.g., cognates, interlingual homographs, and orthographic neighbours) have shown that bilinguals automatically access information in both their L1 and L2 in contexts where only one language is under attentional focus / is relevant. The hypothesis of language non-selective, or parallel, access is now wildly acknowledged as valid.

While the BIA model gives a valuable account of the state of the bilingual lexicon and the process of word recognition as a function of cross-language interactions in highly fluent bilinguals, another line of research has investigated these issues taking into account second language learning history.

As mentioned in the introduction of this thesis, the majority of the world population can use two languages. Yet, a minority of bilingual individuals are balanced in terms of proficiency, knowledge, dominance (how often the languages have been and are being used), and age of acquisition in their two languages. In fact, most bilinguals distinguish their native language, acquired very early on in life and most familiar to them, from their second language, learnt subsequently and still being learnt. Therefore, a unique experience of such bilinguals, in contrast to monolinguals, is that one of their two languages was or is being acquired around a fully formed lexicon and conceptual system formatted by their first language. To account for how L2 can be integrated into an existing L1 system, early researchers have proposed two models.

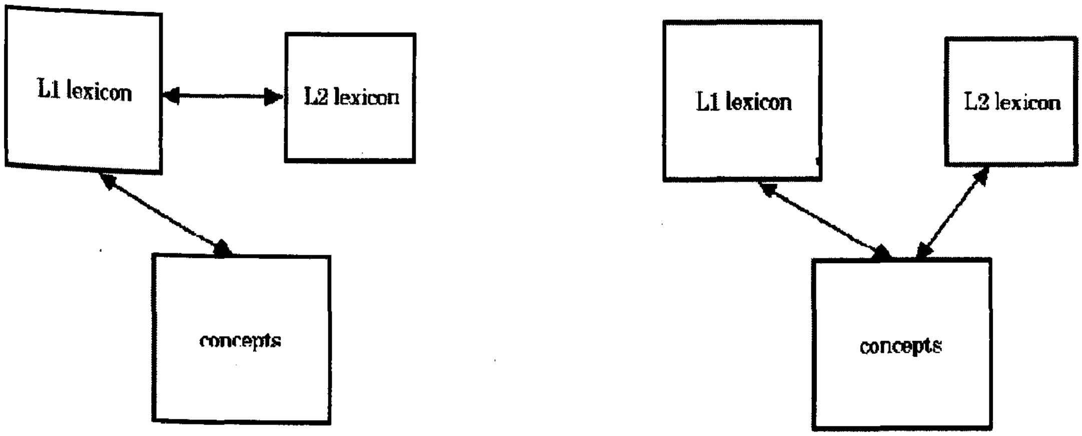

Figure 1-5. The word association model and the conceptual mediation model (Kroll & Stewart, 1994)

The word association model (figure 1-5, left), also referred to as the subordinate system (Wernreich, 1953), proposes that L2 is connected with L1 at the lexical level, and concepts can only be accessed through this lexical link. For example, when a Chinese-English bilingual individual reads an English word, access to word meaning will necessarily activate the translation equivalent in Chinese. This assumption is particularly pertinent in cases where word knowledge of L2 is traditionally acquired by associating L2 words with their L1 translations (which, for instance, is the core method used in China to teach English). On the other hand, the conceptual mediation model (figure 1-5, right) involves a direct conceptual link between the L2 lexicon and semantic memory. In this situation, a bilingual is expected to function as two monolinguals given the independence of access to concepts in L1 and L2.

It must be noted that these two models make no clear assumption regarding the structure and dynamics of the language recognition system. Orthographic features, letters, and words are all comprised within the lexicon level. The smaller box for the L2 lexicon reflects less word knowledge in L2 than L1. The conceptual store, on the other hand, contains abstract semantic information (word meaning) irrespective of language. The fundamental characteristic of this hierarchical arrangement is that the lexical stores are language-specific but the conceptual store is shared. An extensive body of research has provided evidence in support of this assumption (Chen, 1990; Chen & Ng, 1989; Kirsner et al., 1984; see also Kroll, 1993 for a review; Scarborough et al., 1984; Schwanenflugel & Rey, 1986; Smith, 1991). For present purposes, I will focus on the most current debate in this framework concerning the mapping of the L1 and L2 words onto concepts.

Potter et al. (1984) contrasted the word association model with the conceptual mediation model in a series of experiments in which they asked bilingual participants to translate L1 words into L2 and to name pictures in L2. The logic of comparing word translation with picture naming is as follows: if words in L2 are exclusively associated with L1 translations at the lexical level, translating words from L1 to L2 should take less time than naming pictures in L2. This is because word translation can take advantage of lexical links between L1 and L2, thus bypassing the necessity of conceptual processing; on the other hand, to name pictures in L2 would require accessing the meaning of pictures and their names in L1, and then translating them into L2. However, if direct conceptual links between L2 word forms and their meanings are available, as it is proposed in the conceptual mediation model, the two processes (L1-L2 translation and picture naming) should take a similar amount of time.

Potter et al. (1984) provided results in favour of the conceptual mediation model. The time needed to translate words from L1 into L2 was similar to the time necessary to name pictures in L2. Moreover, this pattern of results was consistent in two groups of bilinguals at different levels of L2 proficiency, suggesting that direct conceptual links for L2 words were available even at early stages of L2 learning. However, subsequent studies following the same methodology have failed to replicate the results (H. -C. Chen & Leung, 1989; Kroll & Curley, 1988). Highly proficient bilinguals performed equally fast for word translation and picture naming in L2; but, less fluent bilinguals were faster at word translation. The inconsistency in the findings may be due to different language backgrounds in Potter et al.'s (1984) study. Although, in that study, both groups of participants learned English as their second language, Chinese was the native language for the highly proficient bilinguals, whereas it was French for the less fluent bilinguals. The native and second language were controlled in Chen & Leung (1989) and Kroll & Curley's (1988) studies, which suggests that word-to-concept mappings in bilinguals might indeed depend upon language expertise with conceptual mediation better characterising fluent bilinguals and word association better accounting for the performance pattern of less fluent bilinguals.

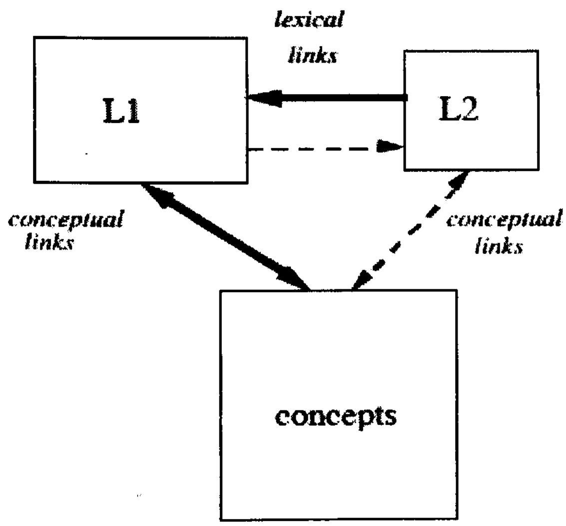

Figure 1-6. The revised hierarchical model (Kroll & Stewart, 1994)

To model the developmental shift from reliance on L1 to independent conceptual processing with increasing L2 proficiency, Kroll et al. (1994) proposed the revised hierarchical model (RHM; Figure 1-6). The RHM integrates the lexical link between L1 and L2 and the direct conceptual link from L2 words to concepts; thus it is able to characterise language representations of bilinguals at both the beginning and more advanced levels of L2 acquisition. Moreover, the model assumes that the conceptual link is stronger for words in L1 (depicted by a solid line) than for words in L2 (depicted by a dotted line) because of the relative proficiency in the two languages. The lexical link is assumed to be stronger from L2 to L1 than from L1 to L2 considering the way L2 words are initially acquired. Also, due to the relative strength of conceptual links, forward translation (L1→L2) is more likely to involve conceptual processing whereas backward translation (L2→L1) should allow rapid lexical processing without significant recourse to meaning.

To test the predictions of RHM, psycholinguists have made extensive use of translation tasks. In Kroll & Stewart's original study (1994), highly proficient Dutch-English bilinguals were asked to translate words in both directions (i.e., forward and backward). In the experimental condition, words were presented in a semantically categorised list; in the control condition, words were presented randomly (i.e., the "mixed condition"). Forward translation was slower with the semantically categorised stimuli than the mixed word list; whereas backward translation was unaffected by the semantic manipulation (i.e., categorisation). Moreover, participants translated faster and more accurately backward than forward. Such a translation asymmetry was consistent with findings of previous research (Sanchez-Casas, Suarez-Buratti et al., 1992). Given the level of L2 proficiency of participants in the study by Kroll (1994), findings strongly suggested that different mechanisms underlie the performance in translation tasks in the two directions. Subsequent research used picture naming as the familiarisation procedure and found that only forward translation of previously named words was facilitated (Sholl et al., 1995). Since picture naming has been shown to require conceptual access (Glaser, 1992; Levelt et al., 1991), the finding that backward translation is insensitive to conceptual priming is consistent with the predictions of the RHM.

To specifically examine the prediction that backward translation is lexically mediated, Talamas et al. (1999) used two manipulations in a translation recognition task. English-Spanish bilinguals were asked to decide whether a Spanish word was the translation equivalent of an English word. The semantic and the lexical condition differed by substituting the target words with words that were close to them either in terms of meaning or form, respectively. A strong interference effect was observed in the lexical condition for a group of bilingual beginners whereas semantic interference was observed for more fluent bilinguals. This again suggests that backward translation progressively shifts from a lexically- to a conceptually mediated process with increasing L2 proficiency. Unfortunately, this study did not also compare backward to forward translation.

Another source of evidence for the RHM comes from studies using semantic priming tasks. In a standard priming paradigm, the prime and the target word are presented in succession. A plethora of studies has shown that, when the two words are related in meaning (e.g., 'doctor – nurse'), the recognition of the target word is facilitated as compared to unrelated pairs (e.g., 'fish – nurse', see Neely, 1991 for a review). Keatley et al. (1994) found that, for low proficient bilinguals, cross-language semantic priming is only observed when the prime word is in L1 and the target word is in L2; no effect was seen for L2 - L1 priming. In highly fluent bilinguals, the authors found an asymmetry in the magnitude of semantic priming, with a stronger effect from L2 to L1 than the reverse direction. Similar results have been reported in other studies as well (Kroll & Sholl, 1992; Tzelgov & Eben-Ezra, 1992). This asymmetric semantic priming effect is consistent with RHM hypotheses: words in L1 have stronger conceptual links and can therefore activate semantic memory to a deeper and broader extent than words in L2; as a result, L1 words are more effective primes than L2 words.

However, other studies have challenged the semantic asymmetry observed in the standard priming paradigm. Keatley et al. (1992), for instance, tested cross-language semantic priming with fixed, limited response time. Effects for both L1 → L2 and L2 → L1 priming disappeared whereas within-language priming survived the speeded experimental context. This finding suggested that the cross-language priming effect might be accounted for by post-lexical meaning integration which would not have been involved in a time-restricted context.

To avoid potential biases due to asymmetries in effortful attentional processing, a subsequent study (Fox, 1996) adopted negative priming which measures the effect of unattended stimuli. Fox et al. (1996) reported that a negative priming effect from previously ignored words was only observed for L1 → L2 but not L2 → L1. This result provides strong evidence in favour of the RHM. However, another observation made in the same study was inconsistent with predictions of the RHM. When the unattended prime was the translation of the target word instead of a semantically related word, negative priming was stronger in the L1 → L2 than the L2 → L1 direction. Recall that the RHM assumes that backward translation capitalises on the use of lexical links, and therefore should lead to shorter reaction time than forward translation. In fact, a number of studies have shown the opposite trend with forward translation being more effective and reliable than backward translation (H. C Chen & Ng, 1989; De Groot & Nas, 1991; Gollan et al., 1997; Jin, 1990; Keatley & De Gelder, 1992).

This section provides a brief overview of the bilingual language memory system which appears to involve a shared conceptual store and highly permeable lexical representations (i.e., open to influences of the other language). Theoretically, this system can account for a variety of cross-language phenomena that have been repeatedly observed in bilingual research in the past twenty years. From a connectionist point of view, the BIA model explains cross-language activations as the result of the non-selective access to lexical form relatives between L1 and L2. The RHM, on the other hand, emphasises cross-language activations at the level of translation equivalents by virtue of L2 acquisition history. Whether one considers the first or the second conceptualisation, a bilingual individual cannot simply be considered as two monolinguals in one brain. Knowledge of L1 and knowledge of L2 interfere and compete with one another in a complicated fashion.

1. 3. Bilingual word production

The observation of cross-language interactions during word recognition does not necessarily imply that the same process occurs during word production. Most L2 learners report that comprehension (i.e., reading and listening) develops quicker and more easily than production (i.e., speaking and writing). This discrepancy suggests that different cognitive mechanisms and language competencies are engaged in the processes of word production and recognition (Costa & Santesteban, 2004; French & Jacquet, 2004). Therefore, the issue of bilingual lexical organisation cannot be addressed completely without considering both the input and the output modalities. So far, there has been less research on bilingual language production than comprehension. One reason might be the methodological difficulty of testing speech production in well-controlled experimental conditions. This section will review some empirical evidence and methodological developments regarding the issue of language selection in bilingual L2 speech production. The scope of the review will be restricted to single word production.

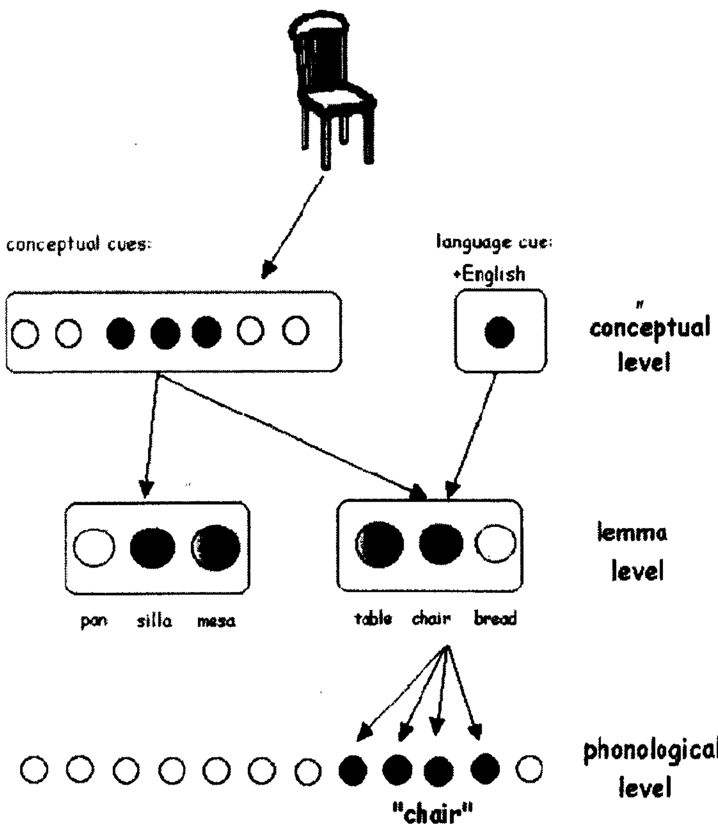

Figure 1-7. A model of bilingual language production adapted from (Kroll et al., 2006).

As discussed in the first section of this chapter, the fundamental architecture of speech production models generally contains three distinct levels of processing (Caramazza, 1997; Dell, 1986; Levelt, 1989; Levelt et al., 1999). First, the conceptual or semantic level of processing involves retrieving the meaning of words which the speaker desires to communicate. Second, at the lexical or lemma level, abstract lexical items (i.e., words) are activated along with their grammatical information. Third, phonological nodes specify the phonology associated with the to-be-spoken words (see figure 1-7 for an illustration of the three levels of processing in bilingual word production).

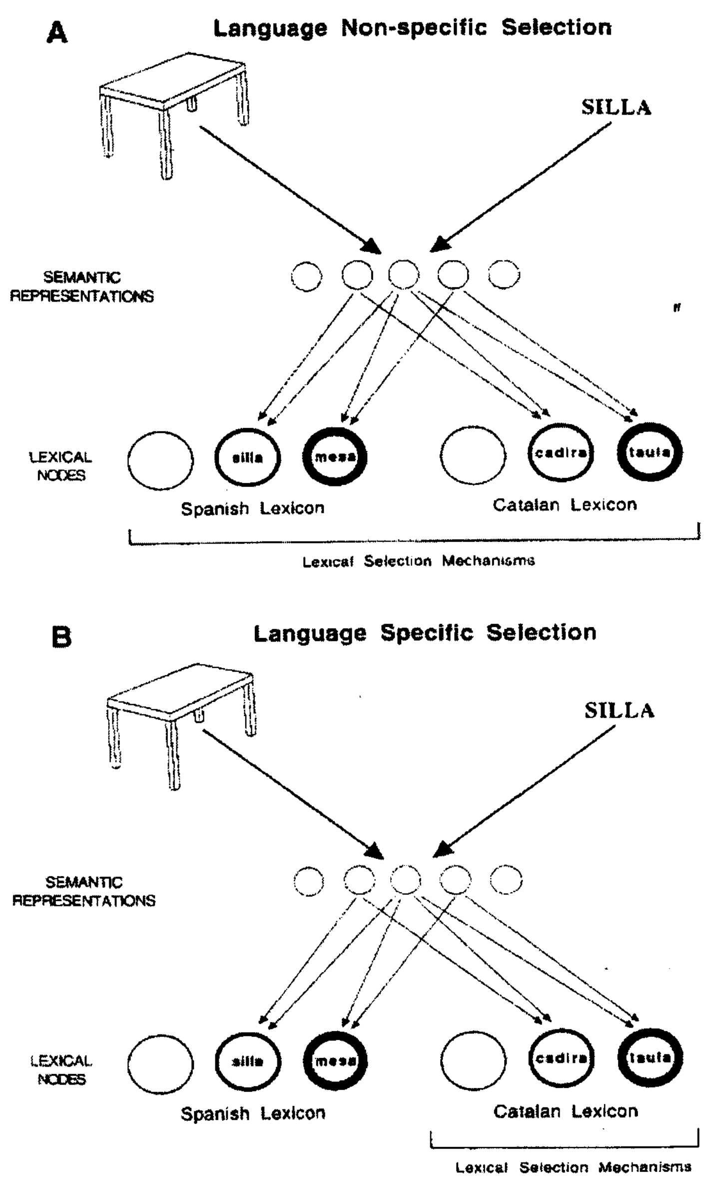

Figure 1-8. Illustrations for language non-specific (A) and language specific selection (B) adapted from (Costa et al., 1999).

Unlike listening or reading, which is largely a bottom-up process, speaking is primarily a top-down process. It requires bilinguals to make conscious effort in the selection of languages in which words are to be presented. The nature of language selection has been a long-standing debate around which two views have arisen: (a) the language specific hypothesis (see figure 1-8, B) proposes that bilingual speakers can select their intended language without being affected by the existence of lexical representations of the unintended language; (b) the language non-specific hypothesis (see figure 1-8, A) implies that language production in bilinguals automatically activates both L1 and L2, whereby cross-language competition for selection has observable behavioural consequences. Evidence supporting both hypotheses has been reported. The seemingly contradictory data may be the result of interpretational difficulties regarding the locus of language selection in terms of the predefined processing levels. This problem may be best resolved by devising a research method which unfolds the whole process of speech planning up to the point of articulation rather than relying on deductive reasoning.

It is well acknowledged that bilinguals often use words in L1 during a L2 conversation (Farch & Kasper, 1986; Poulisse, 1997, 1999; Poulisse & Bongaerts, 1990). These errors, so-called unintentional language switches, have been argued to reveal the influence of L1 in L2 speech. According to Poulisse et al. (1994), the extent of L1 influence is negatively correlated with the bilingual's proficiency in L2. Dutch learners of English, for instance, often replace English (primarily function words) with Dutch words but fluent Dutch-English bilinguals show a better ability at maintaining an English conversation. Poulisse et al. (1994) interpreted this result as a cross-language slip-of-the-tongue phenomenon which can be accounted for by the basic frequency effect (Wheeldon & Monsell, 1992) in a bilingual context: due to the relative familiarities to the languages, L1 words may reach the level of activation required for lexical access before their L2 translations do, resulting in L1 items being accidentally selected instead of the intended L2 items.

Although observing L1 features in L2 speech might be consistent with the non-selective hypothesis, there is at least one problem that needs to be considered when explaining speech errors made by bilinguals. Unlike synonyms, translation equivalents are not functionally interchangeable. In most circumstances where the interlocutor does not know the bilingual speaker's L1, the use of translations will disrupt the conversation. Therefore, the analogy between bilingual speech errors and lexical substitutions of synonyms and semantically related words observed in monolingual speech neglects the bilingual context, which has been shown to be a complex issue (Grosjean, 1997; Grosjean, 1998b; Grosjean, 2001). Moreover, error data does not specify at which stage of speech planning the cross-language interference takes place.

To systematically study the course of speech planning up to the point of articulation, experimental researchers have adopted a variety of picture-naming paradigms. In the picture-word interference task, for example, participants are presented with a picture (the target) and a word (the distractor); they are instructed to name the picture while ignoring the word. The relation between names of pictures and distractor words has been shown to affect picture naming latencies. Interference effects, as manifested by longer response time, are found between picture names and distractor words that are semantically related (e.g., table-chair), as compared to unrelated word-picture pairs (table-orange). Facilitation is observed when the distractor is phonologically close or identical to (e.g., table-tailor) the name of the picture (i.e., the identity effect, for a thorough review of monolingual research using picture-word interference paradigm see Glaser, 1992; MacLeod, 1991; Roelofs, 1992).

Some bilingual studies in which picture names and distractor words belong to different languages have replicated the semantic interference effect observed in the monolingual research (Costa, 2005; Costa & Caramazza, 1999; Costa et al., 1999; Ehri & Ryan, 1980; Hermans et al., 1998; for a review, see M. Smith, 1997; M. C.

Smith & Kirsner, 1982). However, interpretations of the semantic interference effect are not consistent with regard to the language-specificity of lexical access. Hermans et al. (1998), for instance, found that Dutch-English learners took longer to name pictures in English (L2) with semantically related Dutch distractors (L1). They interpreted this result as consistent with the hypothesis of language-nonspecific access: the presence of L1 distractors increased the level of activation for lexical nodes in both L1 and L2 that were semantically related to the picture; this leads to harder lexical selection in the naming process due to the hindrance effect of pre-activated competitors. Moreover, they found that distractors that were phonologically related to the L1 translations of the picture names produced an interference effect. This suggested that the lexical selection mechanism considers lexical candidates in both the target and non-target languages. However, according to Costa et al. (1999), the cross-language interference effect could also be accounted for by language-specific lexical access: given that L1 distractors are assumed to activate both L1 and L2 words semantically related to the picture name, even if lexical selection is restricted to the intended language (i.e., L2), an interference effect could still take place at the conceptual level. In other words, to account for interference in word production, one does not have to assume parallel processing in L1 and L2 because the effect of L1 distractors might be functionally elicited via lexical links to L2 nodes. Also, Costa et al. (1999) found that when the distractor was the translation of the picture name in the non-target language, it induced a facilitation effect in both the L1 and the L2 conditions. This between-language identity effect was interpreted as supporting the language-specific model: if word production involves parallel and language-non-specific activation, the presence of a translation distractor in the non-target language should hinder the naming process, because it increases the activation level of the lexical competitor in the non-target language. On the other hand, if the lexical selection mechanism inspects only words from the intended language, such a translation distractor should result in a facilitation effect, because it also activates lexical nodes in the target language.

Clearly, researchers in the above studies hold different views on how to interpret qualitatively similar results and, in each case, they provide additional evidence to back up their views. It must be kept in mind when contrasting results of these studies that some important experimental details differ between them: participants' L2 proficiency (unbalanced bilinguals versus balanced bilinguals), language combinations (Dutch-English versus Spanish-Catalan), and the modality in which the distractors are presented (auditory versus visual, for a discussion of how these variables may affect the process of picture naming in bilinguals, see Kroll et al., 2006)

A result which has been widely regarded as supporting the language-non-specific model is the observation of a facilitatory effect in picture naming of cognates in bilinguals' two languages. Costa et al. (2000) showed that Catalan-Spanish bilinguals take less time to name pictures in Spanish that correspond to a cognate in Catalan (e.g., banco-banc, meaning 'bank' in English) than those corresponding to a non-cognate (e.g., hoja-fulla, meaning 'leaf' in English). The absence of such an effect in monolingual Spanish speakers suggests that the cognate facilitatory effect is due to the cognate status of the picture names rather than specific lexical-semantic features of these pictures across languages. One way to interpret this result is to suggest that the orthographic and phonological overlap of cognates reduces the level of lexical competition relative to non-cognates which are dissimilar in both respects. Obviously, this interpretation requires the assumption that the lexical selection mechanism considers both the target word and its translation in the non-target language.

Although the positive effect of cognates in speech production has been replicated in other picture-naming experiments (Hoshino & Kroll, 2005; Kroll et al., 2000) and observed in retrieval failures of both normal (Gollan & Acenas, 2000, 2004) and aphasic bilingual speakers (Kohnert, 2004; Roberts & Deslauriers, 1999), there is a lack of agreement regarding the origin of this effect and its implications regarding the bilingual speech production system. As exemplified previously, a cognate (e.g., *café*) shares orthographical forms, and usually, contains similar meanings and phonological segments across two or more languages. Theoretically, therefore, the cognate effect could be raised at the conceptual, lexical, and sublexical level of processing. More likely, it is a result of interactions across these different levels of representations (Costa et al., 2005). Another argument which challenges the interpretations of cognate effect during bilingual word production is the idea that cognates should not be regarded as words related across languages in their linguistic attributes (i.e., form or meaning) but independently represented in bilingual memory (Sanchez-Casas & Garcia-Albea, 2005).

Further support for the language-non-specific model derives from a phoneme monitoring study. Colome et al. (2001) asked Catalan-Spanish bilinguals to decide whether the name of a picture begins with a particular phoneme in the target language. There were three conditions. In the "yes" condition, the picture name was consistent with the prime (e.g., "t" for a picture of a table, *taula* in Catalan). In the "no" condition, the picture name and the prime were inconsistent. In the third condition, the prime was not consistent with the picture name in the target language but, critically, it was the first phoneme in the translation of the picture name in the non-target language.

This study is distinctive from the others discussed above because it provided independent evidence that cross-language interference during bilingual word production can extend beyond the level of lexical selection into phonological segmentation.

This section provided a synthetic and non-exhaustive literature review of bilingual word production in relation to language selection (i.e., specific versus non-specific access) and its locus. The majority of the findings can be accounted for by a model in which both languages are active and compete with one another during L2 word production. The issue of the locus of cross-language competition is more complex. Experimental evidence is overall inconclusive in the sense that some studies showed interference by conceptual and lexical distractors (Costa & Caramazza, 1999; Costa et al., 1999; Hermans et al., 1998) and others suggested that the competition exists at a sublexical level of representation (Colome, 2001); there is also evidence suggesting that bilingual speech is underpinned by interactivity at all levels of processing both within and across the two languages (Costa et al., 2000; Costa et al., 2005; Kroll et al., 2000). Some of the uncertainty arises from theoretical disagreements between researchers based on their interpretations of the cross-language identity effects and the interference of semantically related distractors in picture naming, respectively (for example, see Costa et al., 2003; Costa et al., 1999; Hermans, 2004; Hermans et al., 1998). On the other hand, it can be argued that the existing evidence does not unambiguously resolve the issue of language selection and, particularly, the locus of cross-language effects. In the next section, I will discuss why current experimental paradigms and means of measurement do not ensure that conclusions can be drawn, and I will propose a way forward.

1. 4. General Discussion

One key question is whether or not bilinguals can read or speak in their L2 without accessing correspondent knowledge in L1. A counterintuitive discovery reviewed above is the evidence that, in both the output and the input modalities, the processing of an isolated word by bilinguals is basically language-non-selective. Lexical and semantic knowledge of the non-target language (usually L1) appears to be always active.

It needs to be noted that the scope of the review presented above is limited to the purpose of the present research. For bilingual word comprehension, two models of the bilingual lexicon (i.e., the RHM and the BIA) were presented and empirical evidence against their predictions was mentioned. For bilingual word production, the focus was on studies testing the nature and locus of language selection. There are studies, models, and issues that have not been reviewed here but are relevant to the current discussion. We did not consider, among others, linguistic factors (e.g., the sentential context, Greenberg & Saint-Aubin, 2004; Schwartz & Kroll, 2006a) and non-linguistic factors (e.g., task demands and participants' expectancy, Dijkstra & Van Heuven, 2002; Green, 1998); special populations such as professional translators (Christoffels et al., 2006; Macizo & Bajo, 2006), the processing of mixed languages (Grosjean, 2000), and language switching (Muysken, 2000; Orfanidou & Sumner, 2005). Such variables or conditions have all been shown to affect bilingual performance and they will be mentioned incidentally so as to leave a door open for further discussion. In this discussion, I will focus mainly on issues and limitations in psycholinguistic approach of direct relevance to the experimental work presented hereafter.

What becomes apparent when contrasting the BIA and the RHM of bilingual word recognition is that, although both models capitalise on the phenomenon of cross-language activations, they put forward different hypotheses regarding bilingual lexical representations. The BIA assumes an integrated lexicon in which words from both languages are indiscriminately represented. The RHM suggests that lexical information of each language is stored independently but that the two lexicons interact through links that are stronger from L2 to L1 than from L1 to L2. Each model hence accounts for particular characteristics of lexical information (i.e., interlingual homographs versus translation equivalents) that maybe shared (or independent) to a different extent between languages (Kroll & Tokowicz, 2005; Sunderman & Kroll, 2006). However, another possibility is that both types of codes are represented together in either a unified or independent fashion. The problem is that the predictions in support of each type of lexical organization are insufficiently specific: effects of interlingual homographs on LDT could be the result of highly interactive connections triggered by form similarity across two separate lexicons; likewise, translation priming effects could, theoretically, suggest that translation equivalents are stored in a single unit (French & Jacquet, 2004).

The majority of studies of bilingual reading comprehension has focussed on languages sharing the same fundamental features (for exceptions, see Bowers et al., 2000; Gollan et al., 1997). For example, in the case of English, French, Spanish, and Dutch, there are 14 visual features and 26 letters. Such similarities provide the basis for an integrated lexical and sublexical model (e.g., the BIA). On the other hand, languages that contrast sharply in their writing systems (e.g., Chinese and English) have been largely overlooked, leaving fewer constraints for a model of separated lexicons. The drawback of this bias in bilingual research is the dilemma in accounting for cross-language interactions discussed previously.

Another shortcoming when modelling cross-language interactions in the framework of a single lexical store is the dependence on explicit language nodes. In an integrated model of bilingual word recognition such as the BIA, lexical access is argued to be essentially language-nonselective. To account for real-life experiences of language independence (bilinguals do function without obvious language interference in most situations), the BIA features language nodes (i.e., language tags) which are expected to improve lexical selection by inhibiting activation level of words in the non-target language. The inclusion of language nodes on top of the word identification process implies that the non-selective nature of lexical access is only transient in reading. Indeed, past studies have revealed certain circumstances (e.g., highly selective context, short SOAs) in which prime language selectivity is observed (Dijkstra & Van Heuven, 2002; D. W. Green, 1998; Schwartz, 2003; Van Hell, 1998). In the typical experimental tasks involving single word recognition (e.g., LDT and semantic relatedness paradigm), however, the proposal of language nodes is more likely to be the result of using lexically similar materials, whereas it might be unnecessary to account for bilingualism from a more general point of view (Jacquet & French, 2002). For this reason, bilinguals whose two languages have distinct lexical and sublexical features might be the most neutral population in which the issue of lexical selectivity/non-selectivity can be addressed.

Another characteristic of studies of word recognition is that, so far, evidence of cross-language interactions has been derived mainly from testing bilinguals' responses to mixed languages (e.g., translation equivalents) or interlingual stimuli (e.g., cognates, interlingual homographs, interlingual neighbours). The reliance on these materials gives rise to two issues. One is concerned with methodological limitations, and the other brings up interpretational ambiguities. The following discussion will deal with the methodological issues first and then the theoretical issue.

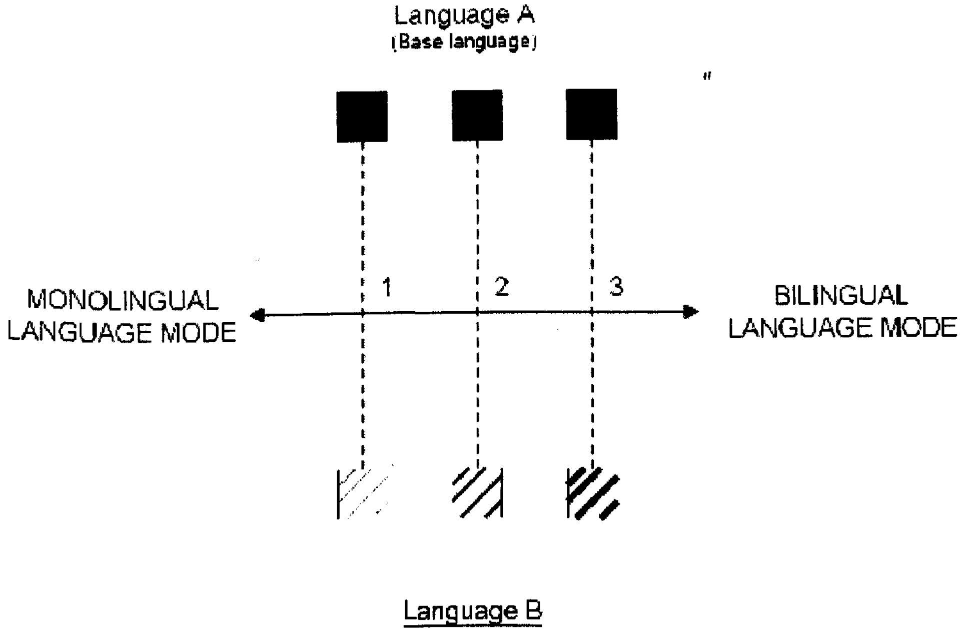

Figure 1-9. Visual representation of the language mode continuum (Grosjean, 1998a)

It has been argued that a bilingual individual may be at various states of activation in terms of the two languages spoken, a notion that is termed the language mode continuum (Grosjean, 1985, 1994; Grosjean, 1997; Grosjean, 1998b; Grosjean, 2001). At one end of the continuum, bilinguals would function as monolinguals, keeping the relevant language active and the irrelevant language being totally deactivated. At the other end of the continuum, they would find themselves in a bilingual mode, where both languages are constantly active for the purpose of communication in a mixed language situation. Between these two extremes, most of the time, a bilingual individual is expected to function neither as a monolingual nor as a bilingual with two fully activated languages. This language mode theory introduces a relative supremacy of one language over the other instead of total dominance (Grosjean, 1997; Lanza, 1992; Treffers-Daller, 1997). Variables that may affect the language mode include language abilities of the interlocutor, demands of a linguistic task, purpose of the interaction, topics, the environment, and so on. As the language mode determines the activation level of bilinguals' languages when communication actually takes place, it is assumed to have an impact on both comprehension and production.

As a theme of research, the concept of language mode still requires complete and direct experimental evidence as to what determines a bilingual's position on the continuum. However, as a potential confounding variable, failure to control for the language context in which a bilingual participant is tested may have serious implications for the way in which experimental findings are interpreted. Unfortunately, a large number of studies have mixed bilinguals' two languages. For example, in the cross-language priming paradigm that was reviewed previously, the prime and target word were from different languages. Manipulations of relationships between them (e.g., translation equivalents, semantic relatedness, form relatedness) induced behavioural changes in LDT performances, which were interpreted in support of bilingual lexical access. However, considering Grosjean's theory, it is almost certain that the bilingual participants in this experiment were in a bilingual mode since the experimental tasks implied explicit processing of stimuli in both languages. Optimal performance is achieved by prompting participants to consciously translate the prime word into the target language equivalent. It is, therefore, not surprising to see that the most reliable form of cross-language priming found was between translation equivalents (Keatley & De Gelder, 1992). Consequently, findings of these studies may be artificially biased toward the hypothesis of parallel activation of L1 and L2 lexicons of during word recognition.

The issue of language modes becomes particularly complex in studies that used interlingual materials instead of explicitly mixing words from the two languages. Experiments in which the stimulus list and task requirements involved only one language are generally considered to create a monolingual condition (e.g., all-in-L2) despite the fact that some of the stimuli may also exist in the other language (e.g., cognates or interlingual homographs). For example, the interlingual status of cognates and homographs has been shown to affect performance in LDT performed in bilinguals' L2 (De Groot et al., 2000; Dijkstra et al., 2000; Dijkstra et al., 1998). More strikingly, the cognate effect of trilingual's L2 and L3 was observed in both a LDT and a word association task that included only L1 words, providing compelling evidence that even in an exclusively native language context bilingual lexical access is language-nonselective (Van Hell & Dijkstra, 2002). Indeed, task instructions in these studies should set bilingual participants in a mode that concerns only the target language at the beginning of the experiment. However, the repeated occurrence of stimuli that could be read in the non-target language might still lead the participants to activate their other language and therefore progressively install them into a bilingual mode as the experiment unfolds. This is particularly likely in highly proficient bilinguals. Unfortunately, there seem to have been no studies in which a post-experimental debriefing session enabled the authors to survey the extent to which their participants were consciously or strategically taking advantage of the interlingual manipulations tested in a concealed manner (see De Groot & Nas, 1991; Gollan et al., 1997 for exceptions in masked priming studies; Sanchez-Casas, Davis et al., 1992).

The aim of the above discussion is not to claim that previous findings are invalid or that the language mode hypothesis may have entirely accounted for the results reported. The criticism is that, unless deliberately controlled and verified, the language context in which a participant operates is a potential confounding variable in studies of bilingual lexical access because (a) it is closely related and critical to the theoretical issue under investigation (i.e., selectivity/non-selective) and (b) a bilingual context may be spuriously elicited even when the mixing of stimuli from two languages is thought to be concealed. Regarding this latter idea, Grosjean (1998a) has commented as follows: "simply knowing that there is a possibility that elements from the other language will be presented (in an experiment, for example) will move the bilingual away from the monolingual endpoint of the continuum. Just one guest word in a stream of base language words can increase this displacement towards the bilingual endpoint." (p137).

Another issue raised by the use of interlingual stimuli is that evidence of cross-language interactions reported in such studies usually conflates the question of lexical representation with the question of lexical processing. When the interlingual status of stimuli shows an effect on L2 processing, it is interpreted as evidence for an integrated representation and language-nonselective access to the two languages. Absence of such interlingual effects is associated with separated lexical stores and language selective access. In fact, there remains the possibility that the two issues tap into different aspects of bilingual word recognition. The question of separated/integrated representation is more related to the development of bilinguals' languages whereas the question of whether lexical access is language-selective or language-nonselective refers to the characteristics of information processing in bilinguals. The two questions are highly related however, as Van Heuven et al. (1998)

pointed out, it is theoretically possible for a bilingual individual to have an integrated lexicon with selective access to words in each language or separated lexicons with parallel activation of both languages.

Cross-language interactions observed with interlingual stimuli do not always suffice to tease apart the representational from the processing account. Taking cognates for example, within the BIA framework, cognate facilitation effects on LDT have been interpreted as evidence for parallel activation of both languages, an explanation in terms of information processing. Other evidence has shown that cognates might be represented distinctively, by means of their morphological features, from other words in the two languages (Sanchez-Casas & Garcia-Albea, 2005). The two interpretations are not necessarily inconsistent with one another. The question then is, if cognates have independent representations from other words in the language system, to what extent this finding can be generalised to lexical processing as a whole. Except for cases in which the two languages include a large percentage of cognates (e.g., Spanish and Catalan), results of studies using interlingual materials are therefore unlikely to characterise bilingual word processing in general.

The two issues discussed above in the context of word recognition also apply to studies of bilingual word production. In keeping with the language mode hypothesis, the use of the picture-word interference paradigm appears to be far from ideal. As described in the previous section, this paradigm includes the presentation of a picture to be named in the target language and a distractor word presented in the other language, which implies an explicit dual-language context. Consequently, the observed effects of semantic interference and phonological facilitation might be spuriously induced by the strong bilingual context of the experiments. Moreover, as Kroll et al. (2006) pointed out, the presence of a distractor word initiates a process of word recognition which may interact with components of speech planning at various stages. In addition to a dual-language context, the picture-word interference paradigm is a highly artificial task which may have little to do with mechanisms at work in everyday life.

Studies of bilingual word production that involve cognates are also subject to interpretational ambiguities. Although cognate facilitation effects on picture naming latencies have been generally taken to demonstrate parallel activation of two languages, other explanations may account for this observation. Costa et al. (2006) argued that, in early stages of L2 development cognates might be more easily acquired and frequently used as compared to non-cognates due to their overlap in several linguistic attributes with translation equivalents in the native language. This might result in an advantage in the processing of cognates when bilinguals have acquired a high level of proficiency in L2. In fact, Costa et al. (2006)'s argument is intrinsically the same as the representational hypothesis put forward by Sanchez-Casas et al. (2005). Both suggest that cognates, given their unique interlingual features, are not ideal for the general purpose of revealing patterns of bilingual language processing.

To summarise, recent studies have converged in providing substantial evidence that, during the processes of single word recognition and production in bilinguals, both the relevant and the irrelevant languages are simultaneously active. The variety of perspectives from which the evidence is derived strongly supports the notion that cross-language interaction is a bilingual phenomenon. However, some methodological shortcomings and theoretical concerns discussed above leave the door open for alternative interpretations which cannot be readily dismissed. There are several ways in which the nature of cross-language interactions can be better understood. The list of questions below provides an overview of outstanding issues in the field. Some of these questions will find preliminary answers in the present work.

1. Do cross-language interactions take place between two languages with radically different writing systems which are likely to have independent lexical stores?
2. In a truly monolingual context, to what extent is access to L1 simultaneous and/or unconscious during L2 word processing?
3. What information (e.g., phonology or orthography) is actually activated in the non-target language?
4. To what extent does bilingual word recognition differ between reading and listening in terms of parallel lexical access?
5. What is the time-course of lexical selection or the locus of cross-language interactions in bilingual word comprehension and production?
6. With the exception of Spanish-Catalan bilinguals who are usually very fluent in both languages and can be viewed as balanced bilinguals, there has been little evidence regarding the directionality of cross-language influences (i.e., is L1 open to influences of L2?).
7. Does bilingual word production involve inhibitory processes on lexical candidates from the irrelevant language? Or is it a process of activation-by-competition, similar to word recognition?
8. Research has suggested that the ability and experience of using two languages confer long-term benefits in a variety of cognitive tasks (e.g., attentional control) for bilinguals (Bialystok et al., 2004). Why

is there relatively less evidence showing corresponding bilingual advantages in the domain of language itself?

Principles of ERPs

This chapter presents an overview of the technique of event-related potentials (ERPs) and its applications in the field of neurolinguistics. The goal of this chapter is to lay the foundation for the next chapter in which ERP research on bilingual language processing will be reviewed. The first section introduces origins of ERPs, their recording and analysis, and some issues regarding the advantages and disadvantages of ERPs as compared to behavioural and other physiological techniques. This section is relatively basic given the availability of other works that provide exhaustive methodological overviews (e.g., Luck, 2005; Picton, Bentin et al., 2000; Picton et al., 1995; Regan, 1989; Rugg & Cole, 1995a). The second section reviews significant language ERP studies which have established primary ERP correlates of language processing. For the purpose of the present thesis, the discussion emphasises to the single word level of processing.

2. 1. ERP recording, analysis, and conceptual issues

A living human brain produces constant electrical activities. These activities can be observed by simply connecting three (you need a ground, not just a reference) electrodes on the surface of scalp and amplifying the signals. The output is a waveform (continuous voltage variations) known as the electroencephalogram or EEG. EEG reflects voltage fluctuations at various scalp sites by comparison to a defined electrode site (the reference). The observed scalp voltages are thought to be a summation of postsynaptic potentials mainly generated in cortical pyramidal cells which have a parallel alignment perpendicular to the surface of the scalp and fire synchronously. By contrast, the EEG is thought to be negligibly affected by presynaptic potentials (that is, action potentials) and activities of other brain neurons than pyramidal cells (Allison et al., 1986; Martin, 1991). Consequently, recordings of EEG do not offer a full account of neural activities in the brain.

Since EEG allows on-line monitoring of brain activities, it is possible to present a stimulus (e.g., an event) to the participant and define a period, called an epoch, of EEG data that is time-locked to the presentation of the stimulus. The underlying assumption is that, within the EEG epoch, some of the voltage variations observed will be associated to neural responses to the stimulus. Such voltage changes can be extracted by averaging a number of EEG epochs together, which leads to event-related potentials (ERPs) or evoked potentials (EP), sometimes called brain potentials. ERP data can only be used to make correlational inferences rather than causational ones. This is because while ERPs are measured as the dependent variable, the neural systems thought to be responsible for their existence are often not manipulated directly; but rather indirectly activated by psychological tasks (i.e., the processing of the stimuli).

When deriving ERPs from the continuous EEG recordings in which they are embedded, there are several technical steps including filtering and artefact rejection to achieve acceptable signal/noise ratios by reducing contaminations from exogenous noise and eye movements in particular (Brunia, 1989; Gratton et al., 1989; Picton, van Roon et al., 2000). The key step then is to group multiple epochs recorded in response to a set of events into an average ERP representing the general brain response to the experimental condition. By doing so, effects of random activities, such as the background and event-unrelated EEG, are eliminated. The residual ERP data are thought to reflect brain activities that are time-locked to information processing induced by the stimuli.

It is important to note that the average ERP does not always resemble waveforms produced in each individual trial. For example, when the waveforms in individual trials show a bimodal distribution with regard to their amplitude or latency, the averaged waveform will fall in the middle of the two modes, and thus it will not represent the actual amplitude or latency in any of the individual trials. To reduce the risk of obtaining an average ERP that misrepresents individual events, an adequate ERP experiment should include sufficient number of trials, maintain a high level of interstimulus consistency within each condition, and encourage participants to keep minimal differences in latency variability across trials.

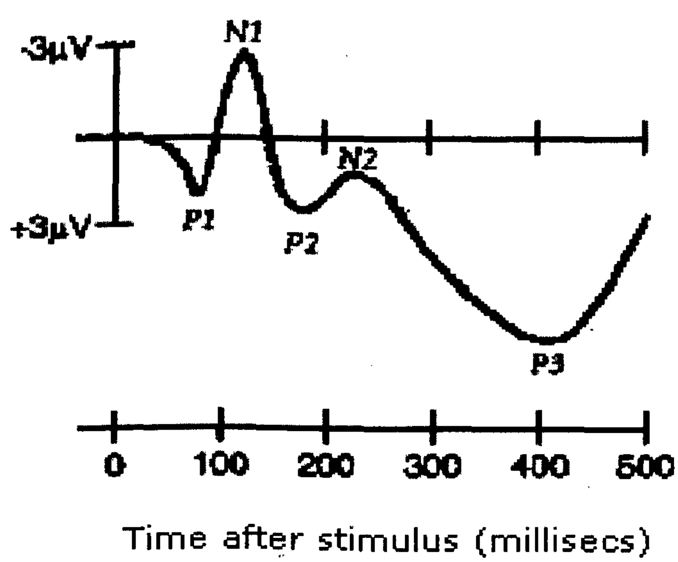

Figure 2-1. An idealised waveform of event-related potential

A standard ERP waveform is characterised by a sequence of positive-going and negative-going deflections which are usually called ERP components (see figure 2-1). It is labelled N (negative) when it is oriented towards negative amplitudes or P (positive) when oriented towards positive amplitudes. The number refers to the serial position of the peak in the sequence of peaks in the waveform (e.g., P2 for the second positive component). It is also common to use precise latencies such as N400 for the negative-going wave peaking at 400 ms.

While technical and theoretical issues in the extraction and definition of ERP components can easily justify a whole book chapter (Donchin, 1979; Naatanen & Picton, 1987; Picton & Stuss, 1980; Rugg & Cole, 1995b) or even a book, we will only cover two main points here. As described earlier, ERP measures voltage changes on the scalp result from the summation of electrical activities in the brain. Electricity is not propagated in a fixed direction through a conductive medium (i.e., brain tissues); instead, they spread out through the conductor. This means that a single voltage recorded at a particular electrode (i.e., one location on the scalp) at a particular time can be produced by an infinite number of source configurations depending on the timing and location of each generator. The nature of volume conduction blurs the surface distribution of voltage so that there is no absolute spatial correspondence between ERPs observed at the surface of the head and the activities of underlying neural systems. There are methods that can effectively reduce the blurring (e.g., Gevins et al., 1999; Pernier et al., 1988; Tucker et al., 1994) and recently, researchers are experimenting simultaneous recordings of EEG with functional neuroimaging tools (Ritter & Villringer, 2006). These may enhance the relationship between topographical ERP data and underlying source in the near future.

The second issue concerns the functional definitions of ERP components. Although the general trend is that early components are mainly associated with automatic, sensory, modality-dependent processing of stimuli and late ones are associated more with strategic, cognitive, modality-independent processing (Picton & Hillyard, 1988; Polich, 1993), two issues need to be kept in mind: First, one component often reflects a number of subcomponents (e.g., the N2 family Luck &

Hillyard, 1994; Naatanen & Picton, 1986) which can only be teased apart by discrete experimental designs. Second, depending on a variety of factors, ERP components with the same labels may not reflect the same underlying brain activity across experiments. For the second point, experiments in the current study will provide a vivid illustration.

Spatial resolution is perhaps the only significant disadvantage of ERPs in comparison with other physiological techniques such as brain imaging. It is generally agreed that the spatial resolution of ERPs is in the order of the centimetre whereas that of Functional Magnetic Resonance Imaging (fMRI) and Positron Emission Topography (PET) is in the millimetre range. Despite this, ERPs hold great promises in terms of non-invasiveness, cost, and, particularly, temporal resolution (which is in the order of the millisecond). As compared to standard behavioural method (i.e., RT and ER), the most significant benefit of using ERPs is that they reflect the complexity of cognitive processes from the onset of stimulus presentation up to the response and beyond. For most models of cognitive psychology within the information-processing framework, an overt response to a cognitive task is expected to be the consequence of at least three distinguishable stages of processes: perception, processing, and execution. Effects on reaction times and error rates are often difficult to relate to a specific stage of processing. With ERPs, it is not only possible to determine at which stage(s) experimental treatments affect a particular condition, but also to examine hypotheses regarding the timing of various cognitive processes in a general sense (Jennings & Cole, 1991). The next section will provide some examples of ERP studies for both purposes.

2. 2. ERPs in linguistic and neurolinguistic research: the N400 and the N2 family

Language is heard in our everyday environment, it is processed naturally, rapidly and effortlessly in real life. In normal individuals, the process from the intention of speaking to the point of utterance is spontaneous and arguably often unconscious. The same is true of the stage from seeing a string of letters (or other symbols) and accessing its meanings. However, both speaking and reading involve a multi-stage process which activates a distributed neural system (Davis, 2004; Fiez & Petersen, 1998; Pulvermuller, 2001). As discussed in the previous section, the high temporal resolution of ERPs makes them ideally suited for the investigation of language processing. Early psycholinguistic studies using ERPs have re-examined a variety of phenomena that have been established in the behavioural psycholinguistic literature. In the domain of language comprehension, influences of lexical properties such as word length, concreteness, lexical frequency, and grammatical class on behavioural tasks have been shown to associate with specific patterns of ERP modulations (for thorough reviews see Bentin et al., 1999; Friederici, 2004; Hauk et al., 2006; Simon et al., 2004). Although findings may differ between studies depending on the specific parameters of experiments, three main components known as the N200, the N400, and the P600, are the most commonly reported indices of language processing. Since the P600 is mainly elicited by grammatical-syntactic manipulations and is most relevant in the case of phrases and sentences (Friederici et al., 1996; Gunter et al., 2000; Kaan et al., 2000; Osterhout & Holcomb, 1992) but see (Kuperberg, 2007) for a dissenting opinion. The following review will concentrate only on two components, the N200 and the N400, which are elicited in single word processing.

The N400 is perhaps the most studied electrophysiological correlate of language processing. It was originally reported by (Kutas & Hillyard, 1980) who described a negative-going waveform that peaked at around 400 ms in response to semantic incongruence of a word in a sentence. For example, when sentences such as "it was his first day at *cup*" are presented one word at a time on the screen, a large N400 is elicited on average by the unexpected endings. Conversely, a small N400 is observed when the sentences end in a semantically appropriated word ('work' in the example above). This effect is mostly significant over the central and parietal region of the scalp and relatively symmetric between the two hemispheres. The N400 can also be observed for word pairs (Bentin et al., 1985; Holcomb, 1988; Van Petten, 1993). A reduced N400 is elicited when the second word of a pair is related to the first (e.g., doctor-nurse) as compared to unrelated (e.g., window-nurse). In comparison to the sentence-elicited N400, the word-elicited or "lexical" N400 is similar in scalp distribution and latency, but it is usually smaller in amplitude. Interestingly, the absence of correlation between the lexical N400 and participant performance in LDT tasks performed simultaneously has been shown repeatedly, whereas a strong negative correlation between the amplitude of N400 and recognition accuracy has been reported in sentence contexts (Van Petten, 1993).

The N400 effect has also been widely documented in the auditory modality (Anderson & Holcomb, 1995; Holcomb & Neville, 1990, 1991). A characteristic of auditory N400 effect is that, compared to the visual modality, the divergence between related and unrelated conditions begins earlier and lasts longer. In particularly, the onset of the N400 effect in the auditory modality is within the duration of the presentation of spoken words. This difference has been accounted for in terms of processing mechanisms underlying speech comprehension. It is well-established in the psycholinguistic literature that the recognition of a spoken word can take place before all the acoustic information is perceived (Grosjean, 1980; Marslen-Wilson, 1987; Marslen-Wilson & Tyler, 1980; Tyler, 1984). According the COHORT model (Marslen-Wilson, 1987; Marslen-Wilson & Tyler, 1980), a word presented auditorily is recognised at the point at which other candidate words can all be rejected. This "uniqueness point" usually precedes the end of the acoustic trace of the word and can be further advanced by co-articulation and other contextual information (e.g., in the case of priming).

The characteristics of the auditory N400 bring up an issue when making temporal inferences from ERP data. While the N400 has been considered an index of processing semantic information during language comprehension, some authors assume that meaning is accessed approximately 400 ms after the onset of word presentation. This view is however misleading. Access to meaning is probably reflected in the onset of the N400 wave, i.e., the time at which the waveforms from two conditions (i.e., related and unrelated) begin to differ, rather than the peak of this difference (e.g., Thierry et al., 1998). While the N400 usually peaks at 400 ms after stimulus onset, the actual divergence in the waveforms appears at around 200 ms in visual experiments and even earlier in auditory experiments. The timing of this separation of ERPs is also consistent with existing evidence from empirical work (Sabol & De Rosa, 1976), which showed that the average encoding time of single word was 183 ms. Therefore, it may be better to consider that semantic access occurs approximately 200 ms before the peak time of the N400.

Apart from temporal considerations on ERP data, there are several theoretical issues that are important when using ERPs and, in particularly the N400, in the study of language comprehension.

Although the N400 was first described in response to contextual violations (e.g., semantic incongruence or unrelatedness), it is not only sensitive to the processing semantically anomalous stimuli. It is neither an index of only contextual or priming effects. Instead, the N400 seems to be sensitive to the difficulty in the process of retrieving conceptual information from long-term memory. This view is supported by substantial and accumulating evidence that factors that potentially influence the ease of accessing semantic information modulate ERPs in the N400 range. 'At the lexical level, the N400 has been shown to strongly respond to repetition both within (Bentin & Peled, 1990; Rugg, 1985; Rugg & Doyle, 1994) and across modalities (Holcomb et al., 2005; Joyce et al., 1999), whether the repetition occurs immediately or within a few trials of the first presentation. Other factors such as word imageability (Swaab et al., 2002), concreteness (Kounios & Holcomb, 1994), lexical frequency (Rugg, 1990; Van Petten, 1993), word classes (content words versus function words Brown et al., 1999; Neville et al., 1992), and relatedness at orthographical, phonological, and morphological level (Kutas et al., 2000), also influence the amplitude and sometimes other dimensions of the N400 sometimes independently and sometimes in an interactive manner. The general picture painted by these studies is that stimuli that are difficult to comprehend elicit large N400 amplitudes and vice versa.

As the N400 has been often associated with semantic processing, a natural hypothesis is that the effect is language-selective. However, this hypothesis is only partially supported. Early studies comparing contextual violations in sentences to music, geometric shapes, or picture-pairs have claimed that the processing of non-linguistic stimuli did not elicit (Besson & Macar, 1986, 1987) or at least partially dissociated (Barrett & Rugg, 1990b) from a typical N400 effect. Furthermore, while pseudowords have been shown to elicit comparable N400 as real words, words that are spelled backwards produce no such effects (Holcomb & Neville, 1990). This evidence suggests that the N400 is particularly selective to "language-like" stimuli, even though semantic priming studies using non-verbal meaningful stimuli such as pictures and environmental sounds have shown N400 modulation of similar magnitude as that found in language priming studies. Recently, an increasing number of studies have reported significant temporal and functional overlap in the N400 waves associated with linguistic and non-linguistic stimuli (Federmeier & Kutas, 2001; Ganis et al., 1996; Jemel et al., 1999; Pratarelli, 1994). In these studies, cross-modal comparisons often reveal differences in the scalp distributions, which are interpreted in terms of distinct neural generators underlying the processing of modal-specific inputs, whereas temporal coincidence is taken to suggest that there is a common amodal processor for conceptual information.

The issue of language-specificity of the N400 has not yet been settled because studies supporting each side of the argument often differ in an important aspect. Studies using non-linguistic stimuli which contain little semantic information (e.g., melodies, geometric shapes, and backward words) generally find no comparable N400 effect between verbal and nonverbal stimuli (see Koelsch et al., 2004 for an exception). Studies using non-linguistic but meaningful stimuli such as pictures (West & Holcomb, 2002) and environmental sounds (Van Petten & Rheinfelder, 1995) have found such effects. Therefore, on the one hand, the absence of N400 can be related to a lack of semantic content in the stimuli; on the other hand, the presence of an N400 can result from internal verbalisations of meaningful stimuli that prompt encoding with words. As will be discussed in later chapters, some of the experiments reported in the present research create a condition in which non-linguistic processing of meaningful stimuli is tested in the N400 range, while, at the same time, the potential involvement of verbal encoding is monitored (see Chapter 8).

Although the precise nature of the N400 is still undetermined, it doubtlessly represents the mostly widely used ERP index as dependent variable in studies of language processing. Interestingly, in the relatively young literature of electrobilingualism (i.e., electrophysiological studies of bilingual language processing), another ERP component, the N2 or N200, which is seldom associated directly with the processing of linguistic information has received exceptional attention. In the field of bilingual word production, in particular, the use of the N2 dominates that of the traditional N400 because of its relation to response inhibition.

As suggested by its name, the N200 (or N2) is a negative-going waveform peaking at around 200 ms after stimulus onset. Since the N2 is amongst the most thoroughly studied families of ERP components, functionally distinct components have been identified within this time window. The best known are the N170 which is thought to be selectively sensitive to faces (Bentin et al., 1996; Rossion et al., 1999) but also see (Thierry et al., 2007) and the Mismatch Negativity (MMN) which reflects the detection of infrequently presented sensory stimuli (deviant) amidst frequent stimuli forming a baseline (standard) in the absence of overt attention (Alho, 1995; Naatanen, 1992; Naatanen & Alho, 1995). Details of other N200 subcomponents can be found in Luck & Hillyard, (1994) and Naatanen & Picton, (1986).

What makes the N200 a useful tool for studies of language processing is its particular sensitivity to response inhibition. In a typical Go/noGo paradigm, participants are asked to respond (Go) to one class of stimuli while ignoring (noGo) the others. As originally reported by Pfefferbaum et al. (1985), withholding responses in the noGo condition elicits a negative-going peak in comparison to the Go condition. The increased amplitude of the N200 has been associated with inhibition at a high-level of executive control. In subsequent studies, the N200 sensitivity to inhibition was shown to be independent of modality and task (e.g., perceptual, cognitive, and obviously, language-related Eimer, 1993; Frings & Groh-Bordin, 2007; Jodo & Kayama, 1992; Rahman et al., 2003; Thorpe et al., 1996).

While the N400 has been shown to reflect processes underlying meaning construction that are relatively fixed temporally, the time course of the N200 effect depends on the type of task and information under processing. Therefore, it has been widely used to study the time course of psychological processes taking place at an early processing stage. Using this index in a lateralised readiness potential study, for instance, N200 effects have suggested that, during picture naming, conceptual access precedes phonological access by 170 ms in German (Rodriguez-Fornells, Schmitt et al., 2002). That is, the N200 modulation driven by access to conceptual information was found 170 ms before the N200 modulation correlated with responses based on phonological information. In both speaking and listening, semantic processing is argued to precede syntactic processing by 70-80 ms in German (Schmitt et al., 2001) and syntactic information such as gender is accessed 60 ms before phonological information in production (van Turenout et al, 1998). Similar studies have been conducted in Chinese to reveal the relative time course of the access to various linguistic features of Chinese characters. (Zhang, Damian et al., 2007; Zhang, Weekes et al., 2007; Zhang & Yang, 2007).

Having described the background and applications of the N200, a comparison can be made between the N200 and the N400. A point worth raising here is that, although N200 modulations have been used as temporal markers for specific cognitive processes, they remain an indirect measure because they only index the underlying process of inhibition. On the other hand, although the stimuli do not have to be linguistic in nature, the N400 is fundamentally sensitive to semantic processing, which is arguably the most critical aspect of language. Also, there may still be a time delay between the availability of linguistic information and the onset of the N200 due to decision-making. This undercuts the precision with which the N200 tracks down psychological processes. Moreover, since the N200 is only observed under conditions requiring response inhibition, it is unknown how the experimental task creating this context may have itself affected the way in which language is processed as compared to normal functioning. Third, making a Go/Nogo decision requires conscious evaluation of the task instruction and stimulus information. The extent to which the N200 effect reflects unconscious processes which constitute a large part of language processing is unknown. Further considerations on the interplay of the N200 and the N400 as electrophysiological tools in the study of languages will be presented in the context of bilingual functioning in the next chapter.

ERPs and Bilingual Language Processing:

A Selective Review

Although early applications of event-related potentials (ERP) to the study of bilingual language processing date back more than twenty years (Fischler et al., 1987; Meuter et al., 1987), other more recent neurophysiological approaches to bilingualism such as functional magnetic resonance imaging (fMRI) appear to have been more influential. Indeed, in a number of recent reviews of psycholinguistic and neurolinguistic literature, ERP studies have received considerably less attention than other neurophysiological methods (Bhatia & Ritchie, 2004a; Kroll & De Groot, 2005; Paradis, 2004) but see also (Mueller, 2005). However, as discussed in the previous chapter, ERPs have remarkable advantages for investigating cognitive processes underlying language processing in general and bilingual functioning in particular. Their fine temporal resolution and the existence of components reflecting particular cognitive processes, such as perceptual, phonological, syntactic and semantic analyses, provide invaluable information regarding the interplay of L1 and L2 processing at different linguistic levels.

For the purposes of the present thesis, this chapter selectively reviews ERP studies on bilingual language processing that focus on the issue of separated versus integrated system (see Chapter Two). While the review is restricted to lexical and semantic access in L2, it is noteworthy that important contributions addressing different issues have been made, including phonological processing (Grubb et al., 1998; Sebastian-Galles et al., 2006; Winkler et al., 1999), morphology (De Diego Balaguer et al., 2005), syntax (Kotz et al., 2007; Weber-Fox & Neville, 1996, 2001), grammar (Elston-Guttler & Friederici, 2005), levels of L2 proficiency (Elston-Guttler, Paulmann et al., 2005), and code-switching (Jackson et al., 2001; Proverbio et al., 2004).

3. 1. ERP studies on second language comprehension

ERP studies of bilingual language comprehension generally belong to two categories. Early studies were mostly "explorative" and therefore fundamentally empirical in nature. While these studies relied on existing knowledge of particular ERP components to characterise the language processes involved, they often made little use of the psycholinguistic literature established on the basis of behavioural research. As a consequence, findings from these studies tend to be stand-alone, as will be discussed later, i.e. they are difficult to interpret in the framework of psycholinguistic theories and cannot be readily compared with one another. More recently however, a number of ERP studies have tested specific predictions within the framework of existing psycholinguistic models. Not only do these studies provide additional support for well-established behavioural effects, but also they extend our understanding of the underlying processing mechanisms. Given that each type of study has its own advantages (see Dijkstra & Van Heuven, 2006; Grosjean et al., 2003), we will describe both types and attempt to incorporate their contribution into a coherent account of bilingual processing.

Ardal et al. (1990) were the first to describe the N400 in bilingual participants. Using a typical sentential priming paradigm, the N400 effects were observed in a group of English monolinguals and a mix of English-French and French-English bilinguals who were fluent in both languages. The N400 effect was delayed when bilinguals read sentences in L2 as compared to L1. The N400 amplitude was also reduced in L2 as compared to L1, but this reduction was only significant over the frontal area of the scalp. Behavioural results, measured by recognition and recall tests post-experiment, did not differ between monolinguals and bilinguals. The delay of peak latency in bilinguals was interpreted as a reduction in automaticity of L2 processing. Interestingly, the age of acquisition for L2 did not distinguish bilinguals in terms of N400 latency and amplitude; thus, the authors concluded that current fluency in L2 was the main factor affecting N400 patterns in bilingual participants.

Subsequent N400 studies have generally replicated the findings of Ardal et al. (1990). With the exception of a couple of studies showing no significant differences between German monolinguals and Japanese-German bilinguals (Hahne & Friederici, 2001; Sanders & Neville, 2003), most N400 results point to a delayed peak latency and/or reduced amplitude in bilinguals as compared to monolinguals (Hahne, 2001; Kutas & Kluender, 1991; Moreno & Kutas, 2005; Phillips et al., 2004; Weber-Fox & Neville, 1996). However, the claim that current fluency, rather than age of acquisition, determines N400 characteristics is only partially supported.

Weber-Fox et al. (1996) compared bilinguals across five groups of age of L2 acquisition (i.e., 1-3, 4-6, 7-10, 11-13, and 14-16) and found that only those who began to learn their L2 after the age of 11 display an N400 peak delay typical of bilinguals. Although L2 fluency was not accurately measured in this study, the differences between early and late bilinguals suggested that prolonged exposure to L2 might affect semantic processing on a large scale. While the effect of L2 fluency was also evident when less proficient bilinguals were compared to highly proficient bilinguals (Phillips et al., 2004), studies which take into account both fluency and age of acquisition usually demonstrated a high correlation between the two factors suggesting that their influences on L2 processing cannot be effectively dissociated (Hahne, 2001; Moreno & Kutas, 2005).

A detailed analysis of the N400 in bilinguals has shown that the N400 peak latency and amplitude in the semantically correct condition is similar to that of monolinguals, whereas it is delayed and larger in the semantically violated condition (Hahne, 2001; Hahne & Friederici, 2001). Furthermore, depending on the age of L2 acquisition, the bilingual N400 has been shown to distinguish categorical from associative relatedness in semantic priming. In late bilinguals, who have acquired their L2 after the age of 12, associated word-pairs (e.g., rose-love) induce an N400 priming effect that is not found for categorical word-pairs (e.g., table-chair) (Kotz & Elston-Guttler, 2004). By contrast, in early bilinguals, the N400 is sensitive to both types of priming (Kotz, 2001).

Curiously, behavioural data in neither of the above two studies showed evidence for an effect of categorical priming. The mismatch between behavioural and ERP data is not surprising itself since a number of authors have reported a similar observation (McLaughlin et al., 2004; Tokowicz & MacWhinney, 2005). It is, however, surprising that no behavioural effect of categorical priming was found even in the case of advanced bilinguals. Unfortunately, the absence of monolingual controls in these studies makes it difficult to determine whether the observed differences between associative and categorical priming were the result of asymmetric development of different types of semantic information in bilinguals, as indeed concluded by the authors, or whether they were due to the particular set of stimuli used by the authors.

Another interesting observation regarding Kotz et al. (2001) and Kotz et al. (2004)'s studies is that their results have been interpreted in the framework of the RHM (Kroll & Stewart, 1994): bilingual performances on categorical and associative tasks have been taken as indication for the development of the word-concept and word-word links respectively. However, I would like to point out that the main hypothesis of the RHM is that, depending on the level of proficiency, bilinguals have two possible routes by which the forms of L2 words are mapped onto their concepts: direct conceptual links (conceptual mediation) and lexical links via L1 translations (word association). While categorical priming has been used widely to test semantic access, considering associative priming (e.g., heart-love) as an index of word association in the RHM may be inappropriate, because word association as defined by Kroll and Stewart (1994) refers to lexical connections between L1 and L2 (i.e., between translation equivalents). Both the categorical and associative priming used in Kotz, (2001) and Kotz & Elston-Guttler, (2004)'s experiments involved explicit conceptual evaluation. Therefore, these conditions cannot adequately distinguish semantic from lexical levels of representations which is the principle of the RHM.

Alvarez et al. (2003) directly tested the predictions of the RHM using ERPs. Beginning English-Spanish bilinguals were engaged in a semantic categorisation task on words from the two languages ("press a button when the word refers to a part of the body in either language"). Critical items were words that repeated the word in the previous trial (i.e., immediate repetition) both within and across languages. An advantage of this design is that while the categorisation task ensures semantic processing of the stimuli, it does not require explicit translation. Furthermore, the translation equivalents used in this study were non-cognates that had little or no orthographic and phonological overlap. This should have constrained possible sources of repetition effects in the between language condition.

Repetition effects, as manifested by the reduction in N400 amplitudes, were larger when both words were in Spanish (L2) as compared to when they were in English (L1). The authors explained this difference in terms of the proficiency of bilinguals in their L2: Since Spanish words were newly acquired and more difficult to process than English words, bilingual participants benefited more from repetition priming in Spanish than English.

The results of cross-language repetition effects were more complicated. First, the reduction in N400 amplitudes was similar for both language orders (i.e., L1-L2 and L2-L1). As these effects were supposed to be semantically driven (given the relative absence of overlap in other stimulus properties), they were most compatible with the conceptual mediation model which suggests that access to word meanings in L2 is direct and comparable with that of L1. However, the finding was unexpected given the level of L2 proficiency of bilingual participants tested in this study. As the RHM argues, a direct conceptual route to L2 semantics is developed only when bilinguals become highly proficient in their L2.

The temporal pattern of N400 effects provided yet a different perspective. The time-course of L1-L2 priming was significantly delayed as compared to L2-L1 priming. This difference goes against the interpretation that cross-language repetition priming is conceptually mediated in both directions. In fact, this finding is more consistent with the word association model which suggested that the L1 translation equivalent is activated when a word in L2 is processed. This would be accounted for by the following theoretical mechanism: When an L1 word preceded by its translation equivalent in L2 is being processed, repetition priming starts immediately at the lexical level of L1 because this information had been accessed upon presentation of the prime in L2. In the L1-L2 condition, however, repetition priming would only start once the L2 word activates its L1 translation equivalent because the L1 prime is less prone to activate the equivalent lexical form in L2. As a result, the priming effect is selectively delayed in the L1-L2 direction. The findings of Alvarez et al (2003) provided the first ERP evidence for the existence of translation asymmetries that had been previously described in a number of behavioural studies.

Although Alvarez et al. (2003) brought important insights into how ERPs can be applied to test predictions of models based on behavioural data, the experimental tasks used in the study did not differ significantly from the tradition of psycholinguistic studies which use a mix of languages, and therefore, it is subject to the same interpretational limitations. While the semantic categorisation task itself does not require translation, the use of a mixed-language design and the length of the inter-stimuli interval (2.7 seconds) enable participants to overtly translate each word before the onset of the next trial. Since bilingual participants are more likely to translate L2 words into L1 than the reverse, the extent of cross-language priming might be artificially increased in the L2-L1 as compared to the L1-L2 direction.

Additional evidence for cross-language activation at the level of translation equivalents was found by testing bilingual processing of distinct L2 translations of a single L1 homonym (Elston-Guttler, Paulmann et al., 2005). Previously, Elston-Guttler et al. (1996) found behavioural evidence for an inhibitory connection, or reversed priming, between semantically unrelated L2 translations of L1 homonyms. Reversed priming in the N200 component and RT was found when bilinguals read English (L2) word-pairs, such as "pine - jaw", in which both words have the same translation in German (*kiefer*). This effect was influenced by L2 proficiency and sentence context: Only low-proficient bilinguals exhibited both the RT interference and ERP effects in the single word context (as opposite to sentence context). Most critically, the ERP modulation was observed in the N200 instead of the N400 range, which suggests that translation into L1may have occurred at the orthographic rather than semantic level. Although this conclusion warrants replications, it is in line with the hypothesis of lexical connections and shared conceptual store between L1 and L2 in the RHM.

While findings of Alvarez et al. (2003)'s and Elston-Guttler et al. (2005)'s study can be generally interpreted within the framework of the RHM, they contrast with findings of an ERP study by Rodriguez-Fornells et al. (2002) which has challenged psycholinguistic theories of cross-language activation in bilinguals. Spanish-Catalan bilinguals were engaged in a language decision task ("press a button when the word is from the target language while ignoring words in the other language and pseudowords"). ERPs to words in the non-target language were insensitive to the lexical frequency of the stimuli presented, indicating that bilinguals did not access the meaning of words presented in the non-target language despite the mixed-language context of the experiment. The authors concluded that, instead of activating both their languages automatically, bilinguals could effectively filter out the activation of words in the non-target language at a relatively early stage of processing, i.e., prior to engaging into semantic analysis. Moreover, fMRI data acquired in parallel during target language processing showed activities in cortical areas that have been associated with phonological processing. This finding leads the authors to speculate that bilinguals might have adopted an indirect route to semantics based on phonological information and this enabled effective prevention of cross-language interference.

To reconcile the discrepancies between Rodriguez-Fornells et al's (2002) study and the evidence of cross-language activation that has been accumulated over years of research, one might turn to the uniqueness of the bilingual population employed in the study. Spanish–Catalan is one of the rare language combinations in which the two languages are highly transparent and acquired so simultaneously that speakers might not always be able to distinguish L1 and L2. The very high level of proficiency in both languages might result in an exceptional ability of language control. However, a more direct explanation for the findings of Rodriguez-Fornells et al. (2002) study may lie with the chosen experimental tasks. While the response decision ("press the button or not") was dependent on the type of language, the hand with which the button was to be pressed was determined by the nature of the first letter of the word –vowel or consonant. This second component of the task invited participants to focus their attention on phonological properties of words which may have in turn enabled relative language independence. This would explain why cortical activations were mainly found in areas of the brain traditionally associated with phonological processing (e.g., posterior inferior frontal area). For a more extensive discussion on the experimental parameters and potential limitations of Rodriguez-Fornells et al's (2002) study, see (Grosjean et al., 2003).

Although the dual-task used by the authors might have biased lexical and semantic processes, Rodriguez-Fornells et al's (2002) results suggested that language independence is achievable under particular experimental circumstances and in a particular case of highly proficient bilingualism. This conclusion was partially echoed in a recent study on bilingual auditory word processing (Phillips et al., 2006). ERPs were recorded from a group of proficient English-French bilinguals during an adaptation-release task in which the prime word was presented four times prior to a single presentation of the target word. In the critical condition involving a change in language, in which the target word was the translation equivalent of the prime, no evidence for cross-language activations in forward translations (i.e., L1-L2) was found. The ERPs to translation equivalents in L2 were comparable with unrelated words in L1 suggesting that bilingual participants did not activate any L2 information while processing words in L1. In the case of backward translation (i.e., L2-L1), however, a small but significant N400 effect was found establishing semantic priming from L2 to L1. Critically, another hypothetical ERP component, the phonological mismatch negativity (PMN) which is sensitive to phonological expectancy (Connolly & Phillips, 1994) was also significantly modulated. This suggests that multiple presentations of a word in L2 fails to prime phonological information of its translation equivalent in L1, which is evidence against the word association model of the RHM.

In addition to methodological differences that often exist among studies on bilingual processing, the findings of Phillips et al. (2006)'s study raise the question of the comparability of lexical and semantic processing between the visual and auditory modalities. Unfortunately, there is a great paucity of ERP studies of auditory word processing in bilinguals. Ideally, therefore, experiments focusing on a particular question should be conducted in both modalities, allowing for direct comparisons of reading and listening. This is also a goal that I pursued in the current thesis.

Besides studies on bilingual processing of translation equivalences, which are all relevant to the testing of RHM assumptions, ERPs have also been used to investigate the hypothesis of language-nonselective access and context effects described in the BIA and BIA+models (Dijkstra & Van Heuven, 1998, 2002). In particular, a series of ERP studies has attempted to replicate and further explore bilingual responses to interlingual homographs, which have been extensively used in behavioural studies. For instance, cross-language semantic priming effects indexed by N400 modulation have been shown using interlingual homographs (De Bruijn et al., 2001; Elston-Guttler, Gunter et al., 2005; Paulmann et al., 2006).

One key question here is whether or not the language context in which the participant is tested can exert a top-down influence on lexical processing. For instance, De Bruijn et al. (2001) showed that the English-Dutch homograph *angel* (meaning "sting" in Dutch) primes the English word "heaven" irrespective of whether it is preceded by an English or a Dutch word. At first glance, this result speaks against a strong influence of immediate language context on lexical processing and stresses the preponderance of bottom-up processing. However, it could also be argued that the language context set by a single word is insufficient to induce observable effects on lexical processing, especially when the two languages are overtly mixed in the experiment, thus requiring permanent shifts between L1 and L2. To address this question using a more naturalistic set up, Elston-Guttler et al. (2005) presented bilingual participants before the ERP testing session with a film excerpt narrated in either their L1 and L2. This "global language priming" preparation affected language non-selective activations. After a group of German-English viewed a 20-minutes film narrated in English, they were able to "zoom into" an all-L2 context whereby interlingual homographs effects of L1 on L2 were minimal, contrasting with the typical interlingual homograph effects seen when the preparation film was in German. Since the present research does not focus particularly on contextual factors, the current review does not go beyond the conclusion that the extent to which L1 and L2 are activated in a nonselective manner is under the influence of general task demands and global language context.

In an extension of De Bruijn et al. (2001)'s study, Kerkhofs et al. (2006) replicated the semantic priming effects and showed that the N400 amplitude is sensitive to the lexical frequency of interlingual homographs in both L1 and L2 independently. When Dutch-English bilinguals performed an English LDT on Dutch-English homographs, the frequency of the English reading (L2) was inversely related to the amplitude of the N400, while the frequency of the Dutch reading (L1) was positively related to it. In other words, the easier the English reading (task relevant) of the homograph, the smaller the N400 whereas the easier the Dutch reading (task irrelevant) of the homograph, the larger the N400.

Kerkhofs et al. (2006)'s findings are remarkable because they not only provide evidence for language nonselective access, but also suggest that lexical frequency effects on the N400 are dependent on task demands, an idea that has seldom received support in previous monolingual research. Apparently, there was an inhibitory relationship between the ease of task-irrelevant reading (Dutch) of homographs and the facility of LDT in English. Unfortunately, the study did not show whether language nonselective effects of lexical frequency are also present when bilinguals read in their L1. Indeed, one couls expect the reverse pattern of results when the language of LDT is changed to L1. Furthermore, this study involved no monolingual control groups in either of the bilinguals' two languages. This is a potentially important limitation because it is speculative to attribute any effects of bilinguals' L1 on L2 processing to parallel activations of both languages unless these effects are (a) absent in monolingual speakers of L2, and (b) comparable with that of monolingual speakers of L1. An in-depth discussion of this issue will be presented in the next chapter to explain the purpose of the design used in the set of experiments reported in the present thesis.

*3. 2. **ERP studies on second language production***

As discussed in the chapter dealing with ERP methodology, ERP recordings are vulnerable to electrical interference generated by motion artefacts (task-irrelevant movements) such as facial movement, eye movements, and eye-blinks. Movements during articulation, in particular, severely affect ERP signals. This limitation has restricted the use of ERPs in the study of overt language production. Most ERP studies on language production have resorted to the go/nogo task (Miller & Hackley, 1992) in which the naming process is tested implicitly. For example, in a simple go/nogo paradigm, participants are instructed to classify pictures depending on a semantic feature (e.g., animal or object) or a phonological feature (e.g., vowel or consonant of the first letter) by pressing or releasing a response button. As reviewed in the previous chapter, the N200 (or N2) component which reflects response inhibition is the targeted index in such go/nogo paradigms. In the N200 time window, the nogo trials often elicit more enlarged amplitudes as compared to the go trials.

By studying the time course of the N200 effect, a number of studies has assessed the relative timing of the retrieval of conceptual, syntactic, and phonological information during language processing (Rodriguez-Fornells, Schmitt et al., 2002; Schmitt et al., 2000; Schmitt et al., 2001; van Turennout et al., 1997). Recently, Guo et al. (2007) found that modulation of the N200 by semantic manipulations occurred 170 ms earlier than modulations induced by phonological manipulations in a group of non-proficient Chinese-English bilinguals naming pictures in English. This finding suggests that, consistent with the general language production models (Levelt, 1989), semantic information is available before phonological information during L2 production.

A few studies have addressed the issue of L1-L2 interactions more directly in production by asking whether or not, and to what extent, the information of both L1 and L2 is accessed in parallel when bilinguals speak in one language. Rodriguez-Fornells et al. (2005) tested a group of early German-Spanish bilinguals in a covert picture-naming task. To ensure that speech planning took place, the participants were asked to press a button when the picture name began with a vowel and withhold their response when the picture name began with a consonant. In the critical condition of "noncoincidence", the names of the picture in the target language and the nontarget language invited contradictory responses (go and nogo). This interference manifested itself by increased N200 amplitude in bilinguals as compared to monolingual controls, showing that bilingual participants "considered" information from both their languages while making a decision. This result is consistent with cross-language activation down to the phonological level during bilingual language production.

It is worth mentioning that Rodriguez-Fornells et al. (2005)'s study was conducted with fMRI as well as ERPs. The fMRI data provided a neurofunctional interpretation of the N200 effect, mostly in terms of executive control. As discussed briefly in the previous chapter, the N200 is not specific to language but rather related to response inhibition in relation to executive control in general (Pfefferbaum et al., 1985; Thorpe et al., 1996). Modulation of the N200 in the study of language production therefore suggests that necessary information has become available to determine whether or not a response is to be given. As the N200 component only reflects the stages of processing in language production indirectly, there are limitations to interpretations built exclusively on such data:

First, in Rodriguez-Fornells et al. (2005)'s study, the N200 effect measured in the go trials started significantly earlier than that recorded in the nogo trials in the noncoincidence condition. From a cross-language activation point of view, there should be no difference between these two types of trials because both are in the noncoincidence condition in which the information of the nontarget language conflicts with that of the target language. The differences must have been elicited by factors influencing the dual-choice task per se, most likely, during the execution of response.

Therefore, a drawback of using the N200 component in the study of language processing is that it can be affected by language-irrelevant factors influencing response inhibition mechanisms.

Second, since the N200 effect manifests itself as a particular pattern of ERP waveforms elicited by a specific experimental paradigm, relying on this index masks the natural differences between the ERPs elicited in different language conditions. For example, Liu et al. (2003) contrasted Chinese to English in a delayed naming task. ERP modulations were compared at three time points: 150 ms, 250 ms, and 450 ms, suggesting differences and/or similarities across languages could rise at several stages of processing. The N200, which seem primarily a response-dependent component, might overlook the characteristics underlying the processing of various types of language information in different languages.

Third, another important aspect of the data that was underspecified in Rodriguez-Fornells et al. (2005)'s study concerns the direction of the cross-language phonological interference. In the experiment, bilingual participants named pictures in German and Spanish in alternate blocks. Significant N200 modulations were reported by comparing the noncoincidence to the coincidence condition in bilinguals. The contributions to this effect of the German and Spanish blocks, respectively, were unspecified. In other words, the authors did not discuss whether the cross-language interference is balanced, asymmetrical, or unidirectional. However, this issue was addressed in Guo et al. (2006)'s study of a group of less proficient Chinese-English bilinguals. ERPs were recorded when the participants performed a variant of the picture-word interference task in which the presentation of the picture which has to be named in one language is followed by a word in the other language. In half of the trials, the word is the translation of the picture's name. The cross-language identity (translation) effect was found in the form of a reduction in N400 amplitude suggesting parallel access to both languages. Critically, this effect was earlier and showed wider scalp distribution from L1 (nontarget language) to L2 (target language) than in the reverse direction. The asymmetry in the time course and magnitude of activation could be attributed to the relative dominance of the two languages. This finding joined the small but developing literature on cross-language influences in both directions during bilingual word processing (Van Hell & Dijkstra, 2002; Van Wijnendaele & Brysbaert, 2002), see also (Christoffels et al., 2007) for similar findings on the cognate facilitation effect and its interaction with language context and switching cost.

3. 3. Summary

This chapter selectively reviewed the use of ERPs in the study of bilingual language processing. Early studies (e.g., Ardal et al., 1990) directly contrasted ERPs of bilinguals to that of monolinguals using traditional experimental psychology paradigms (e.g., semantic priming) and have attributed the contrasts to bilinguals' levels of L2 proficiency and age of L2 acquisition. Other studies, discussed at greater length, tested specific predictions of psycholinguistic models, especially those built on the assumption of cross-language (parallel) activation in bilingual comprehension and production. While inconsistent results have been reported (e.g., De Bruijn et al., 2001; Rodriguez-Fornells, Rotte et al., 2002), discrepancies in the methodologies employed and the bilingual populations compared render comparisons between studies tentative.

As Dijkstra et al. (2006) have argued, cognitive neuroscience needs to be guided by theoretical views developed from an extensive body of research, based notably on behavioural observations. Here, I would like to argue that for neuroscientific studies to make significant contributions to psycholinguistic literature it is not enough to merely replicate empirical findings with advanced brain-imaging tools. Technological advantages should lead to innovations in research methods in a broad fashion. However, this brief review of ERP investigations of bilingualism suggests that there is still progress to be made. The majority of ERP studies have implemented the general paradigms used and criticised in previous behavioural investigations.

Another issue that is worth raising here again is that of the language mode hypothesis. The state of activation of a bilingual's languages may vary from one time to another depending on several exogenous linguistic and contextual variables. Therefore, claims regarding to the degree of L1 and L2 activations under particular experimental circumstances must be cautious, because awareness of the bilingual nature of the experiment does not only pre-activate both languages but may also trigger a range of strategies in the participants. I have discussed this issue regarding the use of interlingual stimuli (e.g., cognates) in chapter 2. Previous studies have shown that unconscious access to word information can be revealed using ERPs (Luck et al., 1996). It is therefore theoretically possible to test potential activations of one language while in a completely monolingual context involving only the other language (i.e., without participant awareness that the other language is involved). Unfortunately, the ERP studies reviewed in this chapter have not capitalised on this capacity of ERPs to index implicit information processing. Instead, the explicit use of cognates, translation equivalents, inter-lingual homographs and active switching between the two languages have inevitably created a dual-language context. As noted by Rodriguez-Fornells et al. (2005), "Anecdotally, most bilingual subjects reported that the nontarget language word "popped up" in their mind, making it hard for them to perform the present task" (p 427).

In sum, ERPs have opened a new window into bilingual language processing. The selective review of the literature presented here suggests that ERP studies need to be designed with the consideration of methodological limitations that have affected behavioural research in the past. Among others, the issue of dual-language activation appears to be the most inexorable. The design of the current research, takes particularly consideration of this fact.

Methods

The aim of this chapter is to describe the general approach of the current research and to explain its rationale. Although the present thesis reports three independent studies, they share in common several experimental parameters, including, the population from which the subjects have been drawn, the general procedure of the experiments, and the equipment that has been used. Therefore, instead of repeating this information for each study, a generic description is provided here. Furthermore, the same principles have guided the building of the design of all the studies reported here and the choice of experimental tasks, stimuli, and experimental factors. I feel that it is necessary to discus the benefits and compromises of the general logic at a purely methodological level before the actual findings are interpreted.

4. 1. Participants

All participants had normal or corrected-to-normal vision and self-reported normal hearing. They were controlled for age (18 to 25), handedness, and gender across experimental conditions. Every participant signed a consent form before taking part in the experiments that were approved by the ethics committee of the School of Psychology, Bangor University. The English monolingual participants were recruited from students taking a psychology undergraduate course at Bangor University and they received course credits for their participation. Bilingual participants were students doing either undergraduate or master courses at Bangor University and they were paid with money.

Each of the studies reported here involved an independent set of fifteen English monolinguals and fifteen English learners who speak Chinese Mandarin as their native and only other language. So far, a convention as to what factors should be taken into account when describing bilinguals has not been firmly established in the literature. Instead of trying to fit current participants into categories that were vaguely defined in previous studies, it might be more fruitful to develop an independent "profile" incorporating factors that are typically considered in bilingual research (i.e., 1, 2, 3 below) and those that are potentially important to the particular circumstances of the current studies (i.e., 4, 5 below).

1. Age of L2 acquisition: the Chinese-English bilinguals started L2 formal instruction at the age of puberty (e.g., 12 or 13). Therefore, they were "late bilinguals" or "adolescent bilinguals" in contrast to "early bilinguals" (i.e., individuals who started learning their second language in early childhood, Skutnabb-kangas, 1984). At the time of experiments, participants had an average of 10 years training in English in China and they have been living and studying in the UK for an average of 18 months.
2. Context of L2 acquisition: English (L2) was first acquired through an extensive period of systematic school training in China. As the result of this so-called "achieved bilingualism" (Adler, 1977), two characteristics need to be kept in mind: first, formal language teaching at school does not offer much opportunity to practice the language outside the classroom environment, which tends to restrict the development of L2 competence and the diversity of its use (see factor 4). Second, Chinese (L1) is heavily relied on when teaching English in Chinese schools. For example,

word-to-word translation equivalences are traditionally used to acquire new vocabulary in L2, rather than direct semantic mapping for instance.

3. Level of L2 proficiency: current experiments required a score of 6 or 6.5 in the International English Language Testing System (IELTS, http://www.ielts.org/candidates/findoutmore/article255.aspx), which is above the entrance requirement for overseas students in most UK institutions, as the main criterion for competence in L2. IELTS was chosen for three reasons. First, the test covers four main skills in language: listening, reading, speaking, and writing; therefore, it provides a multimodal measure of language ability. Second, as a conventional and independent test, it allows a better degree of comparability and potential replication in terms of L2 proficiency for further research, as compared to the use of self-developed evaluation. Third, since it is recognised by institutions in most English-speaking countries, using IELTS score as the measure of English proficiency increases the practical value of the current research. The drawback is that, because it is part of the University's entrance requirement, most participants have taken the IELTS test before they arrived in UK and their English can reasonably be expected to have improved significantly since. As a result, the IELTS score in the studies reported here should be considered a measure of minimal performance instead of an image of the current competence in English. For the same reason, Chinese-English bilinguals might be more appropriately referred to as "English learners" because they do not fall squarely into any specific categories of L2 proficiency.

4. Linguistic overlap between L1 and L2: unlike most European languages which resemble one another in several ways (e.g., orthography), Chinese and English are two radically distinct languages, differing in almost every aspect. Among others, the contrast in writing systems was exploited in one of the current studies to investigate the role of phonology and orthography in cross-language activation (see chapter 6): English uses a 24-letter alphabetic system which has a good, although not perfect, grapheme-to-phoneme correspondence. On the other hand, Chinese uses a monosyllabic logographic system which has no grapheme-to-phoneme correspondence. In other words, the relationship between writing and pronunciation is completely arbitrary in Chinese.
5. Biculturalism: language is always used within a cultural context. While native speakers can be expected to be familiar with the culture of their language, it is less clear to what extent bilinguals are acquainted with the culture of their L2, especially when it contrasts sharply with their native culture (which is the case of English and Chinese). Regarding the tasks and stimuli used in the current experiments, cultural differences are likely to affect relatedness judgments of particular word pairs (e.g., fish and chips are strongly associatively related in English but much less so in Chinese) or the prototypicality of objects (e.g., Chinese versus English teapot, cf. the visual stimuli in appendix 5).

4. 2. Design

The aim of the present thesis is to better understand bilingual language processing, specifically, the level and nature of L1 activation when words are being processed in L2. The first two studies addressed this question in the domain of word comprehension (i.e., reading and listening of single words). The third study examined word production based on picture naming. To ensure that semantic processing took place during reading and listening in studies 1 and 2, a semantic relatedness task was administered in which words are presented in pairs one after the other, and the participant has to decide whether or not the second word (target) is related in meaning to the first (prime) by pressing one of two designated keyboard keys.

The majority of previous research has used LDT as primary measurement of bilingual lexical processing. However, it is unclear what processes are actually involved during LDT, which is a meta-linguistic and therefore artificial task. As argued by Balota (1999), the demands of LDT might interrupt or at least interfere with normal reading or listening processes by placing the focus on lexicality rather than meaning. The semantic relatedness task used in the present studies arguably offered a more natural context for reading and listening comprehension in which access to word meaning is controlled and behaviourally monitored.

To test the hypothesis that L1 is activated during the processing of words in L2, a factor was manipulated in L1 while the experimental procedure was entirely conducted in L2 for bilingual participants. As Chinese and English have different basic writing scripts, interlingual homographs (cognates and false friends) do not exist between the two languages. Therefore, I was in a position to test potential activation of translation equivalences in L1 in the absence of form overlap. In the first experiment, half of the Chinese translations of English word pairs shared a Chinese character in common. This means that both the phonology and the orthography of the repeated character were identical in the Chinese translations of the two English words.

Character repetition in Chinese was built in as an implicit factor independent of the semantic relatedness factor, thus resulting in a 2 X 2design (see table 4-1).

Table 4-1. Design and examples of stimuli, study 1

	Semantic relatedness (explicit factor)	
Chinese character repetition (implicit factor)	Semantically Related (S+)	Semantically Unrelated (S-)
Repetition (R+)	Post – Mail ***You*** Zheng – ***You*** Jian **邮**件 — **邮**政	Train – Ham ***Huo*** Che – ***Huo*** Tui **火**腿 — **火**车
No Repetition (R-)	Love – Rose Ai Qing – Mei Gui 爱情 — 玫瑰	Apple – Table Ping Guo – Zhuo Zi 苹果 — 桌子

The second study adopted the same fundamental paradigm as the first study to tease apart the role of phonology and orthography in the access to L1 translations during L2 word comprehension. To tease apart phonological and orthographical access, the character repetition in Chinese translations was split into two categories: phonologically but not orthographically repeated character and vice versa. Therefore, study 2 featured four independent conditions (e.g., semantically related, phonologically related in Chinese, orthographically related in Chinese, and completely unrelated; see table 4-2).

Table 4-2. Design and examples of stimuli, study 2

Character repetition in Chinese (implicit)		Semantic relatedness (explicit)	
Phonological repetition (P)	Orthographic repetition (O)	Related (S)	Unrelated (U)
Factory – Princesses	Account – Meeting	Love – Rose	Apple – Table
Gong Chang – ***Gong*** Zhu	Kuai Ji – Hui Yi	Ai Qing – Mei Gui	Ping Guo – Zhuo Zi
工厂 — 公主	会计 — 会议	爱情 — 玫瑰	苹果 — 桌子

Note that, in the above examples (table 4-1 and table 4-2), bilingual participants were only presented with English word pairs rather than Chinese translations. The main benefit of this paradigm is that the manipulation in L1 is implicit. Considering the task (semantic relatedness judgements) and the radical contrasts between Chinese and English writing systems, bilingual participants were therefore tested in a genuine "all-in-L2" context. Therefore, any effects of the hidden character repetition in Chinese would suggest that access to L1 translations is a spontaneous, natural correlate of word processing in L2. To verify that potential effects of the hidden factor in L1 would indeed establish activation of L1 rather than reflect other properties of the stimuli that I might have failed to control for (see Materials), English monolinguals and Chinese monolinguals were included in the study as control groups. The English monolinguals were tested on the exact same task and with the same stimuli as the bilingual participants to ensure that character repetition in Chinese does not produce spurious, confounding semantic effect. The Chinese monolinguals[2] were tested on a Chinese version of the experiment and were

[2] The Chinese control participants were Chinese students doing a short-term English language course. They were tested shortly after the arrival in the UK when their English was very limited. Considering the worldwide popularity of English (especially in higher education), these Chinese beginners might define the contemporary status of "monolinguals".

expected to provide a baseline showing the effects of overt Chinese character repetition.

The third study examined bilingual word production based on essentially the same rationale as the comprehension studies, but using pairs of pictures rather than pairs of words. To ensure that participants would access the sound form of picture names, they were asked to indicate whether or not the names of the pictures displayed a phonological repetition. In the English condition, participants had to determine whether the English picture names rhymed and, in the Chinese task, they indicated whether or not a Chinese character was repeated. In a third task, serving as a baseline, participants were asked to make straightforward semantic relatedness judgments. Half of the picture names either rhymed in English or featured a character repetition in Chinese. Therefore, study 3 included four independent conditions overall (see Table 4-3). The English rhyming task and Chinese character repetition task examined potential cross-language activations in both directions. The semantic task was expected to comparatively test the issue of contingence/independence between extraction of semantic information and phonological encoding in bilinguals and monolinguals. Due to practical reasons, study 3 recruited only monolingual English participants as controls.

Table 4-3. Design and examples of stimuli, study 3

Phonological factor (implicit/explicit)		Semantic factor (explicit/explicit)	
Character repetition in Chinese (C)	Rhyming in English (E)	Related (S)	Unrelated (U)
Pen – Piano	B**ox** – F**ox**	Pencil– Eraser	Leaf – Hammer
Gang Bi – ***Gang*** Qin	He Zi – Hu Li	Qian Bi – Xiang Pi	Shu Ye – Chui Zi

4. 3. Stimuli

As reviewed previously, ERPs are sensitive to a number of linguistic variables at both lexical (i.e., single word) and sentence levels of processing. Careful selection and matching of the stimuli between conditions is therefore vital. Each experiment included a total number of 200 pairs of words or pictures, which were evenly distributed and matched across experimental conditions for lexical frequency and concreteness in English (Coltheart, 1981). English words were less than 11 letters in length, and average word and phoneme length was not significantly different between experimental conditions taken in pairs with the sole exception of study 1, in which the visual word length in the repeated character conditions was significantly longer than in the unrepeated conditions (P <0.001). Potential orthographic and/or phonological overlap in the English word pairs in the unrelated condition was not specifically controlled, and this potential confound might induce an unexpected repetition priming effect on some trials. Although the data from the English monolingual participants precluded this possibility in the current studies (see results in Chapter 5, 6, and 7), future studies are advisable to apply a more direct, pre-experimental control of English form overlap.

All Chinese translations were two-character in length and character repetition always occurred in the same position in the two stimuli of a pair (i.e., either the first or the second character was repeated). Given that Chinese has a monosyllabic writing system, the latter constraint lead to automatic control for the corresponding auditory stimuli. To check that semantic relatedness of word and picture pairs was matched between experimental conditions and to test the hypothesis that character repetition in Chinese would not significantly interfere with overt semantic relatedness evaluation, two independent groups of native Chinese and English speakers rated each of the stimulus pairs on a Lickert scale from 1 (unrelated) to 5 (strongly related; see Appendix 2 and 3). As can be seen in the table with other lexical features of the stimuli (see Appendix 4), differences in semantic relatedness ratings were highly significant between semantically related and unrelated pairs ($P < 0.0001$ for all pairwise comparisons). Moreover, there was no difference between conditions involving related pairs or between conditions involving unrelated pairs and, critically, there was no difference in semantic relatedness induced by Chinese character repetition irrespective of semantic links between stimuli ($P > 0.1$ for all pairwise comparisons). Picture stimuli were matched between condition for basic visual parameters (e.g., size, resolution, and background) across conditions. The variability in point of view, shape and colour of the objects presented was large in all the conditions, thus avoiding a systematic bias in terms of inter-stimulus perceptual variance (Thierry et al., 2007). Particular care was taken in the choice of pictorial representations for each target word such that they were not readily biased towards Chinese or English cultural prototypes (see examples in Appendix 5).

4. 4. Procedure

All experiments took place in a sound-proof laboratory where the participant sat on a comfortable armchair 1.5 meter away from a computer screen. After signing the consent form (see Appendix 1) and receiving the instruction, participants viewed two blocks of stimuli presented in a pseudo-randomized order. In studies 1 and 2, each trial began with a pre-stimulus interval of 200 ms. In the reading experiment, a first word was then flashed for 500 ms at fixation followed by the second word of a pair after a variable interstimulus interval of 500, 600, or 700 ms. In the listening experiment, participants heard digitized words pronounced by a native female speaker of English or Chinese. Prime words were presented within a 1000-ms time window followed by a target word after a variable interval of 500, 600, or 700 ms. No word was repeated in either of the studies. Participants were instructed to indicate whether the second word of each pair was related in meaning to the first by pressing keys with left or right index finger (yes versus no). Response sides were fully counterbalanced between blocks and participants. The picture-naming study followed the same procedure as study 1 and 2 except that stimuli were presented with longer inter-stimulus-intervals[3] (i.e., 600, 700, and 800 ms). In study three, experiment order was purposefully not counter-balanced as it was in studies 1 and 2. The semantic task was administered to all participants first, to avoid drawing their attention to phonological links between picture names and obtain a baseline. Then, bilingual participants performed the Chinese and English task in a counterbalanced order. Naturally, English monolingual participants were only given the rhyming task in English. All participants were debriefed orally.

4. 5. ERP Recording

Electrophysiological data were recorded in reference to Cz at a rate of 1 kHz from 64 Ag/AgCl electrodes placed according to the extended 10–20 convention. Impedances were kept-5 kΩ. Electroencephalogram activity was filtered on-line band pass between 0.1 and 200 Hz and refiltered off-line with a 25-Hz, low-pass, zero-phase shift digital filter. Eye blinks were mathematically corrected, and remaining artefacts were manually dismissed. There was a minimum of 30 valid epochs per condition in every subject: after all artefact rejections, early perceptual components (e.g., N1 and

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[3] The current experiment did not include a "familiarisation" procedure in which participants were trained with the desired names of pictures in advance. Although, as a common practice in similar studies, it helps to reduce error rate and increases the reliability of the data, ERPs are particularly sensitive to effects of episodic memory, thus I preferred to take the risk that unexpected names would be generated.

P2) are identifiable on most channels. Epochs ranged from -100 to 1,000 ms after the onset of the second word. Baseline correction was performed in reference to pre-stimulus activity, and individual averages were digitally re-referenced to the global average reference. ERP data were collected simultaneously to behavioural data.

4. 6. ERP Data Analysis

Peak detection was carried out automatically, time-locked to the latency of the peak at the electrode of maximal amplitude on the grand-average ERP. Temporal windows for peak detection were determined based on variations of the Global Field Power measured across the scalp (Picton, 2000). Peak amplitudes were subjected to a repeated measures ANOVA with experimental conditions (e.g., semantic relatedness and character repetition in Exp 1; semantic, orthographical, and phonological relatedness in Exp 2) and electrode (63 levels) as factors using a Greenhouse-Geisser correction where applicable. Pairwise differences between conditions were considered significant when differences were above threshold (p <0.01) for longer than 30 ms over a minimum of three clustered electrodes (Thierry et al., 1998; Thierry et al., 2003). Topographical analyses were based on mean amplitudes measured over 63 electrodes distributed over the entire scalp. Between-group comparisons involved calculating main-effect contrasts (e.g., semantic effect versus Chinese character repetition in Exp 1) and differences in mean amplitudes were entered into a between-subject repeated measure ANOVA with 63 levels of electrodes. Interactions involving the electrode factor were controlled by using within condition vector normalization (McCarthy & Wood, 1985). Every participant qualifies a number of errors and RTs within 2 standard deviations from the mean, and statistics are performed on correct trials only.

Study 1: Native Lexicon Access While Reading and Listening to a Second Language

5. 1. Predictions

The current study tested cross-language activations in a highly constrained experimental context in which automatic processes were expected to occur. In a semantic priming paradigm, character repetition in bilinguals' L1 translations was manipulated implicitly while the semantic relatedness task was performed in L2 exclusively (see Method section). Empirical studies have mainly reported facilitative effects associated with translation equivalents in bilingual's L1 in a variety of experimental conditions (e.g., Gollan et al., 1997; Grainger & Frenck-Mestre, 1998) and independently of semantic priming effects (Basnight-Brown & Altarriba, 2007). Based on these findings, we reasoned that, if cross-language activation of L1 translations was a natural correlate of L2 word comprehension, character repetition in Chinese translations would result in a main effect of facilitation in the form of reduced reaction times (RT) and error rates (ER). With regard to ERPs, the implicit manipulation in L1 was expected to be associated with modulations in the N400 range which have been shown to index semantic integration processes (Kutas & Hillyard, 1980, 1984) and unconscious priming (Kutas & Federmeier, 2000; Luck et al., 1996) also see Chapter 2 for a review.

Previous studies on brain-injured patients with semantic deficits have shown superior performance on the reading aloud test over comprehension test on disyllabic words. This demonstrated the existence of whole-word phonological representation for two-character Chinese words (Law et al., 2006). As the case in the current study, the overlap in one Chinese character forms partial form repetition between two words.

According to the spreading activation account of the N400 effect, which has been supported widely by recent studies using masked priming paradigm (Misra & Holcomb, 2003; Holcomb et al., 2005), repetition priming reduces the amplitude of the N400 without conscious perception of the stimuli or the repetition relationship. We expect that partial repetition in two-character Chinese words would produce an effect to the same direction.

The effects found in bilingual participants should overall be similar to those observed in monolingual Chinese participants if they indeed reflect access to L1. However, considering that the Chinese controls were tested with the Chinese version of the experiment, overall better (e.g., faster response and fewer errors) behavioural performances and discrepancies in ERPs related to the physical aspects of word processing should be expected. The monolingual English participants, on the other hand, were expected to show a semantic priming effect exclusively. Typically, this should also be associated with reduced RT and ER behaviourally (Meyer & Schvaneveldt, 1971; Neely, 1991) and a reduction in the amplitude of N400 (Bentin et al., 1985). Since the auditory experiments were regarded primarily as replications of the visual experiments, the above hypotheses were also valid for the auditory experiments.

5. 2. Behavioural results

In the reading experiment, as expected, English participants responded faster to semantically related than to unrelated word pairs ($F_{1,14} = 32.2$, $P < 0.001$; Fig. 5-1 left) and showed no effect of concealed Chinese character repetition ($F_{1,14} = 1.9$, $P >$ 0.1). Error rates were unaffected by semantic relatedness ($F_{1,14} = 1.7$, $P > 0.1$) or Chinese character repetition ($F_{1,14} = 0.7$, $P > 0.1$). The same overall pattern of performance was found in the Chinese-English bilingual participants (Fig. 5-1 middle). Semantically related word pairs were responded to faster than semantically unrelated word pairs ($F_{1,14} = 28.4$, $P < 0.001$) and no effect of Chinese character repetition was found ($F_{1,14} = 0.2$, $P > 0.1$). Similarly, error rates were not significantly affected by either factor (semantic relatedness, $F_{1,14} = 2.2$, $P > 0.1$; Chinese character repetition, $F_{1,14} = 3.6$, $P = 0.08$). In the Chinese monolingual participants reading Chinese translations of the English words, semantically related word pairs were responded to faster than semantically unrelated word pairs ($F_{1,14} = 10.4$, $P < 0.001$). However, there was a significant interaction between semantic relatedness and Chinese character repetition for both reaction times ($F_{1,14} = 20.6$, $P < 0.001$) and error rates ($F_{1,14} = 11.6$, $P < 0.01$). Post hoc pairwise comparisons showed that semantically unrelated words sharing a Chinese character (condition highlighted in red on Fig. 5-1 right) yielded significantly longer reaction time and higher error rates than all other conditions (all $P < 0.01$).

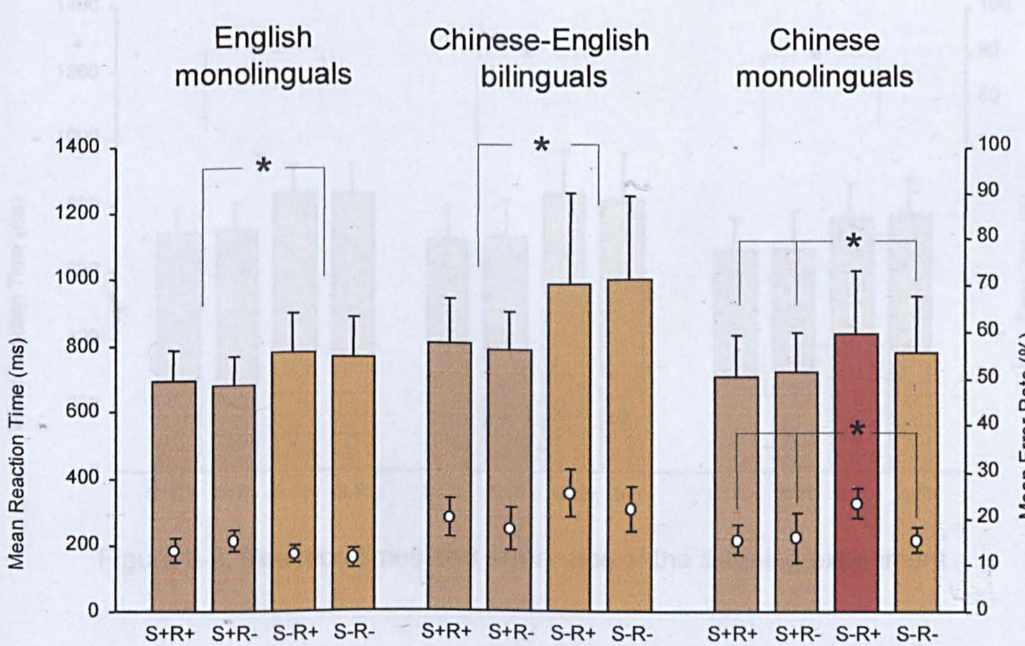

Figure 5-1. Reaction times and error rates in the reading experiment[4]

[4] The bars represent reaction times with reference to the left axis and the bullets represent error rates with reference to the right axis. Conditions in which the word pairs were semantically related or unrelated are labelled S+/S-, respectively. Conditions in which one Chinese character was repeated or

In the listening experiment, the same overall pattern of behavioural performance was found in the English monolinguals and the Chinese-English bilinguals (Fig. 5-2 left and middle); typical semantic priming effects were observed with significantly shorter reaction times for semantically related as compared to semantically unrelated conditions (all $P < 0.001$). In Chinese monolinguals, there was a main effect of semantic relatedness on error rates ($F_{1,14} = 4.88$, $P < 0.05$) and reaction times ($F_{1,14} = 35.1$, $P < 0.001$), such that semantic relatedness increased error rates and decreased reaction times (Fig. 5-2 right). The interaction between semantic relatedness and Chinese character repetition that appeared in the reading experiment was, however, not found in the listening experiment.

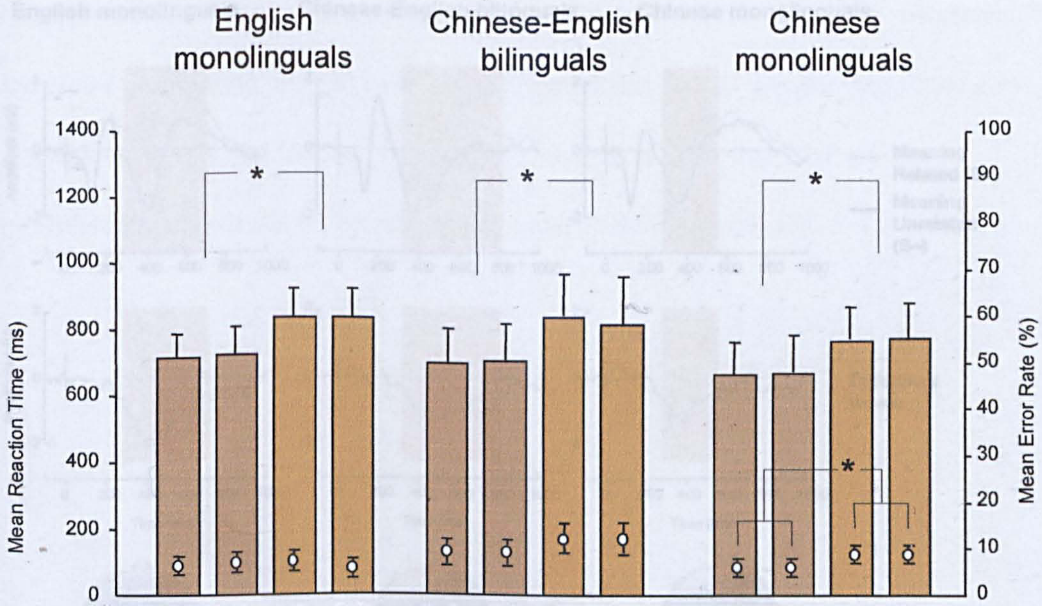

Figure 5-2. Reaction times and error rates of the listening experiment

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not repeated are labeled R+/R-, respectively. Stars indicate significant differences (P < 0.05). Error bars depict standard deviation in all cases.

5. 3. ERP results

In the reading experiment, all three groups of participants showed a N400 effect in response to the semantic relatedness factor. In English monolinguals, semantic relatedness reduced ERP mean amplitude significantly between 350 and 500 ms ($F_{1,14} = 89$, $P < 0.0001$), which is the N400 component typical window (Kutas & Hillyard, 1980, 1984). In Chinese-English bilinguals, the main effect of semantic relatedness ($F_{1,14} = 12.2$, $P < 0.004$) was significantly smaller in magnitude than that found in English monolinguals ($F_{1,14} = 14.79$, $P < 0.001$). The same effect was found in Chinese monolinguals who read Chinese translations of the English stimuli ($F_{1,14} = 23.5$, $P < 0.0001$), except that differences lasted for a shorter period as compared to English monolinguals and Chinese-English bilinguals.

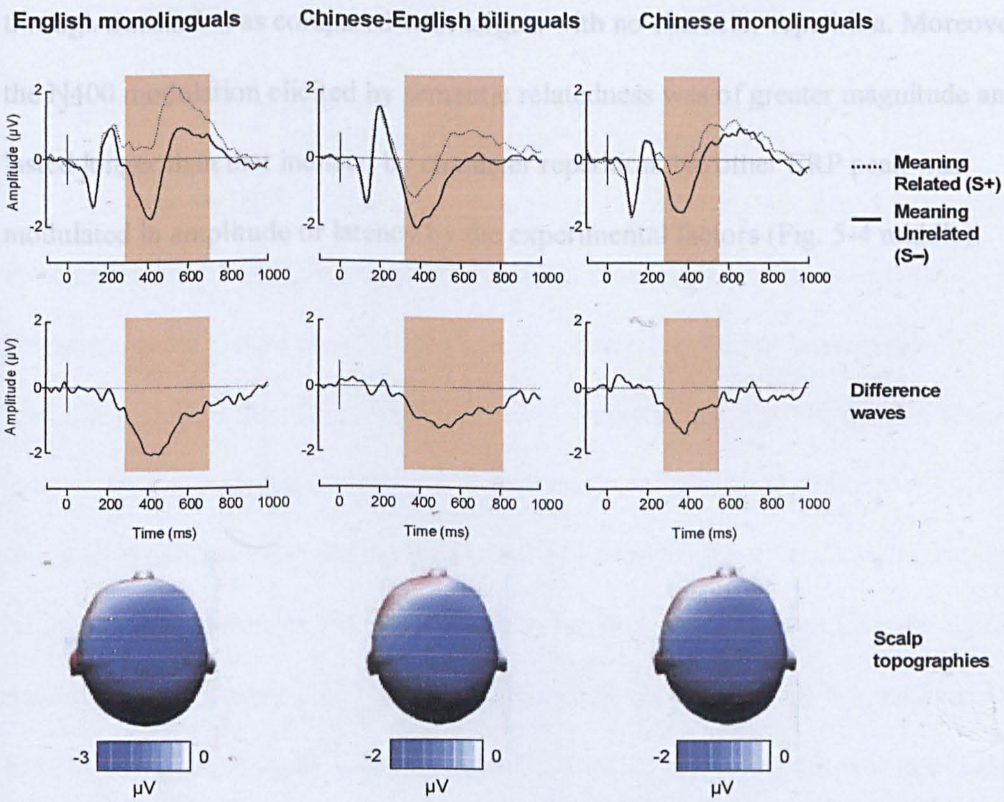

Figure 5-3. ERP results in the reading experiments for the semantically related and semantically unrelated conditions[5]

[5] All waveforms reported in this experiment depict brain potential variations in the linear derivation of a group of nine electrodes centered on Cz where the N400 component is typically maximal (FC1, FC2,

The repeated character condition differed from the unrepeated character condition between 30 and 90 ms in English monolinguals and Chinese-English bilinguals but not in Chinese monolinguals (Fig. 5-4 blue boxes). Apart from this effect, hidden Chinese character repetition had no effect in the N400 range in English monolinguals ($F_{1,14} = 1.89$, $P > 0.1$), and no other amplitude modulation was found on any other ERP components in this group (Fig. 5-4 left). Critically, Chinese-English bilinguals showed a main effect of hidden Chinese character repetition ($F_{1,14} = 8.3$, $P < 0.01$), which did not interact with the semantic effect ($F_{1,14} = 0.18$, $P > 0.1$). The two effects were independent and parallel in terms of directions of priming: mean N400 amplitude was reduced for semantically related targets as compared with unrelated targets and for targets that shared a Chinese character with the prime through translation as compared with targets with no character repetition. Moreover, the N400 modulation elicited by semantic relatedness was of greater magnitude and lasted longer than that induced by character repetition. No other ERP peak was modulated in amplitude or latency by the experimental factors (Fig. 5-4 middle).

FCz, C1, C2, Cz, CP1, CP2, CPz). Orange boxes indicate the duration of significant differences elicited by semantic relatedness in the N400 range. The difference waveforms presented on the bottom are the results of subtracting semantically related from semantically unrelated waveforms.

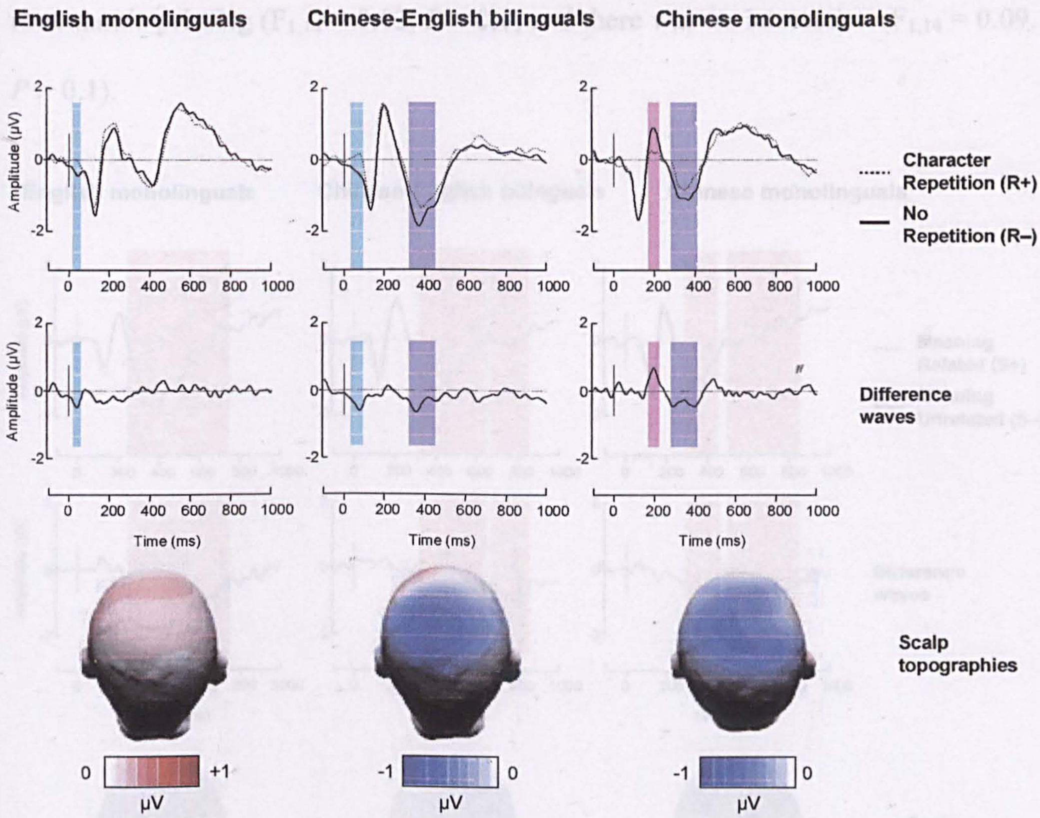

Figure 5-4. ERP results in the reading experiments for the Chinese character repetition and no repetition conditions[6]

In Chinese monolinguals, the same pattern of priming was found as was seen in bilinguals (Fig. 5-4 right). Overt Chinese character repetition reduced ERP amplitude in the N400 range ($F_{1,14} = 5.13$, $P < 0.04$), but did not interact with the semantic priming effect ($F_{1,14} = 0.53$, $P > 0.1$). Interestingly, the N400 modulation induced by semantic relatedness was greater and more durable than that elicited by character repetition, reproducing the pattern of variations found in Chinese-English bilinguals. In addition, in this group we found a main effect of overt Chinese character repetition on the amplitude of the P2 component ($F_{1,14} = 8.1$, $P < 0.02$), between 150 and 200 ms. The P2 was reduced by character repetition priming but was insensitive

[6] The pink boxes indicate significant differences elicited by form repetition in the P2 range whereas the purple boxes indicate its effect in the N400 range. Early perceptual variations attributed to differences in word length are highlighted in blue. Note that the latter do not perseverate into the N1/P2 window. The difference waveforms are the results of subtracting repeated character from unrepeated character waveforms.

to semantic priming ($F_{1,14} = 0.02$, $P > 0.1$) and there was no interaction ($F_{1,14} = 0.09$, $P > 0.1$).

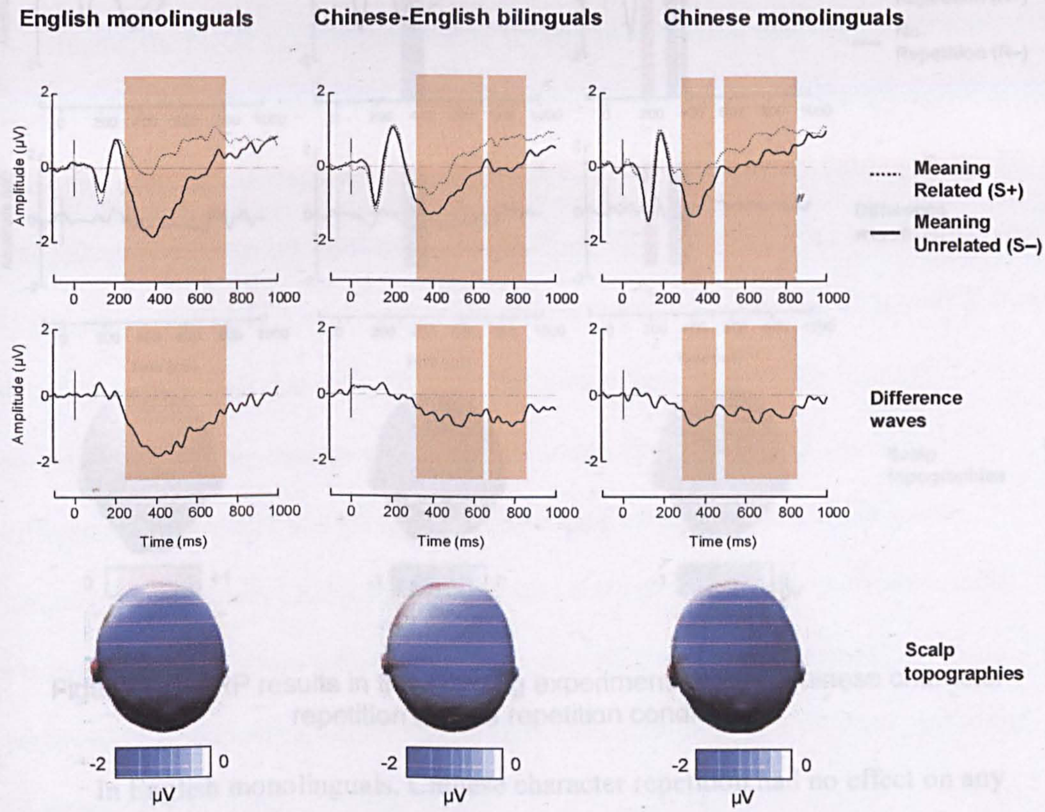

Figure 5-5. ERP results in the listening experiments for the semantically related and semantically unrelated conditions[7]

In the listening experiment, ERP effects overall replicated those found in the reading experiment. The N400 effects for semantic relatedness again appeared in all three groups of participants: English monolinguals ($F_{1,14} = 24.3$, $P < 0.0001$), Chinese-English bilinguals ($F_{1,14} = 19.3$, $P < 0.0001$), and Chinese monolinguals ($F_{1,14} = 20.5$, $P < 0.0001$). However, it is noticeable that the semantic effects in the listening experiment had a more extended time course (slightly earlier onset and longer duration) as compared to those in the reading experiment, consistent with the characteristics of N400 effect in the auditory modality (Holcomb & Neville, 1990).

[7] All depictions used in this figure are the same as those used in figure 5-3.

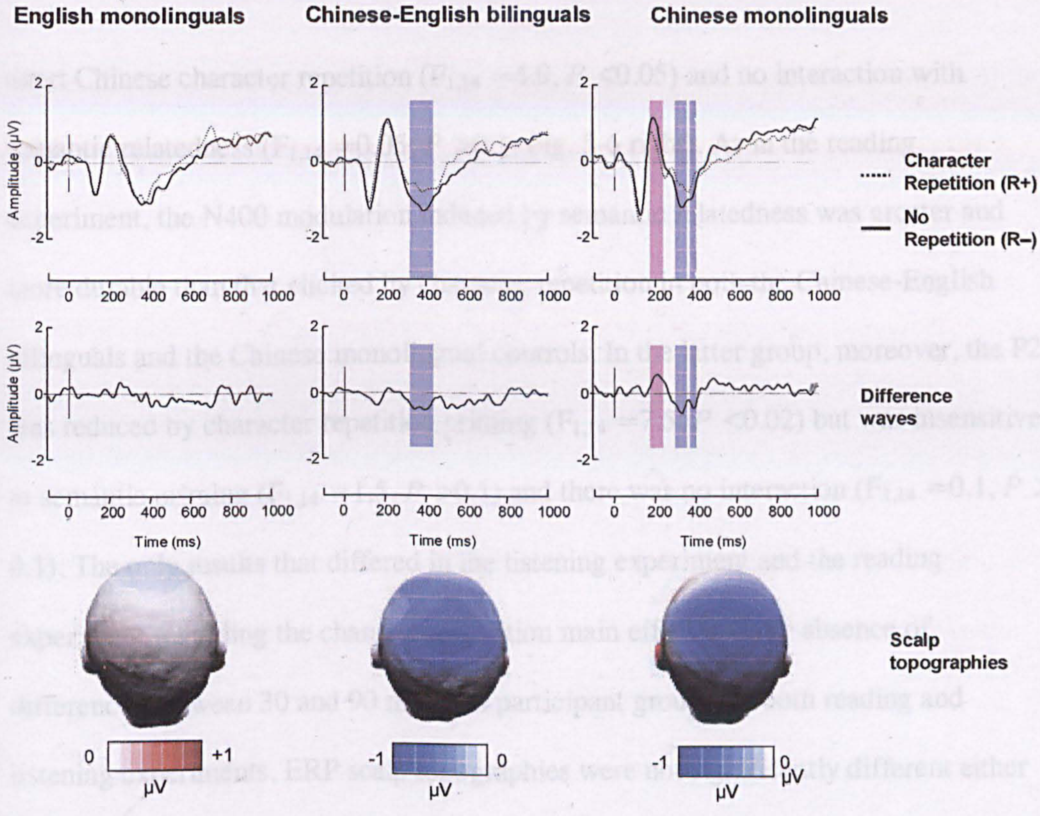

Figure 5-6. ERP results in the listening experiments for the Chinese character repetition and no repetition conditions[8]

In English monolinguals, Chinese character repetition had no effect on any ERP components ($F_{1,14} = 0.33$, $P > 0.1$); neither was there an interaction between Chinese character repetition and semantic relatedness in this group ($F_{1,14} = 0$, $P > 0.1$; Fig. 5-6 left). In Chinese-English bilinguals, there was a main effect of Chinese character repetition ($F_{1,14} = 5.2$, $P < 0.05$) in the absence of an interaction with semantic relatedness ($F_{1,14} = 0.3$, $P > 0.1$; Fig. 5-6 middle). The direction of the effect of implicit character repetition in Chinese was also consistent with that of the visual experiment, in which N400 amplitude was reduced significantly in the repeated condition as compared to the unrepeated condition.

In Chinese monolinguals who listened to Chinese translations, the pattern of differences was comparable with those of Chinese-English bilinguals: priming by

[8] All depictions used in this figure are the same as those used in fig 5-4.

overt Chinese character repetition ($F_{1,14}$ =4.9, P <0.05) and no interaction with semantic relatedness ($F_{1,14}$ =0.05, P >0.1; Fig. 5-6 right). As in the reading experiment, the N400 modulation induced by semantic relatedness was greater and more durable than that elicited by character repetition in both the Chinese-English bilinguals and the Chinese monolingual controls. In the latter group, moreover, the P2 was reduced by character repetition priming ($F_{1,14}$ =7.5, P <0.02) but was insensitive to semantic priming ($F_{1,14}$ =1.5, P >0.1) and there was no interaction ($F_{1,14}$ =0.1, P > 0.1). The only results that differed in the listening experiment and the reading experiment regarding the character repetition main effect was the absence of differences between 30 and 90 ms in all participant groups. In both reading and listening experiments, ERP scalp topographies were not significantly different either between the three groups with regard to the semantic relatedness main effect or between the Chinese-English bilinguals and Chinese monolinguals with regard to the Chinese character repetition main effect.

5. 4. Discussion

The purpose of this study was to investigate the hypothesis of cross-language activation during bilingual word comprehension (i.e., reading and listening to single words). This was tested by using an implicit priming paradigm where, in the critical condition, Chinese translations of English word pairs shared a Chinese character in common. Despite the absence of any measurable effect of the concealed Chinese character repetition on the behavioural performance of bilingual participants, this hidden factor modulated ERPs, just as it did in monolingual Chinese controls overtly exposed to character repetition in Chinese.

The character repetition priming was indexed by an amplitude reduction of the N400 component, which is known to be sensitive to overt (Kutas & Hillyard, 1980, 1984) and unconscious (Luck et al., 1996) semantic priming and as well as to repetition priming (Liu et al., 2003; Osterhout & Holcomb, 1995). This N400 effect, correlated with character repetition, could only be explained by activation of Chinese translations in bilinguals for several reasons:

First, semantic relatedness and character repetition were built in the experiment as independent factors (Table 4-1); the findings of independent main effects of semantic and repetition priming in the current experiment were consistent with previous studies using English words (Rugg, 1985, 1987).

Second, all participants showed the well-established N400 modulation by semantic priming, whether words were presented in their first or their second language. It is noteworthy, however, that the magnitude of the N400 modulation was larger in English monolinguals than in Chinese-English bilinguals, even though the two groups of participants read the same words. Such observations have been made previously (Ardal et al., 1990; Hahne, 2001; Kutas & Kluender, 1991) and can be related to the relative efficiency of semantic access in first and second languages, respectively. Critically, the fact that English monolinguals only showed an N400 modulation by semantic relatedness confirms that the N400 modulation by Chinese character repetition seen in the bilinguals was not caused either by spurious, confounding semantic effects or variables in the processing of word forms (see the early effects below) since both groups read English words, but was genuinely induced by implicit character repetition priming.

Third, the pattern of semantic relatedness and character repetition priming seen in bilinguals was remarkably similar to that found in Chinese monolinguals reading Chinese translations. In particular, both groups of Chinese participants displayed large N400 modulations by semantic priming and smaller, less durable N400 modulations by character repetition, whether the latter was implicit (Chinese-English bilinguals) or overtly perceived (Chinese monolinguals). This pattern is consistent with previous reports of weaker variations in the N400 range elicited by orthographic and/or phonological overlap between words as compared to semantic relationships (Perrin & Garcia-Larrea, 2003; Rugg & Barrett, 1987). Moreover, the character repetition effect was of similar amplitude in Chinese-English bilinguals and Chinese monolinguals, which again suggests that the two effects reflected a similar mechanism.

Lastly, the character repetition effect was found in both a reading and a listening task, i.e., it was modality-independent. Note, however, that this effect need not be symmetrical, i.e., effects of second-language knowledge on first-language processing are likely to be weaker (Van Hell & Dijkstra, 2002; Van Wijnendaele & Brysbaert, 2002). In this thesis, the issue of L2-L1 effect was investigated with the picture-naming experiment (see Chapter 7).

Our previous attempt to identify spontaneous translation effects failed to show Chinese activation in the absence of interference with semantic processing in English (Thierry & Wu, 2004). We see two reasons that the independence of the two factors described here was never shown before to our knowledge. First, word concreteness was not controlled and post hoc comparisons of available concreteness ratings (Coltheart, 1981) for the stimuli used at the time revealed significant differences between conditions. Second, the Chinese translations of the previous stimulus set were one to three Chinese characters in length, and the repeated character was not systematically positioned at the same place in the translations. The first issue might have affected the route by which bilingual participants accessed the meaning of English words in the different conditions (De Groot, 1992; Paivio et al., 1988; Paivio & Desrochers, 1980). Moreover, word concreteness is known to affect the amplitude of the N400, such that concrete words tend to elicit greater N400 amplitudes than abstract words (Kounios & Holcomb, 1994; West & Holcomb, 2000). In sum, uncontrolled concreteness effects probably introduced noise into the response pattern of monolingual English controls and not necessarily with the same effect and to the same extent as in Chinese–English bilinguals. The second issue is likely to reduce repetition priming because no systematic unconscious template can be formed in which to expect character repetition to occur. In addition, the degree to which repetition priming is reduced need not be the same for semantically related and unrelated conditions.

In the present experiment, conditions were matched for (i) lexical frequency and concreteness between conditions, (ii) translations systematically involved two Chinese characters, (iii) character repetition consistently appeared at the same position within Chinese translations of each word pair (see Stimuli, Chapter 4), and, critically, (iv) we also tested a control group of 15 Chinese monolinguals presented with the Chinese translations of the English material. The parallel results obtained for Chinese-English bilinguals and Chinese monolingual controls strongly support the conclusion that the mechanisms operating explicitly in monolinguals and implicitly in the bilinguals are analogous. This conclusion is further supported by the English monolingual controls and overall replication in the auditory modality.

We also found ERP and behavioural effects that appeared in the monolingual control groups, which were less directly related to the main conclusion of cross-language activations, but were still informative regarding the nature of the

L1→L2 effects observed in bilinguals. Because Chinese monolingual participants actually saw or heard the repeated Chinese characters, we expected to see some early orthographic and/or phonological priming effect of Chinese character repetition in these groups. Indeed, the P2 component sensitive to perceptual priming (Liu et al., 2003; van Schie et al., 2003) was significantly reduced when a Chinese character was repeated but was unaffected by semantic relatedness (Figs. 5-4 and 5-6). This P2 modulation, which preceded the N400 effect by at least 100 ms, was seen in neither Chinese-English bilinguals nor English monolinguals. The absence of a priming effect before the N400 window in bilinguals suggests that translation took place at a late, possibly post-lexical processing stage. Indeed, since the character repetition effect had the same time course as the semantic effect in bilinguals, Chinese translation is likely to have happened during or after word meanings have been accessed from English forms.

The only measurable effect of Chinese character repetition in the behavioural data was found in the reading experiment in Chinese monolingual participants, who were explicitly aware of the repetition. Reaction time and error rate were both significantly greater when the second word of a pair shared a Chinese character but was unrelated in meaning to the first (S-R+). Here, the conflict may have arisen in semantically unrelated pairs that share a Chinese character because the repetition implicitly hinted at a semantic link that was not actually present. The absence of such a behavioural effect in the bilingual participants further supports the view that first language activation was induced at a post-lexical stage of processing, where semantic access was achieved through English words. In the listening experiment, however, the S-R+condition did not yield longer reaction times or greater error rates than the S-R- condition. There are two possible explanations for this result. When words were presented auditorily, (i) the repeated characters were temporally further apart than when words were presented visually, and (ii) characters were perceived phonologically whereas their visual form was likely to activate both orthographic and phonological representations.

It is worth mentioning that, interestingly, while all the evidence discussed above pointed to a late stage of processing, the activation of translation equivalents was nevertheless unconscious because, at debriefing, none of the bilingual participants reported being aware of the hidden factor when questioned about the English words presented. To our knowledge, it is the first time that, when questioned, bilingual participants reported being unaware of the cross-language experimental factor as compared to previous experiments overtly using interlingual stimuli (e.g., homographs and cognates) rather than covert translation equivalents. Taking together the time-course of the character repetition effect in ERPs and the absence of awareness on the part of the participants, it may be concluded that the post-lexical translations into L1 is a spontaneous correlate of processing words in L2, even though it may not be required for accessing L2 word meanings.

One peculiarity of the reading experiment data was the finding of significant differences between 30 and 90 ms between the R+and R- conditions in the English monolinguals and the Chinese-English bilinguals (Fig. 5-4 left and middle). We interpret this difference as a consequence of word length differences between conditions (see Stimuli in Chapter 4) because such differences (i) have been found to elicit ERP modulations within 100 ms of stimulus onset (Assadollahi & Pulvermuller, 2003; Hauk et al., 2006; Hauk & Pulvermuller, 2004), (ii) were significant in both Chinese-English bilinguals and English monolinguals who were exposed to the same stimuli, (iii) were not found in the Chinese monolinguals who read Chinese translations of equal length in all conditions, (iv) were not found in comparisons between S+and S- conditions, which did not differ with respect to average stimulus word length, and (v) did not persist beyond 100 ms in either the Chinese-English bilinguals or the English monolinguals. Critically, these early differences did not affect the N1/P2 complex and therefore cannot account for significant main effects of character repetition later seen in the N400 time window. Finally, it is noteworthy that such early differences were not seen at all in any of the groups in the listening experiment, and yet a clear N400 effect was also seen for character repetition in that experiment. We also note that the waveform structure in the semantically related condition differed between English monolinguals and Chinese-English bilinguals. This difference may be accounted for by partial overlap with P300-type activity peaking 600 ms in the case of lexical-semantic tasks and associated with target detection in English monolinguals (Polich, 1993).

In conclusion, the present study makes a direct observation of spontaneous lexical activation of the native language in a context involving only second-language stimuli, instead of a mix of spoken or written words from the two languages, requiring overt switching between languages. Electrophysiological results revealed an automatic translation process in late fluent bilinguals that could not be detected with traditional behavioural measures. In fact, although we found no evidence of pre-lexical access to native translations when bilinguals read or listen to words in their second language, the post-lexical translation mechanism revealed by the N400 reduction appears to be totally automatic and unconscious. This result suggests that native-language activation operates in everyday second-language use, in the absence of awareness on the part of the bilingual speaker. In the general discussion (Chapter

8), these findings will be discussed in relation to the broad literature of psycholinguistic models and other bilingual research.

Study 2: Phonological Mediation in Cross-language Interaction

6. 1. Predictions

Experiment 1 demonstrated that even when bilinguals read and listen to words exclusively in their L2, they cannot avoid activating lexical information of L1 unconsciously. Although this finding is consistent with a number of previous studies showing cross-language interactions, it does not specify the nature of the lexical information accessed in L1 (i.e., phonology and/or orthography). As reviewed in previous chapters, most research on bilingual word recognition has focused on orthographic forms shared between languages (e.g., interlingual homographs, for exceptions see Brysbaert et al., 1999 ; Dijkstra et al., 1999), whereas cross-language phonological interference has been mostly examined in language production (e.g., D Jared & Kroll, 2001; D Jared & Szucs, 2002). However, as suggested by research in the monolinguals, phonology plays a critical and potentially different role in word recognition from that of orthography (Frost, 1998). It is, therefore, important to investigate the independent contributions of the two factors in the bilingual context.

The goal of the experiment presented in this Chapter is to extend the findings of spontaneous access to L1 translations in Chinese-English bilinguals by teasing apart phonological from orthographic activation. Here, character repetition in Chinese was subdivided into two independent conditions: phonological repetition (P) and orthographic repetition (O). If cross-language access to L1 is phonologically based, the effects of character repetition in experiment 1 should be replicated in the phonological priming condition of the present experiment. On the other hand, if the character repetition effect is due to access to the orthographic codes in L1, findings comparable to experiment 1 should be obtained in the orthographic priming condition.

The third possibility is that both phonology and orthography are activated in L1, in which case priming is expected to occur in both conditions. Finally, there is also a possibility that cross-language activation requires the combined contribution of both phonological and orthographic overlap to be significant in the present experimental paradigm. According to this fourth hypothesis, manipulating the two factors separately would abolish the repetition priming effect. Apart from this, the semantic priming effect was expected to provide a baseline comparison for potential phonological and/or orthographic effects in Chinese.

6. 2. Behavioural results

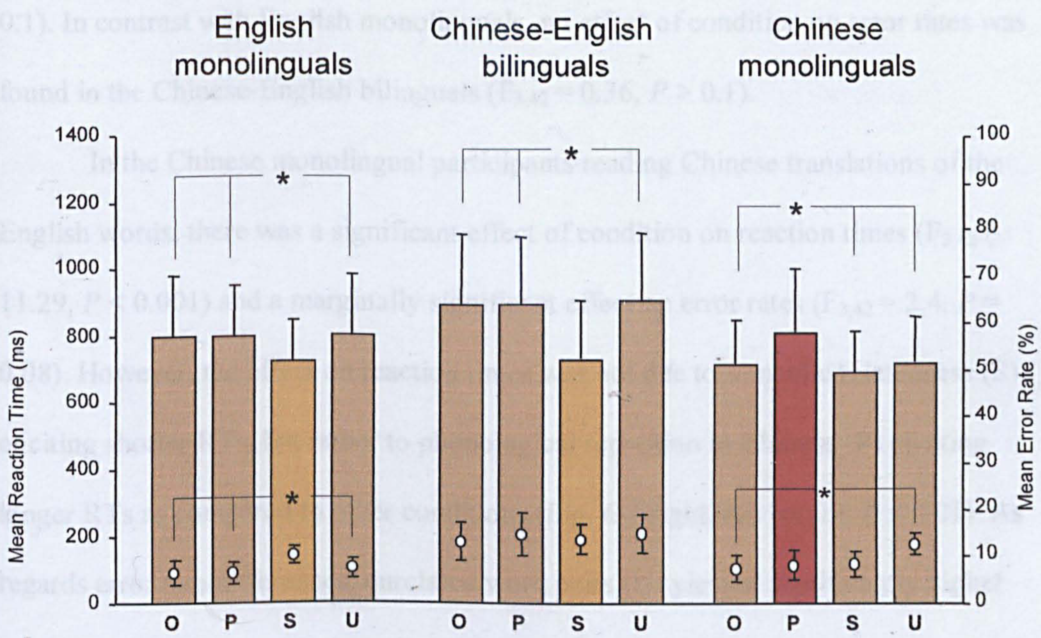

Figure 6-1. Reaction times and error rates of the reading experiment[9]

In the reading experiment, a significant main effect of condition was found in the English monolinguals on both the reaction times ($F_{3,42} = 3.33$, $P < 0.05$) and the

[9] Figures in the current experiment adopt the same depictions and displays that were used in experiment 2, except for the following labels: O (orthographic repetition in Chinese translations), P (phonological repetition in Chinese translations), S (semantically related), and U (unrelated).

error rates ($F_{3,42} = 6.75$, $P < 0.001$). Post hoc analysis (LSD) showed that semantically related word pairs (S) were responded to faster than semantically unrelated word pairs (O, P, and U; all $P < 0.05$). No effect of Chinese character repetition was found in this group whether phonology- or orthography-based (all $P > 0.1$). Unexpectedly, the effect on error rates was due to an increase of the proportion of error for semantically related word pairs as compared to other conditions (all $P < 0.05$). The same pattern of reaction time effe ts ($F_{3,42} = 18.38$, $P < 0.001$) was found in the Chinese-English bilingual participants: Semantically related word pairs were responded to faster than semantically unrelated word pairs (all $P < 0.001$) and there were no effects of phonological or orthographic repetitions concealed in Chinese translations (all $P > 0.1$). In contrast with English monolinguals, no effect of condition on error rates was found in the Chinese-English bilinguals ($F_{3,42} = 0.36$, $P > 0.1$).

In the Chinese monolingual participants reading Chinese translations of the English words, there was a significant effect of condition on reaction times ($F_{3,42} = 11.29$, $P < 0.001$) and a marginally significant effect on error rates ($F_{3,42} = 2.4$, $P = 0.08$). However, the effect on reaction times was not due to semantic relatedness (S) eliciting shorter RTs, but rather to phonological repetition in Chinese (P) eliciting longer RTs as compared to other conditions (Fig. 6-1 right, red bar; all $P < 0.01$). As regards error rate differences, unrelated word pairs (U) yielded significantly higher error rates than word pairs featuring orthographic repetition in Chinese (O; $P < 0.05$) and no other difference was significant (all $Ps > 0.1$).

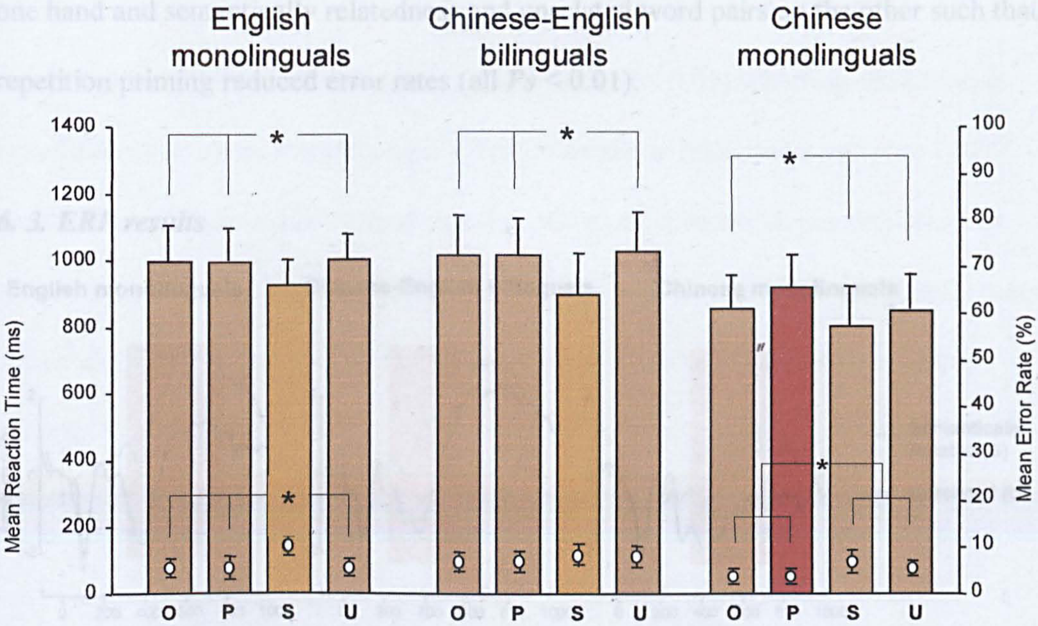

Figure 6-2. Reaction times and error rates of the listening experiment

The same overall pattern of behavioural performance as in the reading experiment was found in the listening experiment. English monolinguals ($F_{3,42} = 9.02$, $P < 0.001$) and Chinese-English bilinguals ($F_{3,42} = 23.98$, $P < 0.001$) both displayed the typical semantic priming effects on reaction times (all $P < 0.01$). No effects of Chinese character repetition were seen in either group (all $P > 0.1$). The effect on error rates in the English monolinguals ($F_{3,42} = 23.33$, $P < 0.001$) was again due to a significant increase in the number of errors made for semantically related word pairs (all $P < 0.01$), and no such effect was found in the Chinese-English bilinguals (all $P > 0.1$).

In the Chinese monolinguals, phonological repetition in Chinese significantly affected reaction times ($F_{3,42} = 4.5$, $P < 0.05$) such that word pairs featuring a phonological repetition were responded to slower than all other word pairs (all $P < 0.05$). Unlike in the visual experiment, however, a significant effect on error rate was found ($F_{3,42} = 9.11$, $P < 0.01$) between orthographic and phonological repetition on the one hand and semantically relatedness and unrelated word pairs on the other such that repetition priming reduced error rates (all $Ps < 0.01$).

6. 3. ERP results

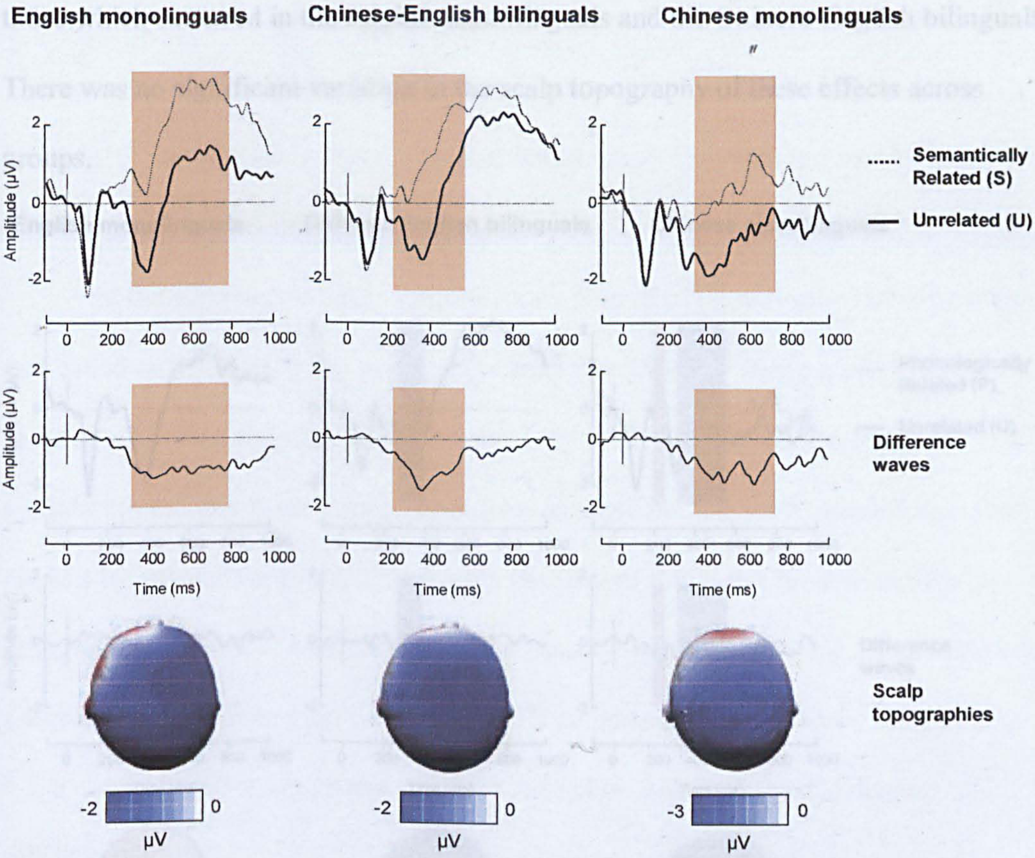

Figure 6-3. ERP results in the reading experiments for the semantically related and unrelated conditions

In the reading experiments, ERP differences between experimental conditions were found in all three groups of participants. In the English monolinguals, post hoc analysis (LSD) of the main effect ($F_{3,42} = 49.61$, $P < 0.001$) revealed a significant difference on mean ERP amplitudes between the semantically related and unrelated conditions in the range of the N400 from 300 ms post stimulus onwards ($P < 0.001$). Semantically related word pairs elicited a reduced N400 as compared to unrelated word pairs. A similar pattern of result was found in the Chinese bilinguals ($F_{3,42} =$

27.54, $P < 0.001$) although this effect was less durable than in the English monolinguals. Chinese monolinguals ($F_{3,42} = 5.22$, $P < 0.05$) who read the Chinese translations also showed a prolonged effect of semantic relatedness on mean ERP amplitude in the same direction, suggesting comparable semantic priming effect as those which occurred in the English monolinguals and the Chinese-English bilinguals. There was no significant variation in the scalp topography of these effects across groups.

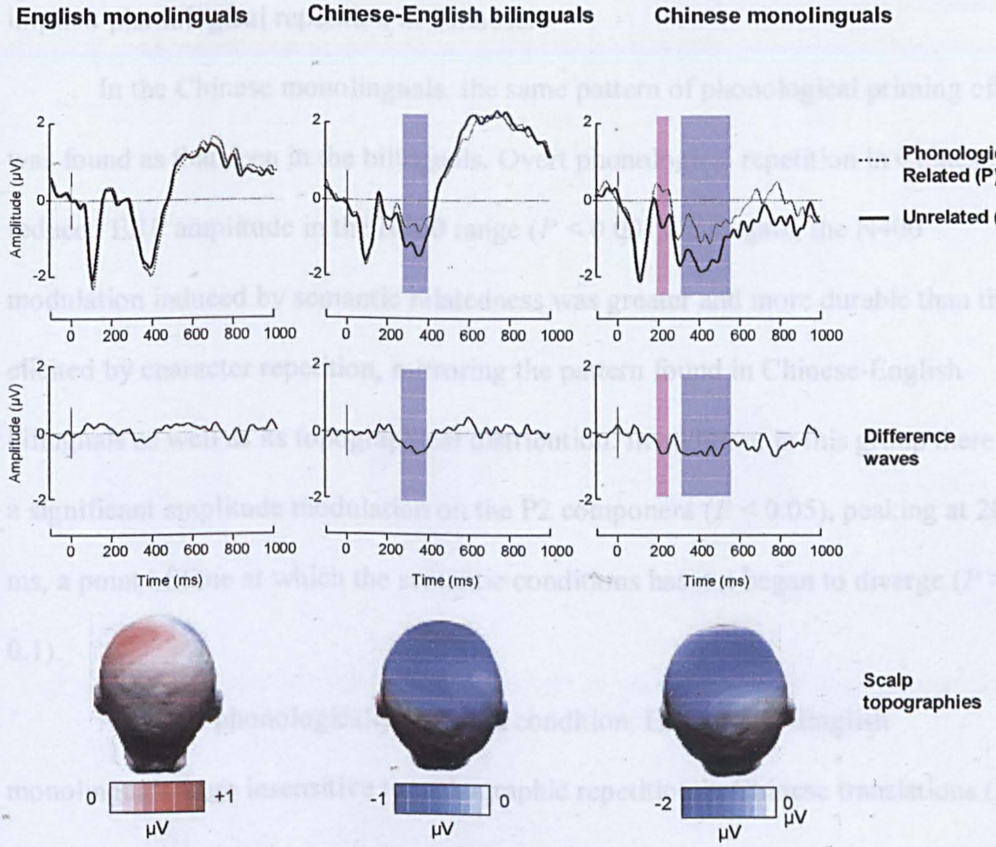

Figure 6-4. ERP results in the reading experiments for the phonological repetition in Chinese translations and the unrelated conditions

The hidden phonological repetition in Chinese translations had no effect in the N400 range in the English monolinguals ($P > 0.1$), and no other amplitude modulation was found on ERP components between the two conditions (P and U). In comparison, Chinese-English bilinguals showed a significant effect of phonological repetition in

Chinese translations while reading English words ($P < 0.01$): mean N400 amplitude was reduced for English word pairs that shared a phonological repetition through Chinese translations as compared to unrelated word pairs. This phonological effect, together with the semantic priming effect, was responsible for the significant main effect of experimental conditions on mean ERP amplitude in the N400 range in Chinese-English bilinguals. However, the N400 modulation elicited by semantic relatedness was of greater magnitude and lasted longer than that induced by the implicit phonological repetition in Chinese.

In the Chinese monolinguals, the same pattern of phonological priming effect was found as that seen in the bilinguals. Overt phonological repetition in Chinese reduced ERP amplitude in the N400 range ($P < 0.001$), but again, the N400 modulation induced by semantic relatedness was greater and more durable than that elicited by character repetition, mirroring the pattern found in Chinese-English bilinguals as well as its topographical distribution. In addition, in this group there was a significant amplitude modulation on the P2 component ($P < 0.05$), peaking at 200 ms, a point of time at which the semantic conditions has not began to diverge ($P > 0.1$).

As in the phonologically repeated condition, ERPs of the English monolinguals were insensitive to orthographic repetition in Chinese translations ($P > 0.1$), suggesting that the implicit condition in Chinese phonology was comparable with the baseline comparison (U) in English. Interestingly, the Chinese-English bilinguals who reacted to implicit phonological repetitions in Chinese were insensitive to implicit orthographic repetitions ($P > 0.1$), thus the same pattern as English monolinguals regarding this comparison. On the other hand, explicit orthographic repetition in Chinese modulated ERP amplitudes in the Chinese monolinguals. The same pattern of variations was found as for phonological repetition: The mean amplitudes of P2 and N400 were both modulated when Chinese monolinguals read Chinese target words that shared one visual character with the prime words ($P < 0.05$).

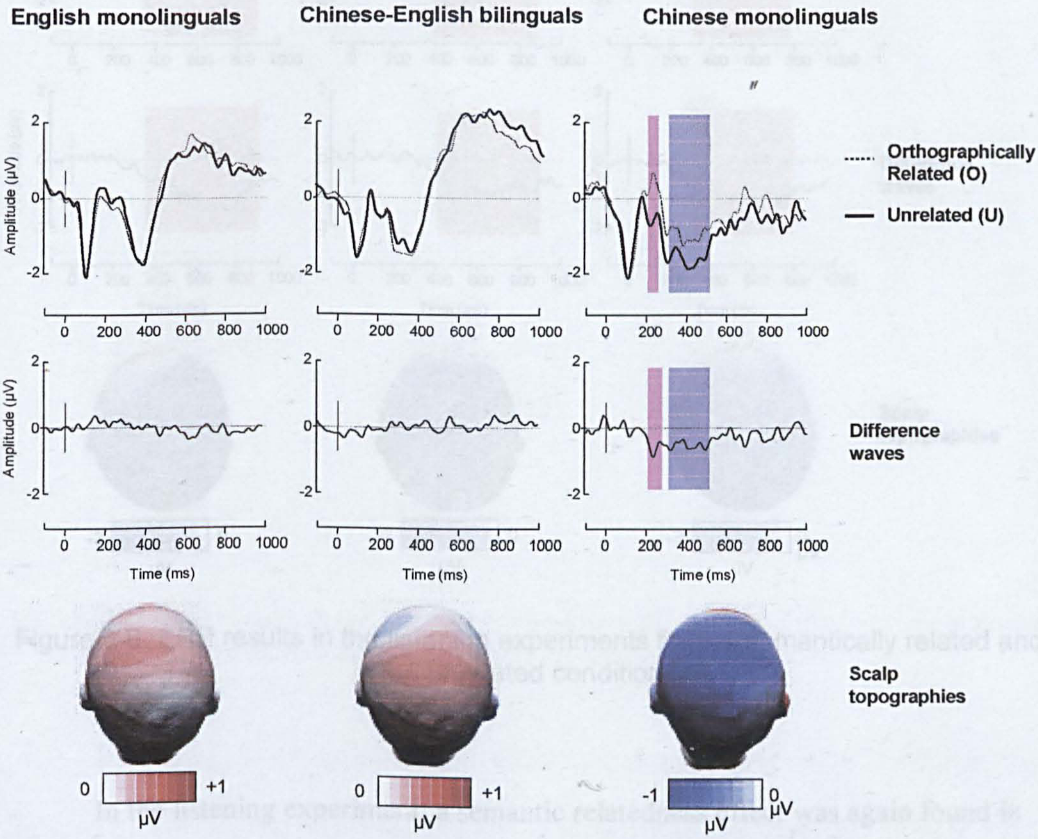

Figure 6-5. ERP results in the reading experiments for the orthographic repetition in Chinese translations and the unrelated conditions

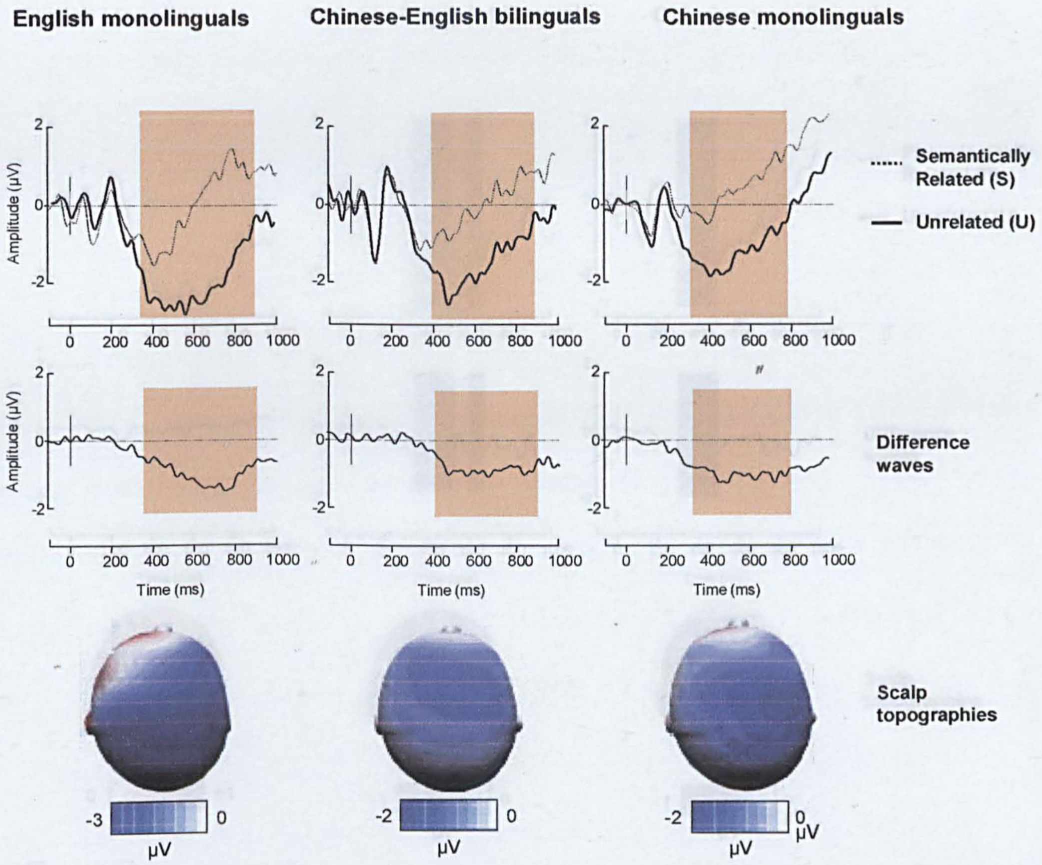

Figure 6-6. ERP results in the listening experiments for the semantically related and the unrelated conditions

In the listening experiment, a semantic relatedness effect was again found in all three groups of participants. In the English monolinguals, semantically related word pairs elicited smaller amplitude in the N400 component as compared to unrelated word pairs ($P < 0.0001$), and this difference was found to be the only explanation for the difference between the four experimental conditions ($F_{3,42} = 8.71$, $P < 0.001$; see figure 6-7 and figure 6-8). The Chinese-English bilinguals ($F_{3,42} = 5.23$, $P < 0.05$) and Chinese monolinguals ($F_{3,42} = 12.77$, $P < 0.001$) showed the same pattern of semantic effect (all $P < 0.05$).

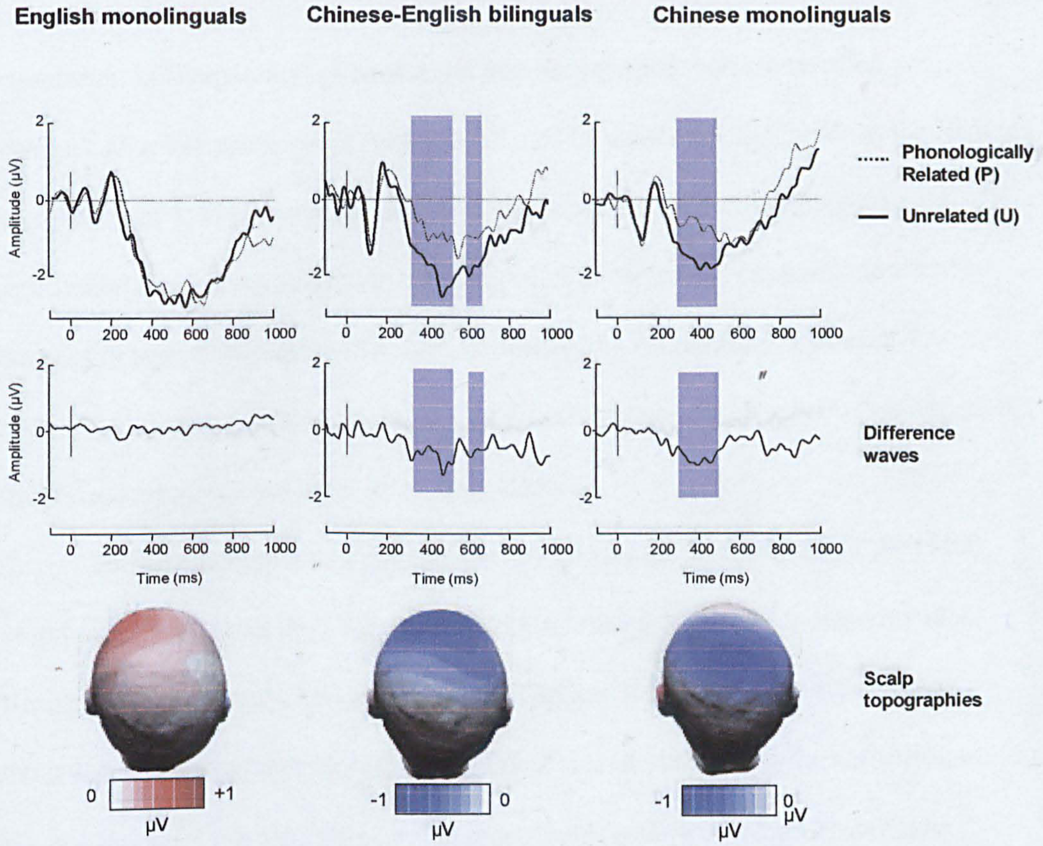

Figure 6-7. ERP results in the listening experiments for the phonological repetition in Chinese translations and the unrelated conditions

In the English monolinguals, no difference was found between word pairs that featured a phonological repetition in Chinese translations and unrelated word pairs ($P > 0.1$). In the Chinese-English bilinguals, the same comparison revealed a significant difference. Implicit phonological repetition in Chinese translations while reading English word pairs reduced mean ERP amplitude in the N400 range (between 350 and 550 ms, and a brief effect again around 600 ms; all $Ps < 0.05$). The phonological effect lasted longer and elicited greater amplitude reduction in the auditory than visual modality. Comparable results were found in the Chinese monolinguals: explicit overlap in phonology in Chinese significantly modulated the N400 amplitude ($P < 0.05$). Interestingly, the early P2 effect seen in the reading experiment was absent in the listing experiment.

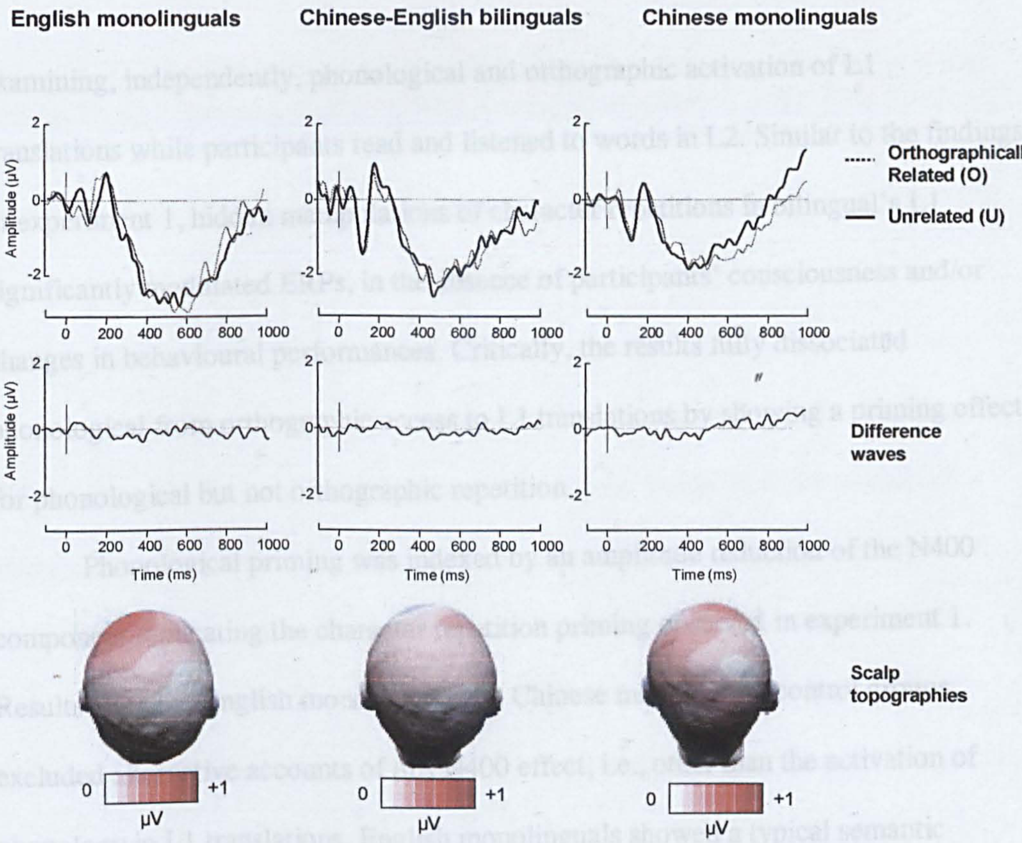

Figure 6-8. ERP results in the listening experiments for the orthographic repetition in Chinese translations and the unrelated conditions

When comparing word pairs that featured orthographic repetition in Chinese translations with unrelated word pairs, no difference was found in either group of participants. ERP waveforms of the two conditions overlapped closely in the N400 time course as well as early components (e.g., P2). In the Chinese monolinguals, in particular, auditory presentation of words did not trigger orthographic repetition priming. This result contrasted sharply with the significant effect of phonological repetition in the reading experiment, i.e., the reverse manipulation (see above).

6. 4. Discussion

The purpose of this study was to further investigate the nature of cross-language activation during bilingual word comprehension. This was done by examining, independently, phonological and orthographic activation of L1 translations while participants read and listened to words in L2. Similar to the findings of experiment 1, hidden manipulations of character repetitions in bilingual's L1 significantly modulated ERPs, in the absence of participants' consciousness and/or changes in behavioural performances. Critically, the results fully dissociated phonological from orthographic access to L1 translations by showing a priming effect for phonological but not orthographic repetition.

Phonological priming was indexed by an amplitude reduction of the N400 component replicating the character repetition priming observed in experiment 1. Results from the English monolingual and Chinese monolingual control groups excluded alternative accounts of this N400 effect, i.e., other than the activation of phonology in L1 translations. English monolinguals showed a typical semantic priming effect in both behavioural data and ERPs, suggesting that they were engaging in the experimental task (semantic relatedness judgment) as expected. In effect, English participants were necessarily unaware of the repetition priming experimental manipulations (i.e., phonological and orthographic repetition in Chinese translations), indicating that the implicit Chinese factors were unaffected by confounding semantic or lexical variables in English.

On the other hand, Chinese monolinguals who read Chinese words showed a priming effect of explicit phonological repetition very similar to that implicitly active in Chinese-English bilinguals. While the bilingual participants did not display any early P2 effects, the N400 correlates of phonological repetition were highly comparable between the two groups in terms of the extent and time course of amplitude modulations. Moreover, the effect was smaller and less durable than the semantic priming effect in both the Chinese monolinguals and Chinese-English bilinguals (see Exp 1). These correspondences between the two groups suggest that the phonologically-based N400 effect reflects the same processing mechanism whether it was explicitly or implicitly observed. This account was further strengthened by the fact that the critical results in the reading experiment were replicated in the listening experiment.

Conversely, orthographic repetition in Chinese characters had a significant effect only when Chinese monolinguals read Chinese words. In Chinese-English bilinguals reading English words, ERPs were insensitive to orthographic repetition priming, showing a similar pattern of variations as that of English monolinguals. Taken together these findings demonstrate that implicit access to L1 translations while reading and listening to words in L2, as revealed by character repetition priming in experiment 1, is the result of implicitly accessing phonological instead of orthographic information of L1 translations. This was shown by separating these two dimensions in Chinese character repetition and finding that the priming effect was preserved exclusively in the phonological priming condition. Note that results from the control Chinese monolingual participants served as an interpretative tool for the effects seen in bilinguals using a similar rationale as that of experiment 1.

In the current experiment, teasing apart phonological from orthographic effects has also led to several noticeable changes in the Chinese monolinguals' behavioural performances and ERPs from the results of experiment 1. In the previous experiment, the character repetition incorporated both phonological and orthographic overlap and priming effects were comparable in both modalities. Here, while the phonological priming effect was found in both reading and listening experiments, the orthographic effect was only seen when participants read words and absent in the listening experiment. Recall that the Chinese monolinguals were fully aware of the character repetitions as they read or listened to word pairs in Chinese; therefore, this demonstrates a profound asymmetry between phonological and orthographic activation during word comprehension, even in L1. The robustness of the phonological priming effect suggests that the activation of phonological codes is a mandatory, automatic correlate of the retrieval of word meanings. Orthographic knowledge might be secondary –more artificial– information activated only in reading. Interestingly, this idea fits well with the pattern of behavioural results. While orthographic repetition was ineffective in Chinese monolinguals, reaction time was significantly longer in the phonologically repeated condition in both reading and listening experiments, an effect which may have arisen for the same reason as character repetition interference in experiment 1 (see Chapter 5). This finding further demonstrates that phonological information is more critical than orthographic codes during word processing (Frost, 1998). It is also consistent with previous studies demonstrating superior written to oral naming performance by neuropsychological Chinese patients (Law & Bella, 2001; Law et al., 2006). The implications of these findings will be discussed to a greater extent in the general framework of reading models (e.g., the dual-route theory) in Chapter 8.

A peculiar difference between the current experiment series and the previous one is the ERP differences between 200 and 270 ms after the presentation of the stimuli in the Chinese monolinguals. In the previous experiment series, Chinese character repetition (both phonological and orthographic) reduced the amplitude of the P2 component, an effect that was associated with perceptual repetition priming. In the present experiment, the P2 effect was found in the opposite direction: Both phonological and orthographic repetition increased the amplitude of the P2 rather than reducing it, and this was only observed in the reading experiment, not in the listening experiment. One hypothetical explanation for this effect is that, in contrast to lexical level priming observed in the N400 window, perceptual priming requires complete overlap in sound and orthographic form to occur. In other words, when repetition in one dimension is incongruent with information in the other, the repetition along one dimension would trigger negative priming and increase P2 amplitude rather than reducing it. This interpretation is partly supported by the results in the auditory modality because no such P2 effect was found in the listening experiment. Indeed, if the orthographic code is not activated at all during listening, then there is negligible negative priming arising from incongruent information from the orthographic code, hence the absence of P2 amplitude increase in the listening experiment.

Study 3: Native Lexicon Access in Second Language Production

7. 1. Predictions

Previous experiments have established that bilinguals unconsciously access their native language while reading and listening to words in their second language by showing an implicit repetition priming effect via L1 translation equivalents. Here, we modified the paradigm to examine the issue of cross-language interaction in word production. The experiment proceeded in three phases in which bilingual participants had to make semantic relatedness judgment on picture pairs, make rhyming decision on the names of the pictures in English and detect character repetitions in the Chinese names of the pictures. The stimuli included pairs of pictures that were either related in meaning or not. The unrelated picture pairs were subdivided in three subgroups: (i) pictures whose names rhymed in English, pictures whose names shared a character in Chinese names, picture whose name showed no overlap either in English or Chinese (see examples in Chapter 4). There were two main hypotheses on the performances of Chinese-English bilinguals: (1) Access to L1 (Chinese) translations was expected to occur during picture naming in L2 (i.e., the English rhyming task), in which case Chinese character repetition should lead to a priming effect; (2) If cross-language interaction is bidirectional (i.e., L1→L2 and L2→L1), we also expected to find similar effects of English rhyming in the Chinese task.

The semantic relatedness task served two purposes: (a) it was expected to provide a reference for the window in which semantic priming effects are found to enable a comparison with the time-course of lexical processing of picture names (as indexed by the rhyming and character repetition effects in English and Chinese respectively). This comparison was expected to bring insight into the debate on the locus of activation of the non-target language during speech production. (b) In the semantic relatedness task, bilingual participants were expected to demonstrate a higher level of cognitive control than monolingual participants. Specifically, when extracting and associating the meanings of two pictures, lexical manipulations in the picture names should have less influence on the performances of bilinguals than monolinguals, showing that bilinguals can more readily dissociate semantic from linguistic attributes of pictorial stimuli. This hypothesis derives from works by Helen Bialystok and her colleagues on the developmental benefits of bilingualism on cognitive abilities (Bialystok, 2005; Bialystok et al., 2004).

7. 2. Behavioural results

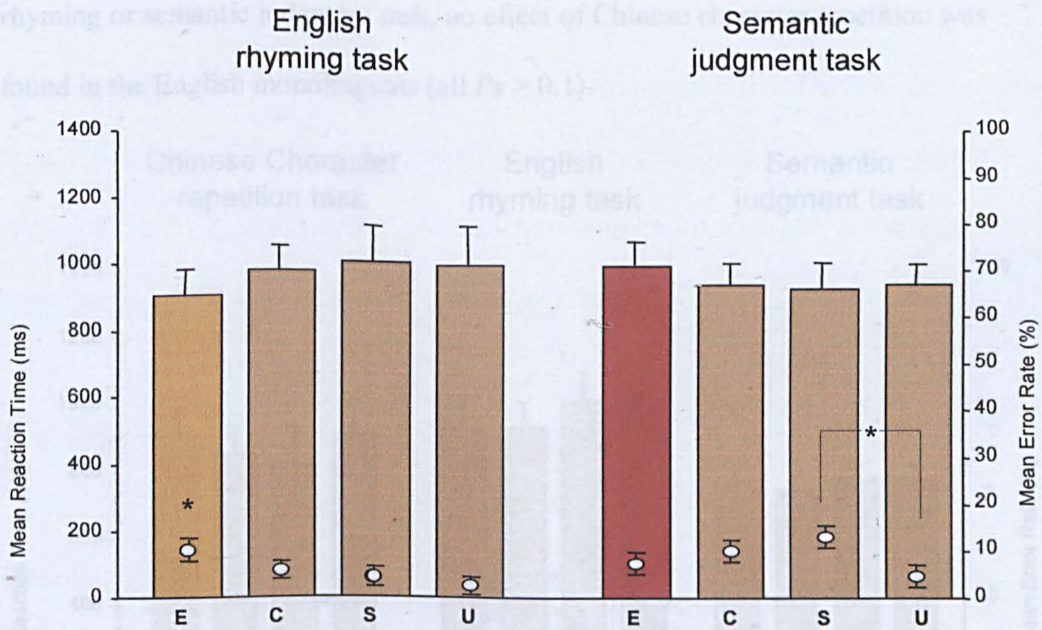

Figure 7-1. behavioural results of English monolinguals in the English rhyming task and the semantic relatedness judgment task

In the Englis rhyming task, a repeated ANOVA revealed a significant difference between experimental conditions in reaction times ($F_{3,42} = 2.91$, $P < 0.05$). Post hoc analysis (LSD) attributed this difference to rhyming in English. When

English monolinguals made rhyming judgments on the English names of pictures presented in pairs, target pictures that rhymed with the prime pictures were responded to faster (represented by the yellow bar) than in other conditions ($Ps < 0.05$) and they made more error in that condition ($F_{3,42} = 8.61$, $P < 0.001$) than in the other three (all $Ps < 0.001$). In the semantic relatedness judgment task, the significant effect of condition on reaction times ($F_{3,42} = 2.95$, $P < 0.05$) was also due to the condition in which picture names rhymed in English (represented by the red bar), however, in the form of longer reaction times as compared to the other conditions (all $Ps < 0.05$). The only significant difference in error rates was found between the semantically related (S) and unrelated pictures (U; $F_{3,42} = 4.32$, $P < 0.05$), with participants making more errors on related than unrelated pictures ($P < 0.05$). Notice that, in either the English rhyming or semantic judgment task, no effect of Chinese character repetition was found in the English monolinguals (all $Ps > 0.1$).

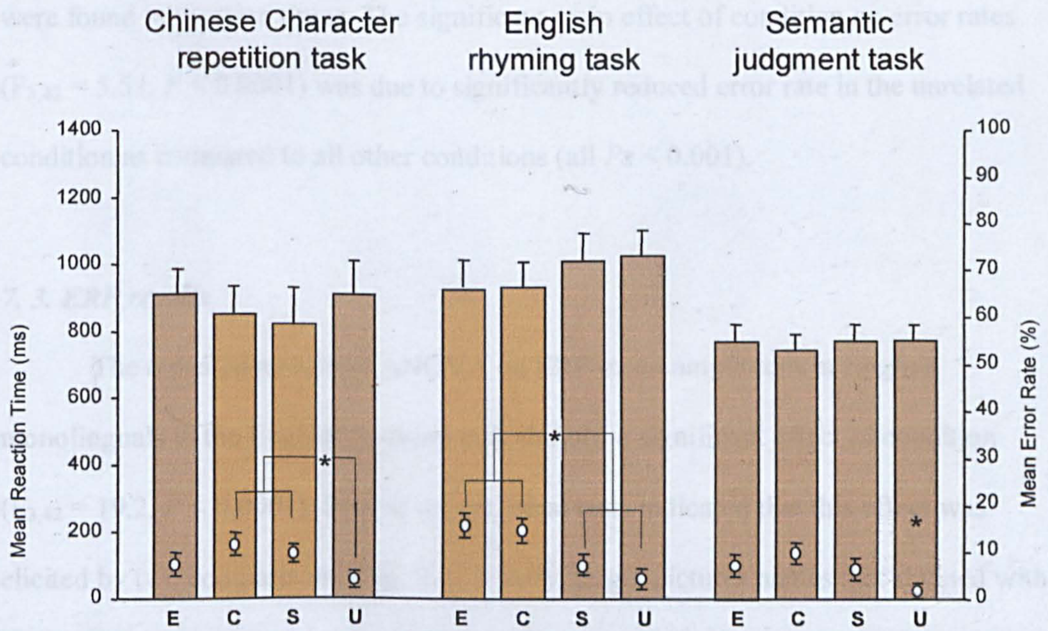

Figure 7-2. behavioural results of Chinese-English bilinguals in the Chinese character repetition task, the English rhyming task, and the semantic judgment task

When judging whether two picture names shared a character in Chinese, Chinese-English bilinguals responded faster ($F_{3,42} = 2.98$, $P < 0.05$) to pairs of pictures that either had names with a character repetition or were related in meaning (both *Ps* < 0.05). Interestingly, they also made more errors ($F_{3,42} = 3.42$, $P < 0.05$) in these two conditions (C and S) as compared to the unrelated condition (both *Ps* < 0.05). No effect of English rhymes was found on either reaction time or error rate in this task (all *Ps* > 0.1). In the English rhyming task, target picture names that rhymed with that of prime pictures in English were responded to faster but less accurately (all *Ps* < 0.05) than the semantically related and unrelated picture pairs, showing a comparable pattern of performance with the English monolinguals. Critically, the implicit (irrelevant) factor of character repetition in Chinese names also reduced reaction time ($F_{3,42} = 3.08$, $P < 0.001$) and increased the error rate ($F_{3,42} = 4.7$, $P < 0.001$) significantly. In the semantic judgment task, no differences between conditions were found in reaction times. The significant main effect of condition on error rates ($F_{3,42} = 5.57$, $P < 0.0001$) was due to significantly reduced error rate in the unrelated condition as compared to all other conditions (all *Ps* < 0.001).

*7. 3. **ERP results***

The repeated measured ANOVA on ERP mean amplitudes in English monolinguals in the English rhyming task showed a significant effect of condition ($F_{3,42} = 19.2$, $P < 0.0001$). Follow up statistical tests indicated that this effect was elicited by two comparisons (Fig. 7-3). Firstly, target pictures names that rhymed with prime picture names in English elicited significantly reduced ERP amplitude as compared to unrelated pictures ($P < 0.0001$). Significant differences between the rhyming and the unrelated condition started at 220 ms after the presentation of the target picture. Secondly, target pictures related in meaning to the picture primes reduced the amplitude of the N400 as compared to unrelated picture targets ($P <$ 0.0001) This difference started at around 350 ms post stimulus. There was no difference between the ERP elicited by target pictures whose names in Chinese shared a Chinese character with that of the prime and the ERP elicited by unrelated target pictures ($P > 0.1$).

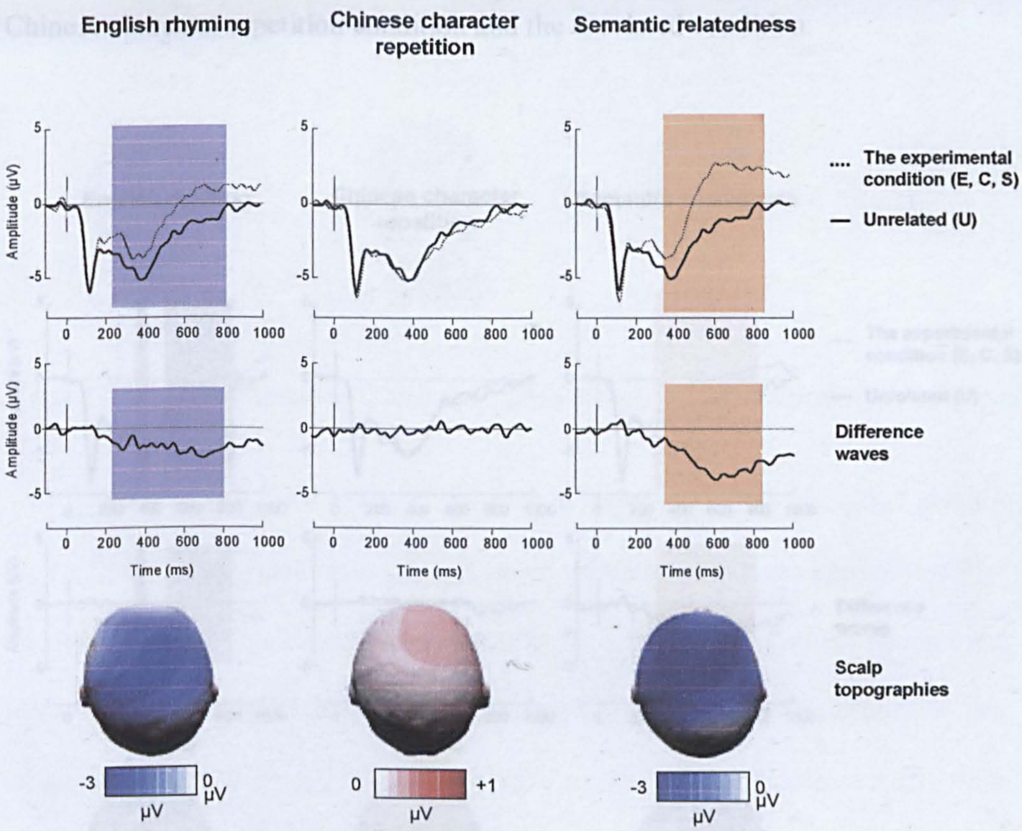

Figure 7-3. ERP results of English monolinguals in the English rhyming task

In the semantic relatedness judgment task, significant experimental effects on mean ERP amplitudes ($F_{3,42} = 10.16$, $P < 0.0001$) were explained by two comparisons (Fig. 7-4). Firstly, semantic relatedness reduced the mean amplitude as compared to the unrelated condition ($P < 0.0001$). This effect which started at around 300 ms and extended across the typical N400 time window was highly comparable with the semantic priming effect found in the English rhyming task. Secondly, at around 500 ms post target picture onset, a significant ERP amplitude reduction was found when comparing target pictures whose names rhymed with that of prime pictures as compared to semantically unrelated target pictures ($P < 0.05$). Compared to the English rhyming effect in the English rhyming task, the effect of English rhyme in the semantic task appeared at a later stage and modulated ERPs to a smaller extent. As in the English Rhyming task, there was no significant difference between the ERPs in Chinese character repetition condition and the unrelated condition.

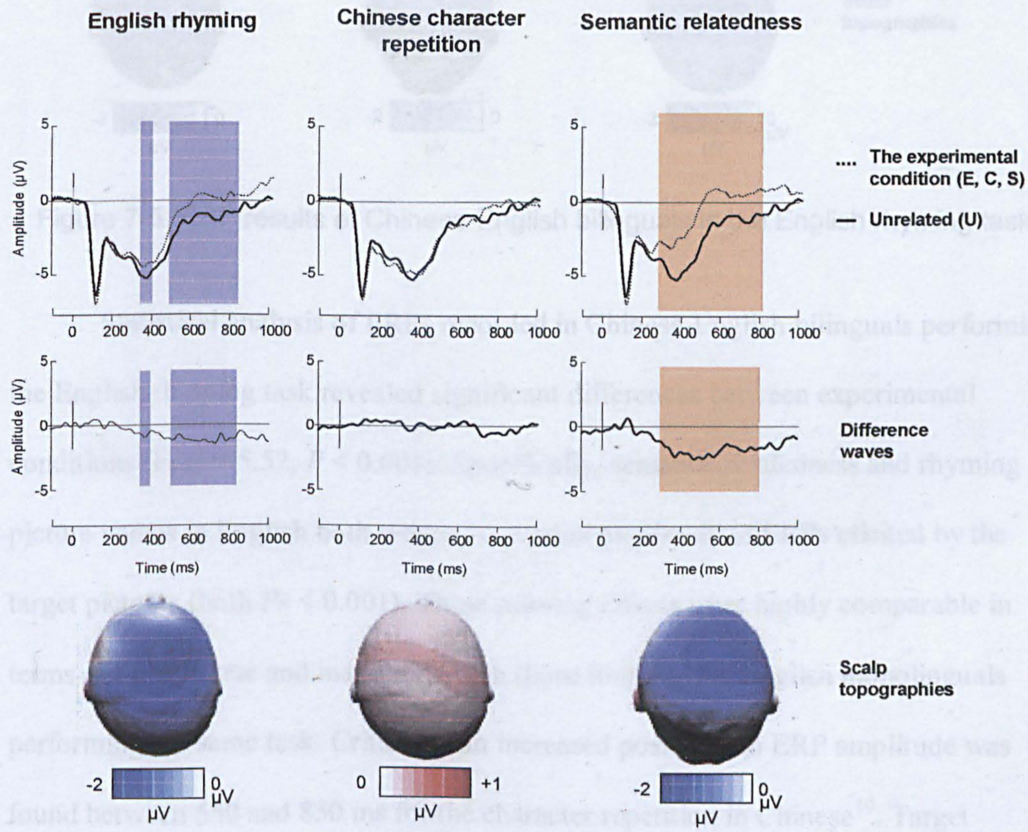

Figure 7-4. ERP results of English monolinguals in the semantic relatedness judgment task

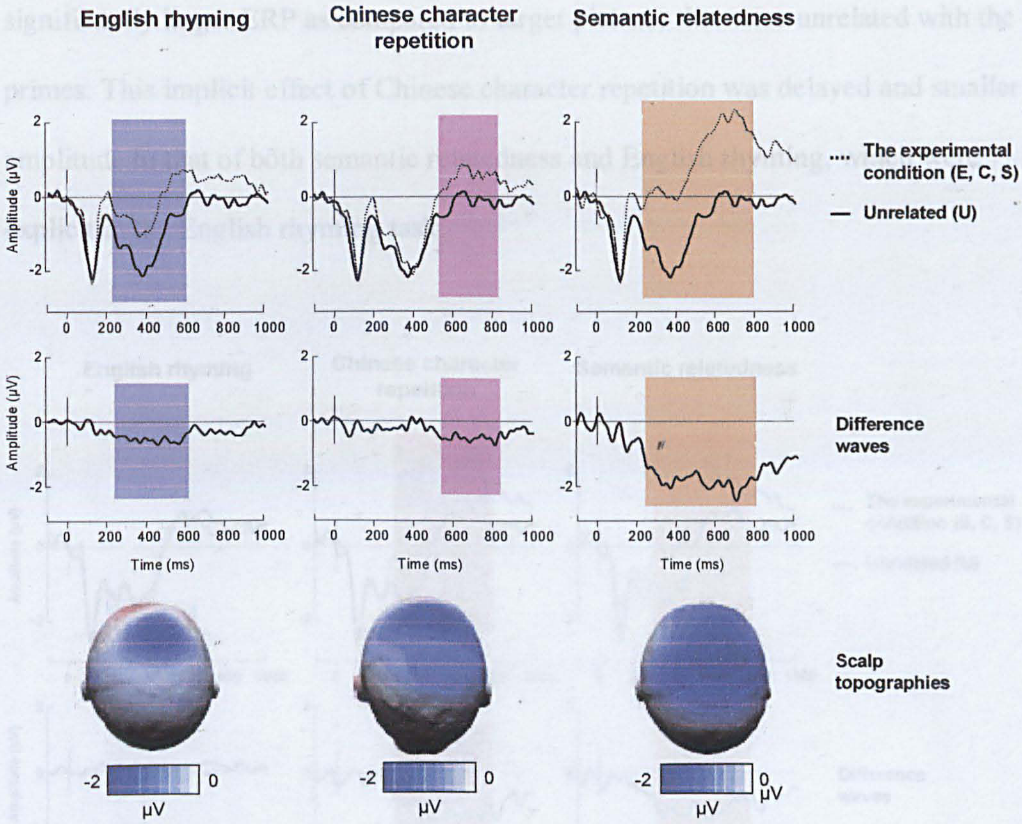

Figure 7-5. ERP results of Chinese-English bilinguals in the English rhyming task

Statistical analysis of ERPs recorded in Chinese-English bilinguals performing the English rhyming task revealed significant differences between experimental conditions ($F_{3,42} = 5.52$, $P < 0.001$). Specifically, semantic relatedness and rhyming picture names in English both reduced the mean amplitude of ERPs elicited by the target pictures (both $Ps < 0.001$). These priming effects were highly comparable in terms of time-course and magnitude with those found in the English monolinguals performing the same task. Critically, an increased positivity in ERP amplitude was found between 550 and 850 ms for the character repetition in Chinese[10]. Target picture names that shared a Chinese character with that of pictures primes elicited a

[10] It was unknown whether this effect was due to the activation of the phonology or the orthography of L1 translations as the repeated character was both a homophone and a homograph. These factors were not tested independently as in experiment series 2 because of the extreme difficulty of finding typical images that reliably correspond to a target words and also meet the other criteria (see Method).

significantly larger ERP as compared to target pictures that were unrelated with the primes. This implicit effect of Chinese character repetition was delayed and smaller in amplitude to that of both semantic relatedness and English rhyming, which were explicit in the English rhyming task.

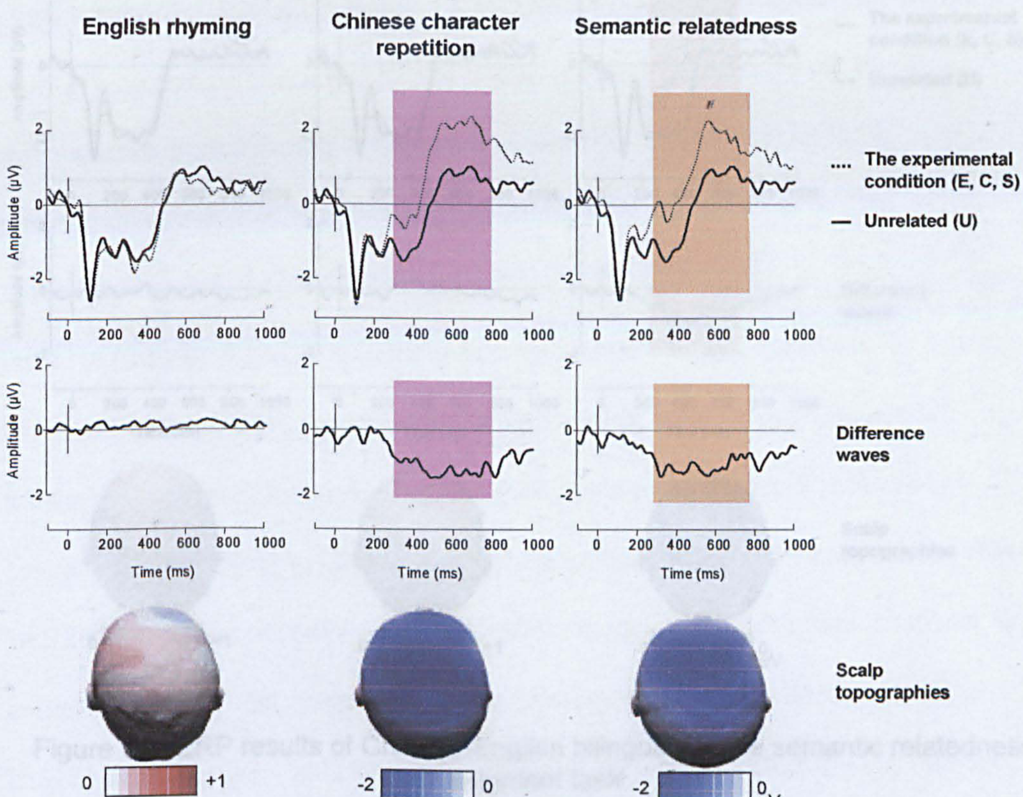

Figure 7-6. ERP results of Chinese-English bilinguals in the Chinese character repetition task

When asked to judge whether the Chinese names of two pictures shared a character, target pictures that were either semantically related or shared a character in their Chinese names with the prime pictures induced a significantly smaller N400 than pictures that were unrelated to the primes (both *Ps* < 0.05). Both priming effects started at around 300 ms after stimulus presentation and, together, they explained the significant differences between experimental conditions ($F_{3,42} = 2.77$, $P < 0.05$).

Noticeably, rhyming in English yielded no significant effect on any ERP components when compared to the unrelated picture pairs.

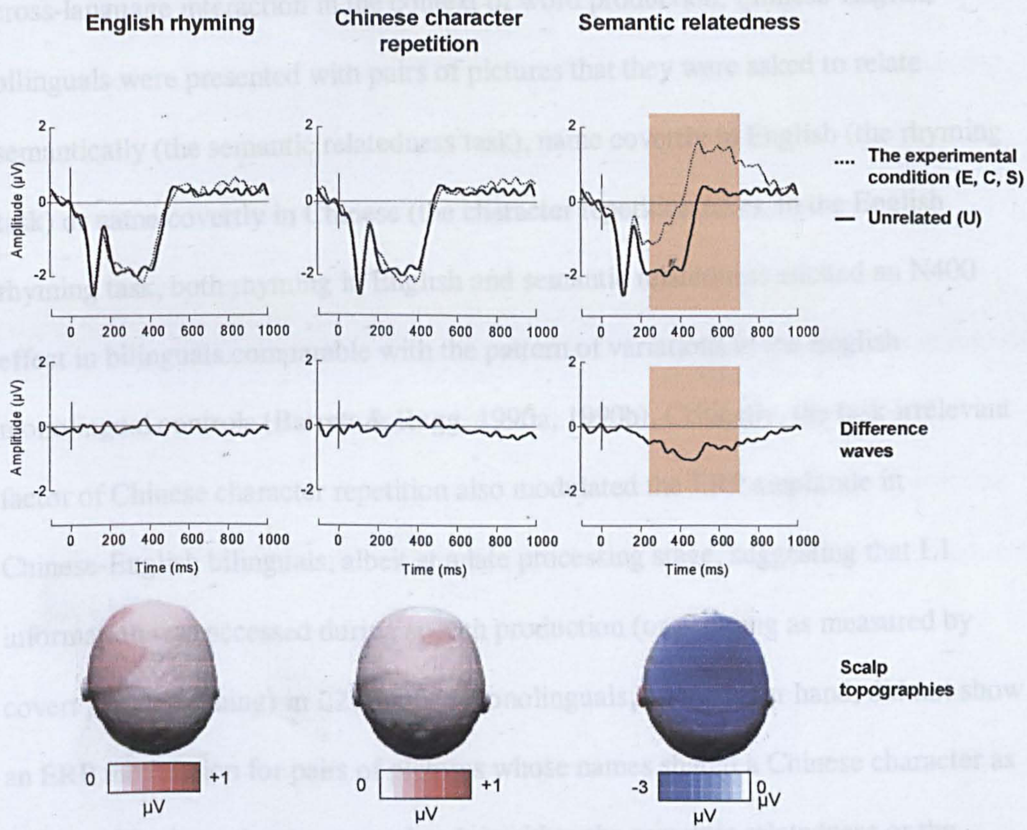

Figure 7-7. ERP results of Chinese-English bilinguals in the semantic relatedness judgment task

Finally, when making semantic relatedness decision on pair of pictures, semantic relatedness reduced the mean ERP amplitude in Chinese-English bilinguals, a similar effect to that was found in the English rhyming and Chinese character repetition tasks ($F_{3,42} = 10.22$, $P < 0.0001$). However, in this task, neither rhyming picture names in English nor character repetition in Chinese modulated ERP amplitudes significantly (all $Ps > 0.1$). This finding contrasts with the case of English monolinguals, who showed a priming effect by English rhymes when performing the semantic relatedness task.

7. 4. Discussion

The overarching goal of this experiment was to examine the issue of cross-language interaction in the context of word production. Chinese-English bilinguals were presented with pairs of pictures that they were asked to relate semantically (the semantic relatedness task), name covertly in English (the rhyming task) or name covertly in Chinese (the character repetition task). In the English rhyming task, both rhyming in English and semantic relatedness elicited an N400 effect in bilinguals comparable with the pattern of variations in the English monolingual controls (Barrett & Rugg, 1990a, 1990b). Critically, the task-irrelevant factor of Chinese character repetition also modulated the ERP amplitude in Chinese-English bilinguals, albeit at a late processing stage, suggesting that L1 information was accessed during speech production (or planning as measured by covert picture naming) in L2. English monolinguals, on the other hand, did not show an ERP modulation for pairs of pictures whose names shared a Chinese character as compared to those that were unrelated, in either the semantic relatedness or the English rhyming tasks, indicating that the manipulation in Chinese did not interact with or bias the results. Furthermore, in the Chinese character repetition task, the priming effect by character repetition in Chinese was replicated when the participants explicitly retrieved Chinese names.

Consequently, the effects of Chinese character repetition in the English rhyming task can only be explained by the activation of task-irrelevant language information during bilingual word production. While this evidence clearly supports the language-nonselective hypothesis, echoing findings from studies of word comprehension (see experiment series 1 and 2), there are important differences that distinguish the mechanisms operating in the input (e.g., reading and listening) and the output (e.g., speaking) domains of bilingual word processing.

In experiment series 1 and 2, the evidence of cross-language activation in L1 was derived exclusively from an ERP index of Chinese character repetition priming, in the absence of any alteration of behavioural performance. This discrepancy between ERP and behavioural results suggests that bilingual's access to L1 translations was indeed implicit rather than a surface process. Here, in the English rhyming task, Chinese character repetition reduced the reaction time and increased the error rate to a comparable extent as rhyming in English. Considering the ERP correlates of character repetition priming together, the findings seem to suggest that cross-language interaction in word production was more explicit, affecting bilinguals at both the neurophysiological and the behavioural level.

The contrast in the behavioural findings between the comprehension and the production experiments may relate to the differences in the time-course of the ERP effects of the Chinese character repetition priming in the two sets of experiments. In experiment series 1 and 2, the ERP index of L1 translation access was an amplitude reduction between 350 and 550 ms, a time window classically associated with semantic analysis in the literature, and indeed synchronous to the semantic relatedness effects found in these studies. Therefore, I argued that access to L1 translations was a spontaneous correlate of semantic retrieval during reading and listening to words in L2. Conversely, in the picture naming experiment, the ERP effects of Chinese character repetition was found, in the English rhyming task, from 550 to 850 ms, a time window that has been associated with re-evaluation processes or "second-pass" resolution of syntactic (Hagoort, 2003; Hahne & Friederici, 1999; Osterhout, 1997) as well as semantic anomalies (Kolk et al., 2003; Kuperberg, 2007; van Herten et al., 2005). More critically, the ERP effect of Chinese character repetition commenced at the point of time when the English rhyming effect began to decay. This pattern of variations may suggest that activation of L1 translations is a delayed process, i.e. intervening after the retrieval of the semantic and lexical form of L2 words during production.

It is worth noting that the temporal pattern of the character repetition effect in the English rhyming task should not be the result of processing pictures instead of words. As found in the Chinese character repetition task, where Chinese was the target language, the explicit effect of character repetition priming emerged as early as 300 ms post stimulus, a point of time that is comparable to that of the English rhyming effect in the English monolinguals. Comparatively, the time lag of the character repetition effect in the English naming task suggests a distinct mechanism operating in a context of cross-language interaction.

Another noteworthy difference between the comprehension and production experiments is that bilingual participants in the rhyme in English experiment were aware of the fact that some of the Chinese names of the pictures had one character repeated. This finding is consistent with the feedback from bilingual participants tested in other experiments of L2 word production (Rodriguez-Fornells et al., 2005), and it is also in line with the behavioural effects of Chinese character repetition found exclusively in the production experiments. For this reason, it is inappropriate to describe the Chinese character repetition effects found in the English naming task as a wholly "implicit" effect, because participant were not completely unaware of the manipulation in Chinese as they were in experiment series 1 and 2.

The above discussion reviewed some differences between the patterns of bilingual word production and comprehension revealed in similar experimental paradigms. Cross-language interaction was found in both domains as effects of task-irrelevant priming of character repetition in Chinese (L1). However, as compared to reading and listening, the activation of L1 translations when naming words in L2 influences bilinguals' behavioural performance, may occur at a later stage of word processing, and appears to be more conscious.

Due to practical reasons the picture naming experiments were not an exact methodological replication of experiments on word comprehension (e.g., no Chinese monolinguals were available for the picture naming experiments). When Chinese-English bilinguals were asked to name pictures in Chinese (i.e., the character repetition judgment task), rhyming in English did not affect either their behavioural performances or the ERPs (see figure 7-2 and 7-6). Given that English rhyming effects have been found in both the English monolinguals and the Chinese-English bilinguals in the English rhyming task, the absence of such an effect in the Chinese task suggests that English (L2) is not accessed when naming pictures in Chinese (L1). This would support the view that cross-language interaction is unidirectional (i.e., L1→L2 only). It is worth noting that the issue of the directionality of cross-language interaction was only examined in a context of word production here (i.e., the reading and the listening experiments tested potential influences of L1 on L2 only); therefore, the finding of asymmetric interaction between L1 and L2 in the naming experiments does not necessary imply that the same is true in word comprehension. Previous studies have shown that, in word association and lexical decision tasks, L2 information affects bilingual's behavioural performances in L1 (Van Hell & Dijkstra, 2002; Van Wijnendaele & Brysbaert, 2002).

In the picture naming experiments, participants were asked to perform a semantic relatedness task in which they had to judge the relatedness between two pictures and were encouraged not to retrieve any lexical information associated with them (e.g., the phonology of picture names). Since the semantic relatedness task was always presented before the naming tasks in English and –in the case of Chinese-English bilinguals– Chinese, and since the experiment did not include a familiarisation procedure (see Method), both groups of participants were expected to be neutral vis-à-vis the lexical items corresponding to pictorial stimuli. However, while the semantic priming effect was found in both the Chinese-English bilinguals and the English monolinguals, there were significant differences in the responses to lexical manipulations (i.e., rhyming in English and character repetition in Chinese): rhyming in English affected significantly both the behavioural performance (figure 7-1) and the ERPs (figure 7-4) of the English monolinguals, indicating that semantic processing of a picture automatically activates corresponding lexical information. In other words, English monolinguals tend to automatically access names when viewing pictures. In contrast, no such effect of English rhymes was found when Chinese-English bilinguals were judging semantic associations between pairs of pictures. Most critically, the character repetition in Chinese, which had a significant effect in bilingual participants during both the Chinese character repetition and the English rhyming task, failed to influence ERP amplitudes in the semantic relatedness task. This finding suggested that viewing a picture does not necessary trigger word retrieval in bilinguals, a hypothesis that is still a matter of debate in the field of monolingual language research. A more thorough discussion on how this finding contributes to the literature on developmental benefits of bilingualism and lexical-semantic encoding of pictures will be presented in Chapter 8.

General Discussion

The present thesis was motivated by a main question regarding bilingual lexical access: whether or not the first language of bilingual individuals is active when processing in the second language. Is L1 activated during L2 processing even when languages are not mixed in the experimental context? Is this potential cross-language activation dependant upon the type of information accessed in L1 (e.g., phonology or orthography), the nature of processing (e.g., comprehension versus production), and the direction of the effects (i.e., L1 → L2 or L2 → L1)? These questions were investigated in three studies. First, we will summarise the major findings of these studies and discuss them in the framework of contemporary psycholinguistic models and other relevant literature reviewed in chapters 3 and 4 of the thesis. In particular, the discussion will focus on the methodological characteristics of the present studies, and explain how they contribute to the current debate beyond previous ones. Second, by exploring the nature of bilingual language processing, I shed light on some open questions in cognitive psychology of language. Indeed some of the findings reported here validate the hypothesis that bilingual research may serve as a tool to better understand the language system in general (French & Jacquet, 2004; Kroll & De Groot, 2005; Schwartz & Kroll, 2006b). Third, before the conclusion, I will discuss potential shortcomings of the current studies and outstanding questions for future research.

8. 1. Summary of the present studies

The primary objective of the first study was to re-examine the hypothesis of cross-language activation that has been supported by numerous -including recent-studies (Duyck, 2005; Haigh & Jared, 2007). This was done using an implicit priming paradigm in which Chinese-English bilinguals read and listened to words in English while half of the English word pairs shared a Chinese character via their Chinese translations. A priming effect of the factor hidden in Chinese translations was clearly visible in the ERPs of the bilingual participants. Since this effect was (a) unseen in the English monolinguals, and (b) replicated in the Chinese monolingual controls performing the same task on Chinese words, it was taken as an indication that information of the Chinese translations was automatically activated when bilingual participants processed the English words. Broadly speaking, this finding is in line with most current psycholinguistic conceptualisations assuming that both languages of bilinguals are active during word comprehension in L2.

In the first study, the critical stimuli were English target words that shared a Chinese character repetition with the prime via Chinese translations. The rationale behind this manipulation was that when bilinguals read or listen to words in L2, translation equivalents in L1 might be accessed to facilitate conceptual access for the new L2 words. This model is most compatible with the word association hypothesis as specified in the revised hierarchical model (Kroll & Stewart, 1994). Results of the first study generally support this hypothesis but also entail some developments and modifications to the original predictions of the RHM. First, while the evidence for the RHM derives primarily from experiments involving translation performance (see Chapter 1 for a review), in this study, the character repetition priming of Chinese translations was implicit: (a) the experimental task was performed exclusively in English and did not involve explicit translations (e.g., semantic relatedness judgment task); (b) when asked, the Chinese-English bilingual participants were totally unaware of the hidden experimental factor involving Chinese translations; (c) the Chinese character repetition effect was only found in ERPs and not in the behavioural data (meaning that if the study had involved only behavioural measurement, it may well have arrived at a different conclusion). The implicitness of the Chinese character repetition ascertains that the effects found were not the result of a translation strategy or another confounding variable that may have installed the participants in a "bilingual language mode" (Grosjean, 1998b; Grosjean, 2001). This is not to argue that studies testing translation performance or mixing stimuli from both languages of the bilinguals necessarily always suffer from these limitations. In particular, studies using the masked priming paradigm, in which participants are generally unaware of the prime word from the other language, have been considered functionally monolingual. In such studies, however, the magnitude of the priming effect is often attenuated by the level of masking (Brysbaert et al., 1999; Gollan et al., 1997; Grainger & Frenck-Mestre, 1998; Jiang, 1999). Here, by presenting both the prime and the target words in bilingual's L2, we ruled out any possible effects of artificial dual-language activations or masking, and created a "pure" monolingual context. In this context, we established for the first time that cross-language activation can occur outside awareness in bilingual participants, a result that has not been previously established in the psycholinguistic literature.

Second, owing to the method of event-related potentials, the first study was able to reveal the time-course of the cross-language activation. In the ERPs of the bilingual participants, the effect of semantic relatedness and that of Chinese character repetition appeared independently at the same moment of time (around 350 ms), even though the former effect was more pronounced and lasted longer than the latter. This pattern of results suggests that direct semantic access to words in L2 and the activation of L1 translation equivalents can co-exist simultaneously. This finding has consequences regarding the assumptions of the RHM because, even when bilingual individuals have attained sufficient expertise in their L2, word processing in L2 may still not be autonomous as if they were functionally monolingual (Segalowitz & Hulstijn, 2005). At the same time, however, the retrieval of word meaning in L2 might not depend at all on lexical association with L1 translations, because the Chinese character repetition effect would have been expected at an earlier stage than the semantic relatedness effect. Therefore, to give an accurate account of the mechanism at work in the English learners tested in the present study, who have initially acquired their English vocabulary through Chinese translations and eventually attained a relatively high-level of proficiency, one needs to consider contributions from both conceptual mediation and word association: while access to word meanings in L2 is a direct process, access to L1 translations remains an active, spontaneous correlate of this process.

Since study 1 focused on potential activation of L1 translation equivalents during word processing in L2 (i.e., the RHM), it has limited implications regarding the Bilingual Interactive Activation model (BIA), which predicts that cross-language activation takes place at the lexical level (see Sunderman & Kroll, 2006 for a recent study that has directly compared predictions of the two models). Nonetheless, the fact that Chinese and English do not share basic writing scripts appears to be problematic for models assuming that words in L1 are accessed via lexical form relatives in L2. Therefore, our findings extend the concept of cross-language activation put forward in BIA to language combinations which do not rely on the Roman alphabet. With regard to the issue of integrated (e.g., in the BIA) versus separate (e.g., in the RHM) lexical representations, the two languages of bilinguals tested in the present study had to be differentiated on the basis of sublexical components (e.g., fundamental writing scripts). However, the fact that cross-language activation of translation equivalents took place in such a natural and unconscious manner suggests that the two lexicons are highly connected with one another.

In the second study, the main purpose was to further analyse the nature of cross-language activation in terms of the type of information that is activated in L1. Specifically, we set out to determine whether the character repetition effect observed in study 1 was the result of accessing the phonology and/or the orthography of L1 translation equivalents. Thus, we examined independently English word pairs that concealed a phonological or orthographic repetition via their Chinese translations while keeping the control semantic relatedness condition similar to that of the first study. We found that, in both the reading and listening experiments, phonological repetition in Chinese translations elicited amplitude reduction in bilingual participants, and this effect was not only comparable with the Chinese monolingual controls but also replicated the character repetition effect found in the first study. Furthermore, the hidden factor of phonological repetition in Chinese translations was also unconscious to bilinguals and did not interact with their behavioural performance. On the other hand, orthographic repetition in Chinese translations yielded no such effect in bilingual participants, despite the fact that Chinese monolinguals were sensitive to such repetition when visually presented with the task in Chinese. These findings strongly suggest that the nature of the information activated in L1 was phonological rather than orthographic.

As in the monolingual domain, most research on bilingual word comprehension has focussed on the visual processing of orthographic variables whereas little attention has been paid to phonology. For example, in empirical studies investigating the issue of cross-language activation with cognates or interlingual homographs (see Chapter one), the extent of phonological overlap between stimuli across languages is often unspecified. Some studies simply state that the phonology of the interlingual homographs used is different in the bilingual's two languages (Beauvillain & Grainger, 1987; Cristoffanini et al., 1986). In light of the result of study 2, it is possible that phonological overlap / neighbourhood is the determinant of most cross-language effects observed, and the difference in phonological consistency between studies using cognates and interlingual homographs might explain the discrepancies in their findings. Nevertheless, it is important to refer to a few available studies that have provided evidence for the active role of phonology in bilingual word recognition (Brysbaert et al., 1999; Dijkstra et al., 1999) as well as word production (Jared & Kroll, 2001; Jared & Szucs, 2002).

For example, Dijkstra et al (1999) tested bilinguals with interlingual stimuli that varied in their degree of orthographic, phonological, and semantic similarity, respectively, in Dutch (L1) and English (L2). In a progressive demasking task and a LDT, they reported effects of phonological similarity different from those elicited by orthographic and semantic similarity. Specifically, homographs and translation equivalents were responded to faster than control stimuli but near-homophones were responded to slower than control stimuli. The authors interpreted the inhibitory effect of phonological similarity based on the fact that Dutch and English words almost never have identical phonology (i.e., near-homophones), so that the two partially overlapping phonological representations competed with one another at the lexical level and delayed response time. On the other hand, homographs with complete overlap do exist across languages; they lead to stronger activation of orthographic representations and thus reduce identification time. This finding provided strong evidence for distinct contributions of phonological and orthographic codes to word recognition in bilinguals.

However, one problem in the above studies is that most European languages (e.g., Dutch, French, English, and Spanish) share the same alphabetical system and the grapheme-to-phoneme (spelling-to-sound) rules of these languages have considerable similarities. As a result, the extent to which the orthographic and phonological codes of these languages can be dissociated is very limited and they are likely to interact with one another during word processing. For example, in a study of English-Afrikaans bilinguals (Doctor & Klein, 1992), participants' responses to interlingual homophones (e.g., lake-lyk) and interlingual homographs (e.g., kind) in a generalised LDT were compared. It is obvious that the two sources of overlap between languages were not fully independent. While this limitation does not necessarily invalidate the findings, it may have undercut their strength. The dilemma is that if the study adopts languages that do not share the same writing scripts, such as Hebrew and English (Gollan et al., 1997), then interlingual homophones can be tested with the least confounding effects from orthography, but the study of cross-language orthographic activations becomes impossible due to the inexistence of homographs.

The study of Chinese-English bilinguals using an implicit priming paradigm via L1 translations constitutes an ideal context in which the contribution of phonological and orthographic codes can be analysed separately. On the one hand, grapheme-to-phoneme mapping in Chinese characters is totally arbitrary so that the activation of phonological and orthographic information can be prompted independently during Chinese word processing (see stimulus samples in Chapter 4). On the other hand, the critical conditions in the second study presented here were those involving phonological or orthographic repetition in the Chinese translations of

English word pairs; hence, the lack of visual and auditory relationship between Chinese characters and English words was not an issue because the experiment did not use interlingual homographs.

In the third study, we studied bilingual word production using a covert/silent picture naming task. Bilingual participants named pictures in L1 and L2 in a block-design experiment. The results were in favour of the language-nonselective access hypothesis: character repetition in Chinese translations modulated the ERPs of the bilingual participants while they made rhyming judgments in English. This finding is in line with most psycholinguistic and electrophysiological studies reviewed in chapters 3 and 4 (Colome, 2001; Hermans et al., 1998; Rodriguez-Fornells et al., 2005). It is also consistent with the concept of cross-language activation demonstrated in the first and second studies. However, the results of the production study also revealed some discrepancies between the underlying processes of word production and comprehension in L2.

The most evident contrast between comprehension and production was that access to translation equivalents in L1 was less implicit in this study and affected behavioural performance when bilinguals named pictures as compared to reading or listening to words in L2. In the English rhyming task, character repetition in Chinese significantly lengthened response times and increased error rates in bilingual participants, who reported intrusive experiences of the experimental factor in the non-target language. Interestingly however, awareness in this task on the part of the participants suggests that, contrary to what some researchers have argued (de Bot, 1992; Green, 1986), bilinguals do not have perfect control over the activation or the deactivation of words in L1 and L2 when speaking in one language. On the contrary, bilingual participants reported being aware of and yet unable to inhibit the activation of Chinese when naming pictures in English. However, in the Chinese character repetition task, which is supposed to reflect access to the output form of L1 spoken words, there was no sign of access to the English names of pictures. This finding establishes an asymmetry in cross-language activation during bilingual word production. In addition, this point must be modulated by the fact that we tested late bilinguals rather than highly proficient early bilinguals.

Until now, the general consensus in the literature of bilingual word production is that lexical access occurs in parallel in both languages up to the lemma level and, subsequently, the processing becomes language-specific from the phonological level onwards which is part of the lexical selection process.

> Hermans et al. (1998) summarises the situation as follows: " In a task in which the speaker is explicitly discouraged from accessing representations in his or her first and more dominant language, a bilingual speaker will indeed behave like a monolingual during the later stages of the process of lexical access. However, during the initial stages of the process of lexical access in a foreign language, a bilingual speaker cannot prevent interference from the first language. (p 226)"

Surprisingly, results obtained from the bilingual participants showed the exact opposite pattern: the effect of English rhymes was found 150 ms before that of character repetition in Chinese (i.e., the nontarget language) during the English rhyming task, indicating that (a) the initial stages of lexical processing may be language-selective; and (b) non-target language activation is subsequent to the retrieval of conceptual information as well as the phonological form of the picture names in the target language.

To integrate the above two findings, the current study seems to have revealed a novel mechanism underlying bilingual word production, that is different from previous models which have heavily focussed on the issue of lexical selection. For the Chinese-English bilinguals tested in the current study, L1 (i.e., Chinese) did not appear to be a source of interference in the initial stages of naming in L2 (i.e., English), because, in this period of time, lexical access was not parallel in both languages but rather selective. This was shown by the fact that, up to 550 ms post stimulus presentation, the ERPs of Chinese-English bilinguals did not differ significantly from that of the English monolinguals with respect to the Chinese character repetition factor (neither of the two groups was sensitive to the task-irrelevant factor). Most critically, within this period of time (i.e., 550 ms), not only was the ERP effect of semantic priming significant but the priming effect prompted by English rhyming also reached its peak. Therefore, the activation of lexical candidates in the non-target language did not seem to be limited to the first 550 ms after stimulus presentation.

The ERP effect of Chinese character repetition reached significance at around 650 ms, in the temporal window of the P600 component. The P600 effect is classically associated with the reanalysis of linguistic stimuli often triggered by syntactic anomalies (Friederici et al., 1996; Osterhout & Holcomb, 1992). Recent studies have not only demonstrated that lexical and semantic factors can modulate the syntactic P600 effect (Gunter et al., 2000; Osterhout et al., 1994), but also the fact that semantic anomalies can elicit a P600 effect in the absence of any syntactic violations or ambiguities (Kim & Osterhout, 2005; Kuperberg et al., 2003; Vissers et al., 2006). For example, Vissers et al. (2006) have found P600 elicited by a homophone (e.g., *bouks*) of the best completion word in a high-cloze sentence (e.g., in that library the pupils borrow *books*) but not in a low-cloze sentence (e.g., the pillows are stuffed with *books*), while the N400 was indifferent in the two conditions. Evidence like this has challenged the traditional syntactic account, and suggested that the P600 reflects a monitoring mechanism which checks processing errors during language integration/production when words have alternative interpretations or place the individual in a the state of indecision.

In study 3, bilingual word production was tested via covert picture naming. Participants had to make judgments on pairs of pictures on the basis of their Chinese or English names. The rhyming task was chosen because previous studies on monolinguals have established that rhyming is associated with reduced negativity in the N400 range during both reading (Grossi et al., 2001) and picture naming (Barrett & Rugg, 1990a). Furthermore, an auditory study has shown that target words spoken in different voices from prime words elicit the same pattern of ERP variations, indicating that this pattern does not index physical-acoustic mismatch, but only phonological match (Praamstra & Stegeman, 1993). Therefore, the N400 rhyming effect appears to reflect the mental preparation of spoken sounds in as much as the N2 effect indexes response inhibition in a dual-choice go/nogo paradigm (see Method section for a review). However, the possibility remains that when bilingual participants make rhyming judgments on picture names in the target language they may involuntarily and subsequently name the picture in the non-target language during reanalysis of the stimuli, despite the fact that the task instructions did not explicitly encourage them to access both languages. The reprocessing of the picture names may have happened as part of the speech monitoring process and accounted for the P600 effect to Chinese character repetition observed in the current experiment. In other words, bilingual participants would have accessed Chinese labels of the pictures as they were checking for possible sources of errors and preparing for the response to the English rhyming task (note that the average RT in the Chinese character repetition condition was 920 ms), but not in the initial stages of lexical selection. The fact that, in the current study, bilingual participants were tested both in the Chinese and the English tasks may have encouraged this monitoring process. Note also that this interpretation is consistent with Costa et al.'s (2005) model of word selection in bilinguals, since lexical selection appears to be language selective. Suppose the process of word production could be examined more naturally, without superfluous influences from the experimental task itself, we would expect to find language-specific retrieval of spoken words, as it was seen in the first portion of the ERP data in the current experiment. This possibility will be considered more extensively in the following section on the limitations of the experiments presented in this thesis.

8. 2. From bilingualism to cognitive psychology

The overarching goal of this thesis was to better understand how bilinguals read, listen, and speak in their L2. Beyond this, the current studies have provided some results that also shed light on more general issues in the cognitive psychology of language.

There is an important debate in research on the mechanisms of reading on whether the meaning of words is retrieved through a phonological route, an orthographic route or a combination of the two (the dual route model). Until now, it has been commonly accepted that reading involves implicit access to the sound form of words (Rayner & Pollatsek, 1989) but, there is little consensus regarding the mechanism underlying this process and to what extent phonological access is mandatory for semantic access. Some theorists of phonology strongly argue that lexical access is mediated by automatic and mandatory activation of the phonological code (Lukatela & Turvey, 1991; Luo et al., 1998; Van Orden, 1987). Others claim that meaning can be retrieved directly via a visual-orthographic route (Chen & Shu, 2001; Coltheart, 1997; Pugh et al., 1994) while the amount of phonological processing involved depends on factors such as writing systems (Frost, 1994), reading skills (Unsworth & Pexman, 2003), lexical properties (Jared & Seidenberg, 1991), and task demands (Milota et al., 1997).

In the literature, phonological encoding in reading has often been investigated with homophones and pseudohomophones (pronounceable non-words that sound like a word, Lesch & Pollatsek, 1998; Lukatela & Turvey, 1994a; Lukatela & Turvey, 1994b). For example, in a semantic relatedness task where access to phonology is not explicitly required, word-homophone pairs (e.g., lion – bare) and word-pseudohomophones pairs (e.g., table – chare) yielded increased reaction time and error rate as compared to control pairs (e.g., lion – bean, table – chark; Luo et al., 1998). These findings have been taken as evidence that phonological information is automatically accessed in silent reading and is a stage of visual word recognition. However, explicit phonological manipulations (e.g., the use of pseudohomophones) create an artificial situation that is not commonly encountered in everyday life. Moreover, the existence of homophone effects does not speak to the question of phonological mediation in the process of accessing word meaning, neither does it effectively rule out the possibility of a visually-based, non-phonological approach to reading. In fact, studies that exclusively examine phonological variables are likely to misjudge the role of orthography. In studies of monolingual individuals, this issue is further complicated by the technical difficulty of testing both phonological and orthographic effects without resorting to explicit or artificial manipulations.

In the second study of the thesis, we have tested bilinguals' responses to phonological and orthographic repetition in L1 translations while reading and listening to words in L2. This implicit priming paradigm based on the translation equivalents of ordinary words in the native language avoided the artificial context and other confounding variables yielded by the use of homographs, homophones, and pseudohomophones. Furthermore, thanks to the monosyllabic nature of Chinese characters (i.e., one character always represents one syllable), overlaps in phonology and orthography were perfectly matched across conditions (see examples of stimuli in Chapter 4).

As reported in Chapter 6, the results provided evidence that when bilinguals read or listen to words in their second language, the phonological form of translations in the first language is spontaneously accessed but orthography is not. This finding strongly argues in favour of automatic phonological activation in silent reading and is somewhat incompatible with the dual-route hypothesis. Indeed, potential orthographic mediation did not survive implicit priming via translations, which is a clear indication that it is not a natural or automatic process. Instead, word comprehension in both visual and auditory modality was spontaneously accompanied by phonological mediation in the absence of participants' awareness.

Developmental research has demonstrated that children's phonological knowledge plays a key role in the acquisition of reading (Admas, 1990) and predicts early reading abilities (Bradley & Bryant, 1983). Furthermore, deficits in the development of phonological representations prior to literacy acquisition have been considered the cause of later reading impairments (Ziegler & Goswami, 2005), and brain damage that caused language impairment usually affects the oral picture naming and writing-to-dictation more severely than written naming (Law & Bella, 2001; Law et al., 2006). Interestingly, the Chinese-English bilingual participants tested here acquired English as a second language in a classroom context where they learned to speak, read, and write at the same time. Unlike native speakers of English, they did not experience a developmental period where they became familiarised with the phonological characteristics of English before being exposed to its orthography. Thus, our findings of phonological access during the processing of words in the second language are not biased towards phonology due to the context of language acquisition. Therefore, I propose that spontaneous phonological access in silent reading is an intrinsic property of reading in all languages. Future studies looking at different language combinations will shed more light on this hypothesis.

Another long-standing research question in language research concerns the dissociation between verbal and nonverbal conceptual processing of stimuli. For example, does the conceptual processing of an image which corresponds to a concrete object automatically activate the corresponding orthographic/phonological memory system? While behavioural differences in the access to the meaning of images from words suggest multiple conceptual stores (McCarthy & Warrington, 1988; Shallice, 1993) and are consistent with neuroimaging evidence for the segregation of verbal and nonverbal semantic access (Thierry & Price, 2006), there is little consensus on whether the two processing domains can be functionally dissociated. For example, Lupker et al. (1989) found that picture categorisation facilitated the naming of pictures with rhyming labels but not the picture names themselves (i.e., word naming). This study provided mixed evidence for the debate of phonological activation during semantic processing of pictures (Lupker & Williams, 1989). The authors argued that the rhyming effect resulted from participants' strategy involving sub-vocalisation of the names of the pictures. This would have affected picture naming more than word naming because the former often lasted longer than the latter. Therefore, the absence of initial activation in lexical memory would be the norm during semantic processing of pictures (see also Babbitt, 1982).

Although it was not the aim of the third study of the present thesis, this very issue was examined in both monolinguals and bilinguals because participants were asked to either make semantic relatedness judgment on pairs of pictures while refraining from accessing their name or make rhyming judgements on the name of the same pictures in other blocks. To our surprise, we found evidence for synchronous phonological and semantic priming in English monolinguals. The Chinese bilinguals, however, were unaffected by these manipulations in either of their two languages (i.e., rhyming and character repetition), suggesting that they did not make use of lexical information during conceptual analysis (see Chapter 6 for detailed results). This finding is particularly striking given the extended time-course of ERP recording (i.e., up to 1 sec after the picture was presented). To my knowledge, it is the first time that an interaction between language ability (i.e., monolingual vs. bilingual) and pattern of lexical-semantic processing of images has been demonstrated. Our results show a "bilingual benefit" in controlling access to linguistic memory during the processing of meaningful stimuli.

The above conclusion is in line with the view that bilingual experience has enhancing effects on a wide variety of mental abilities. In a series of studies, Bialystok and her colleagues have shown that, as compared to monolinguals, bilinguals have enhanced performance in circumstances that require a high level of involvement of executive functions to effectively control and allocate attentional resources in order to meet task demands because they need to manage two competing languages in everyday life (Bialystok, 2001, 2005)[11]. This bilingual advantage has been established in childhood (Carlson & Meltzoff, 2008), adulthood (Bialystok et al., 2006), and later life (Bialystok et al., 2004).

For example, in a typical Simon task, coloured stimuli are presented either on the left or the right side of a computer screen. Participants need to respond to the colour of the stimuli by pressing one of two keys either with the left of the right hand. The congruent trials involve colours for which a correct response is on the same side as the stimulus and the reverse is true in incongruent trials. Monolingual individuals suffer from the conflicting cues at the opposite location in the incongruent trials (Lu & Proctor, 1995). Bilinguals have been found to outperform monolinguals on various versions of the Simon task and other similar tasks that require inhibition of task irrelevant information (Bialystok, 1999, 2006; Bialystok et al., 2004; Bialystok et al., 2006; Bialystok & Shapero, 2005).

However, while the literature provides substantial support for the claim of superior performance of bilinguals as comparable to monolinguals in nonverbal tasks, it remains unclear whether this bilingual advantage results from the fact that they practice two, instead of one, languages. Indeed, there is little direct evidence for the "bilingualism account", namely that bilinguals develop greater flexibility than monolinguals in linguistic activities due to the demands of coordinating two languages in everyday life. By showing that bilingual participants can inhibit the activation of task-irrelevant lexical information during a semantic relatedness judgment task on pictures, we provide support for a link between language control and generic executive function abilities in bilinguals.

[11] Others have argued that non-linguistic factors, such as ethnicity and socioeconomic status, could explain at least partially the differences between bilinguals and monolinguals in attention and executive functions (Farach & Noble, 2005; Mezzacappa, 2004; Morton & Harper, 2007).

8. 3. Limitations and future research

As in the case of most electrophysiological studies of language processing in general and those of bilingual functioning in particular, the experiments reported here are limited by a number of practical considerations. Here, I introduce these considerations; I explain the reason why we had to compromise regarding particular stimulus properties and not others and I propose several ideas to reduce the methodological shortcomings and other limitations in the thesis for future research. Second, I will discuss the possibility to modify and apply the implicit priming paradigm developed here for the investigation of psycholinguistic models of bilingual language processing.

The first two studies in the thesis examined bilinguals in a single-word context, and focused on lexical-semantic stages of word processing. A source of variation when testing single word processing in the absence of any linguistic context is the existence of multiple definitions and translation equivalents in the other language of the participants. Most words in English activate more than one meaning. For example, the word "spring" may refer to the first season in a year, a small stream of water, or an elastic coil of wire. Other words may have similar meanings but different grammatical status (e.g., "smell" is both a noun and a verb). Alternative meanings may yield access to several Chinese translations and sometimes prompt access to a translation that is wholly different to the experimentally intended one. Furthermore, English words with a single primary definition may still be associated with more than one Chinese translation simply because there can be several Chinese words representing the same meaning depending on the individual reader or listener. Although particular attention was paid to these issues when selecting the stimuli, this cross-language lexical-semantic "noise" could not be eliminated due to the lack of a post-experimental verification procedure[12]. Nevertheless, the fact that cross-language priming was significant in experiment series 1 and 2 despite this source of noise suggest that cross-language activation is a very robust phenomenon.

With regard to the stimuli and the experimental task used, the proportion and types of semantic relatedness might have been two other sources of confounds. Previous semantic priming studies have shown that the magnitude of priming increases as the proportion of related trials increases (De Groot, 1984). This is explained in terms of an expectancy strategy which benefits in high related/unrelated ratios (Neely, 1991). The proportions of semantically related stimulus pairs was 50%, 25%, and 25% in the first, second, and third study, respectively, in order to counterbalance the experimental conditions (e.g., Chinese character repetition vs. English rhymes). While the participants would have expected as many related and unrelated word pairs in study 1, the semantic priming effect was likely to combine with a probability effect due to the relatively low proportion of semantic relatedness in study 2 and 3 (Donchin, 1981; Sutton et al., 1965). Indeed, in both studies 2 and 3, a late parietal complex (LPC/P600) was visible between 500 and 700 ms in the semantically related condition. This LPC is likely to be a P300-family event, indexing re-evaluation of the stimulus often observed in response to a low-probability target stimulus.

As reviewed in Chapter 3, previous studies on semantic priming effects in L2 have differentiated categorical from associative priming at both the behavioural and

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[12] The population from which the bilingual participants were drawn was a small group of Chinese students who are closely related to one and another. During the debriefing stage, the factor in Chinese translations was not explicitly revealed to prevent future participants from knowing this core component of the experimental paradigm which was supposed to be implicit. As a result, there was no way to find out whether or not the bilingual participants have accessed the intended Chinese translations in all the conditions.

the electrophysiological levels (Kotz, 2001; Kotz & Elston-Guttler, 2004). For example, categorical L2 word pairs (e.g., "heart" – "liver") did not bring forth an N400 priming effect in late learners of L2 while associative word pairs (e.g., "heart" – "love") did, This suggests that the two types of relatedness tap into different processing mechanisms or levels of sensitivity within semantic priming. However, this distinction was not made in the current studies and the semantic priming in word pairs or pairs of pictures involved both types of relatedness. In light of the findings reported by Kotz and her colleagues, a semantic priming paradigm such as that implemented in the present thesis would benefit from using only associative word pairs.

However, the mix of associated and categorical word pairs in the current experiment was the result of practical concerns which was unlikely to be overcome without compromising on other more important properties of the stimuli (e.g., the consistency of character repetition in L1). It is noteworthy that bilingual performance in translation tasks has been shown to be affected by factors such as word concreteness and lexical frequency (De Groot, 1992; De Groot, 1995), which can be readily examined by manipulating these characteristics as an experimental factor with minimal modifications to the current paradigm.

The present thesis examined word processing in L2 in the context of reading comprehension, listening comprehension, and covert picture naming. The fact that all bilingual participants involved were drawn from the same population allowed systematic comparisons to be made across the three domains. However, this also restricted the degree to which current findings can be generalised, most significantly, in three ways.

First, Grosjean (1998a) has argued that language proficiency is the main defining characteristic of bilingual individuals and that proficiency accounts for different performances as well as approaches to L2 word processing. Indeed, in the Revised Hierarchical Model (Kroll & Stewart, 1994), the determining factor of the processing patterns of lexical-semantic access in bilinguals is their proficiency in L2: beginners are more reliant on word association and proficient speakers are more reliant on conceptual mediation, respectively. The present thesis made the case that late fluent Chinese-English bilinguals accessed Chinese translations while processing words in English. As the studies did not compare bilinguals at different levels of L2 proficiency, the influence of proficiency on cross-language interactions remains an open question. Therefore, current findings cannot fully address the assumptions behind the RHM until further evidence regarding the effects of L2 proficiency becomes available.

Second, the studies reported here lacked diversity in L2 learning history among the bilingual participants. Participants have been learning English as their L2 in the classroom since the age of 12, and by the time of experimentation, they had lived and studied at a UK institution between one and two years. Previous studies have suggested that differences in the age and context of L2 acquisition can result in substantial variability in language knowledge, processing patterns, lexical representations, and translation performances (H. -C. Chen & Leung, 1989; De Groot, 1995; Kroll & Curley, 1988; Segalowitz, 1997). One recent study in particular has shown that, compared to behavioural assessments, ERPs are particularly sensitive to L2 words acquired through classroom instructions (McLaughlin et al., 2004). Since Chinese-English bilinguals gain basic knowledge of common words via classroom instruction and mainly based on word associations, this finding may account for the absence of behavioural effects in studies 1 and 2. Studies looking at bilingual participants who acquired L2 in different contexts and at different ages are needed to test the effect of these other variables.

Third, research on Chinese-English bilinguals or even Chinese monolinguals constitutes a relatively small, but growing part of the existing literature. Most previous studies have looked at bilinguals whose L1 and L2 are both European languages (e.g., English, French, Spanish, and Dutch). Therefore, subsequent studies will face two major questions regarding the native language and the cultural background of bilingual individuals: (a) is cross-language activation of L1 translation equivalents generalisable to other language/cultural combinations? (b) What exactly gives rise to the character repetition priming effect in Chinese? The available Chinese literature does not allow us to draw specific conclusions regarding the nature of L1 access. Individual Chinese characters always have meanings; therefore it is unclear whether the priming effect found is purely formal/lexical or partly conceptual. I have shown that studies of bilingual individuals can contribute novel understanding in the study of language processing in general, but our knowledge of language-specific processing in monolinguals appears to be the bottleneck for the understanding of bilingual functioning.

8. 4. Conclusion

The overarching goal of the present thesis was to reveal the operating mechanisms underlying bilingual word processing. The findings demonstrated that (a) translation equivalents in L1 are accessed when bilinguals read, listen, and retrieve the phonological form of words in L2; (b) cross-language activation is automatic, unconscious, simultaneous to semantic access, and mediated by the phonological route during reading and listening; (c) it is delayed, conscious, and unidirectional (L2→L1) during covert picture naming (i.e., word production here); (d) bilingual individuals can access conceptual representations from pictures without accessing corresponding lexical labels in either language, an ability that is unseen in the monolingual individuals.

References

Adler, M. (1977). *Collective and Individual Bilingualism: a sociolinguistic study.* Hamburg: Helmut Buske Verlag.

Admas, M. (1990). *Beginning to Read.* Cambridge, MA: MIT Press.

Alho, K. (1995). Cerebral generators of mismatch negativity (MMN) and its magnetic counterpart (MMNm) elicited by sound changes. *Ear Hear* **16**(1): 38-51.

Allison, T., Wood, C. C., & McCarthy, G. M. (1986). The central nervous system. In M. Coles, E. Donchin & S. Porges (Eds.), *Psychophysiol: Systems, Processes, and Applications* (pp. 5-25). New York: Guilford.

Alvarez, P. R., Holcomb, P. J., & J, G. (2003). Accessing word meaning in two languages: An event-related brain potential study of beginning bilinguals. *Brain Lang* **87**(2): 290-304.

Anderson, J. E., & Holcomb, P. J. (1995). Auditory and visual semantic priming using different stimulus onset asynchronies: an event-related brain potential study. *Psychophysiol* **32**(2): 177-190.

Ardal, S., Donald, M. W., Meuter, R., Muldrew, S., & Luce, M. (1990). Brain responses to semantic incongruity in bilinguals. *Brain Lang* **39**(2): 187-205.

Assadollahi, R., & Pulvermuller, F. (2003). Early influences of word length and frequency: a group study using MEG. *Neuroreport* **14**(8): 1183-1187.

Babbitt, B. C. (1982). Effect of task demands on dual coding of pictorial stimuli. *J Exp Psychol Learn Mem Cogn* **8**(1): 73-80.

Balota, D. A., Paul, S., & Spieler, D. (1999). Attentional control of lexical processing pathways during word recognition and reading. In S. Garrod. & M. Pickering. (Eds.), *Studies in Cognition: Language Processing* (pp. 15-57). London: UCL Press.

Barrett, S. E., & Rugg, M. D. (1990a). Event-related potentials and the phonological matching of picture names. *Brain Lang* **38**(3): 424-437.

Barrett, S. E., & Rugg, M. D. (1990b). Event-related potentials and the semantic matching of pictures. *Brain Cogn* **14**(2): 201-212.

Basnight-Brown, D. M., & Altarriba, J. (2007). Differences in semantic and translation priming across languages: the role of language direction and language dominance. *Mem Cognit* **35**(5): 953-965.

Beauvillain, C., & Grainger, J. (1987). Accessing interlexical homographs: some limitations of a language-selective access. *J. Mem. & Lang* **26**: 658-672.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *J Cogn Neurosci* **8**(6): 551-565.

Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalogr Clin Neurophysiol* **60**(4): 343-355.

Bentin, S., Mouchetant-Rostaing, Y., Giard, M. H., Echallier, J. F., & Pernier, J. (1999). ERP manifestations of processing printed words at different psycholinguistic levels: time course and scalp distribution. *J Cogn Neurosci* **11**(3): 235-260.

Bentin, S., & Peled, B. S. (1990). The contribution of task-related factors to ERP repetition effects at short and long lags. *Mem Cognit* **18**: 359-366.

Besson, M., & Macar, F. (1986). Visual and auditory event-related potentials elicited by linguistic and non-linguistic incongruities. *Neurosci Lett* **63**(2): 109-114.

Besson, M., & Macar, F. (1987). An event-related potential analysis of incongruity in music and other non-linguistic contexts. *Psychophysiol* **24**(1): 14-25.

Bhatia, T. K., & Ritchie, W. C. (2004a). *The Handbook of Bilingualism*. Cambridge, MA: Blackwell.

Bhatia, T. K., & Ritchie, W. C. (2004b). Introduction. In T. K. Bhatia & W. C. Ritchie (Eds.), *The Handbook of Bilingualism* (pp. 1-2). Cambridge, MA: Blackwell.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Dev* **70**: 636-644.

Bialystok, E. (2001). *Bilingualism in Developement: Language, Literacy, and Cognition.* New York: Cambridge University Press.

Bialystok, E. (2005). Consequences of bilingualism for cognitive development. In J. F. Kroll & M. B. De Groot A (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches.* (pp. 417-432). New York: Oxford University Press.

Bialystok, E. (2006). Effect of bilingualism and computer video game experience on the Simon task. *Can J Exp Psychol* **60**(1): 68-79.

Bialystok, E., Craik, F. I., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: evidence from the Simon task. *Psychol Aging* **19**(2): 290-303.

Bialystok, E., Craik, F. I., & Ryan, J. (2006). Executive control in a modified antisaccade task: Effects of aging and bilingualism. *J Exp Psychol Learn Mem Cogn* **32**(6): 1341-1354.

Bialystok, E., & Shapero, D. (2005). Ambiguous benefits: the effect of bilingualism on reversing ambiguous figures. *Dev Sci* **8**(6): 595-604.

Bowers, J. S., Mimouni, Z., & Arguin, M. (2000). Orthography plays a critical role in cognate priming: Evidence from French/English and Arabic/French cognates. *Mem Cognit* **28**: 1289-1296.

Bradley, L., & Bryant, P. (1983). Categorizing sounds and learning to read - a causal connection. *Nature* **301**: 419-421.

Brown, C. M., Hagoort, P., & ter Keurs, M. (1999). Electrophysiological signatures of visual lexical processing: Open- and closed-class words. *J Cogn Neurosci* **11**(3): 261-281.

Brunia, C. H. M. (1989). Correcting ocular artifacts in the EEG: A comparison of several methods. *J Psychophy* **3**: 1-50.

Brysbaert, M., Van Dyck, G., & Van de Poel, M. (1999). Visual word recognition in bilinguals: evidence from masked phonological priming. *J Exp Psychol Hum Percept Perform* **25**(1): 137-148.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cogn Neuropsychol* **14**: 177-208.

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Dev Sci* **11**(2): 282-298.

Chen, H. C. (1990). Lexical processing in non-native language: effect of language proficiency and learning strategy. *Mem Cognit* **18**(279-88).

Chen, H. C., & Leung, Y. S. (1989). Patterns of lexical processing in a non-native language. *J. Exp. Psychol. Learn. Mem. Cogn* **15**(2): 316-325.

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

Chen, H. C., & Shu, H. (2001). Lexical activation during the recognition of Chinese characters: evidence against early phonological activation. *Psychon Bull Rev* **8**(3): 511-518.

Christoffels, I. K., De Groot, A. M. B., & Kroll, J. F. (2006). Memory and language skills in simultaneous interpreting: The role of expertise and language proficiency. *J Mem Lan* **54**: 324-345.

Christoffels, I. K., Firk, C., & Schiller, N. O. (2007). Bilingual language control: an event-related brain potential study. *Brain Res* **1147**: 192-208.

Colome, A. (2001). Lexical Activation in Bilinguals' Speech Production: Language-Specific or Language-Independent? *J. Mem. & Lang* **45**(4): 721-736.

Coltheart, M. (1981). The MRC psycholinguistic database. *Q. J. Exp Psychol* **33**: 497-505.

Coltheart, M. (1997). Reading comprehension is not exclusively reliant upon phonological representation. *Cogn Neuropsychol.* **14**(1): 167-175.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1997). *Access to the Internal Lexicon* (Vol. VI). New York: Academic Press.

Connolly, J. F., & Phillips, N., A. (1994). Event-related potential components reflect phonologica and semantic processing of the terminal word of spoken sentences. *J Cogn Neurosci* **6**: 256-266.

Costa, A. (2005). Lexical access in bilingual production. In J. F. Kroll & A. De Groot, M. B (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches* (pp. 308-325). New York: Oxford University Press.

Costa, A., & Caramazza, A. (1999). Is lexical selection in bilingual speech production language-specific? Further evidence from Spanish-English and English-Spanish bilinguals. *Biling: Lang. Cogn* **2**: 231-244.

Costa, A., Caramazza, A., & Sebastian-Galles, N. (2000). The cognate facilitation effect: implications for models of lexical access. *J Exp Psychol Learn Mem Cogn* **26**(5): 1283-1296.

Costa, A., Colome, A., Gomez, O., & Sebastian-Galles, N. (2003). Another look at cross-language competition in bilingual speech production: Lexical and phonological factors. *Biling: Lang. Cogn* **6**: 167-179.

Costa, A., La Heij, W., & Navarrete, E. (2006). The dynamics of bilingual lexical access. *Biling: Lang. Cogn* **9**(2): 137-151.

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in bilingual's two lexicons compete for selection? *J Mem Lan* **41**: 365-397.

Costa, A., & Santesteban, M. (2004). Bilingual word perception and production: two sides of the same coin? *Trends Cogn Sci* **8**(6): 253; author reply 254.

Costa, A., Santesteban, M., & Cano, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. *Brain Lang* **94**(1): 94-103.

Cristoffanini, P., Kirsner, K., & Milech, D. (1986). Bilingual lexical representation: The status of Spanish-English cognates. *Q J Exp Psychol A* **38**: 367-393.

Crystal, D. (1987). *The Cambridge Encyclopedia of Language.* Cambridge, UK: Cambridge University Press.

Davis, M. H. (2004). Units of representation in visual word recognition. *Proc Natl Acad Sci U S A* **101**(41): 14687-14688.

de Bot, K. (1992). A bilingual model: Levelt's "speaking" model adapted. *Applied Linguistics* **13**: 1-24.

De Bruijn, E. R. A., Dijkstra, T., Chwilla, D. J., & Schriefers, H. (2001). Language context effects on interlingual homograph recognition: evidence from event-related potentials and response times in semantic priming. *Biling: Lang. Cogn* **4**(2): 155-168.

De Diego Balaguer, R., Sebastian-Galles, N., Diaz, B., & Rodriguez-Fornells, A. (2005). Morphological processing in early bilinguals: an ERP study of regular and irregular verb processing. *Brain Res Cogn Brain Res* **25**(1): 312-327.

De Groot, A. M. B. (1984). Primed lexical decision: combined effects of the proportion of related prime-target pairs and the stimulus-onset asynchrony of prime and target. *Q J Exp Psychol* **36A**: 253-280.

De Groot, A. M. B. (1992). Determinants of word translation. *J Exp Psychol Learn Mem Cogn* **18**: 1001-1018.

De Groot, A. M. B. (1995). Determinants of bilingual lexicosemantic organisation. *CALL* **8**: 151-180.

De Groot, A. M. B., Delmaar, P., & Lupker, S. J. (2000). The processing of interlexical homographs in translation recognition and lexical decision: support for non-selective access to bilingual memory. *Q J Exp Psychol* **53**(2): 397-428.

De Groot, A. M. B., & Nas, G. L. J. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *J Mem Lan* **30**: 90-123.

De Moor, W. (1998). *Visual woordherkenning bij tweetalige personen [Visual word recognition in bilinguals], Unpublished master's thesis.* University of Ghent, Belgium.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychol Rev* **93**(3): 283-321.

Dijkstra, T., De Bruijn, E. R. A., Schriefers, H., & Ten Brinke, S. (2000). More on interlingual homograph recognition: language mixing versus explictness of instruction. *Biling: Lang. Cogn* **3**(1): 69-78.

Dijkstra, T., Grainger, J., & Van Heuven, W. J. B. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *J. Mem. & Lang* **41**(4): 496-528.

Dijkstra, T., & Van Heuven, W. J. B. (1998). The BIA model and bilingual word recognition. In J. Grainger & A. M. Jacobs (Eds.), *Localist Connectionist Approaches to Human Cognition* (pp. 189-225). Hillsdale: NJ: Lawrence Erlbaum Associates.

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Biling: Lang. Cogn* **5**: 175-197.

Dijkstra, T., & Van Heuven, W. J. B. (2006). On Language and the Brain-Or on (Psycho)linguists and Neuroscientists? Commentary on Rodriguez-Fornells et al. *Lang Learn* **56**(1): 191-197.

Dijkstra, T., Van Jaarsveld, H., & Ten Brinke, S. (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Biling: Lang. Cogn* **1**: 51-66.

Doctor, E. A., & Klein, D. (1992). Phonological processing in bilingual word recognition. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 237-252). Amsterdam: Elsevier.

Donchin, E. (1979). Event-related brain potentials: a tool in the study of human information processing. In H. Begleiter (Ed.), *Evoked Potentials and Behavior* (pp. 13-75). New York: Plenum.

Donchin, E. (1981). Presidential address, 1980. Surprise!...Surprise? *Psychophysiol* **18**(5): 493-513.

Duyck, W. (2005). Translation and associative priming with cross-lingual pseudohomophones: evidence for nonselective phonological activation in bilinguals. *J Exp Psychol Learn Mem Cogn* **31**(6): 1340-1359.

Ehri, L. C., & Ryan, E. B. (1980). Performance of bilinguals in a picture-word interference task. *J Psycholinguist Res* **9**(3): 285-302.

Eimer, M. (1993). Effects of attention and stimulus probability on ERPs in a Go/Nogo task. *Biol Psychol* **35**(2): 123-138.

Elston-Guttler, K. E. (1996). Processing L1 homonyms, polysemous nouns, and cognates in the L2: Evidence of L1 lexical-conceptual relationships as an influential factor in L2 lexical processing. *Working papers in English and Applied Linguistics* **3**: 59-78.

Elston-Guttler, K. E., & Friederici, A. D. (2005). Native and L2 processing of homonyms in sentential context. *J Mem Lang* **52**(2): 256-283.

Elston-Guttler, K. E., Gunter, T. C., & Kotz, S. A. (2005). Zooming into L2: Global language context and adjustment affect processing of interlingual homographs in sentences. *Brain Res Cogn Brain Res* **25**: 57-70.

Elston-Guttler, K. E., Paulmann, S., & Kotz, S. A. (2005). Who's in control? Proficiency and L1 influence on L2 processing. *J Cogn Neurosci* **17**(10): 1593-1610.

Farach, M. J., & Noble, K. G. (2005). Socio-economic influences on brain development: a preliminary study. In U. Mayr, E. Awh & S. W. Keele (Eds.), *Developing Individuality in the Human Brain: A Tribute to Michael Posner.* (pp. 189-208). Washingto, D. C.: APA.

Farch, C., & Kasper, G. (1986). Cognitive dimensions of language transfer. In E. Kellerman & M. Smith (Eds.), *Cross-Linguistic Influence in Second Language Acquisition*. Oxford: Pergamon Press.

Federmeier, K. D., & Kutas, M. (2001). Meaning and modality: influences of context, semantic memory organization, and perceptual predictability on picture processing. *J Exp Psychol Learn Mem Cogn* **27**(1): 202-224.

Fiez, J. A., & Petersen, S. E. (1998). Neuroimaging studies of word reading. *Proc Natl Acad Sci U S A* **95**(3): 914-921.

Fischler, I., Boaz, T. L., McGovern, J., & Ransdell, S. (1987). An ERP analysis of repetition priming in bilinguals. *Electroencephalogr Clin Neurophysiol Suppl* **40**: 388-393.

Fox, E. (1996). Cross-language priming from ignored words: Evidence for a common representational system in bilinguals. *J Mem Lang* **35**: 353-370.

French, R. M., & Jacquet, M. (2004). Understanding bilingual memory: models and data. *Trends Cogn Sci* **8**(2): 87-93.

Friederici, A. D. (2004). Event-related brain potential studies in language. *Curr Neurol Neurosci Rep* **4**(6): 466-470.

Friederici, A. D., Hahne, A., & Mecklinger, A. (1996). Temporal structure of syntactic parsing: early and late event-related brain potential effects. *J Exp Psychol Learn Mem Cogn* **22**: 1219-1248.

Frings, C., & Groh-Bordin, C. (2007). Electrophysiological correlates of visual identity negative priming. *Brain Res* **1176**: 82-91.

Frost, R. (1994). Prelexical and postlexical strategies in reading: evidence from a deep and a shallow orthography. *J Exp Psychol Learn Mem Cogn* **20**(1): 116-129.

Frost, R. (1998). Toward a strong phonological theory of visual word recognition: true issues and false trails. *Psychol Bull* **123**(1): 71-99.

Ganis, G., Kutas, M., & Sereno, M. (1996). The search for "Common Sense": An electrophysiological study of the comprehension of words and pictures in reading. *J Cogn Neurosci* **8**(2): 89-106.

Gerard, L. D., & Scarborough, D. L. (1989). Language-specific access of homographs by bilinguals. *J. Exp. Psychol. Learn. Mem. Cogn* **15**: 305-313.

Gevins, A., Le, J., Leong, H., McEvoy, L. K., & Smith, M. E. (1999). Deblurring. *J Clin Neurophysiol* **16**(3): 204-213.

Glaser, W. R. (1992). Picture naming. *Cognition* **42**(1-3): 61-105.

Gollan, T. H., & Acenas, L. A. (2000). *Tip-of-the-tongue incidence in Spanish-English and Tagalog-English bilinguals.* Paper presented at the Third International Symposium on Bilingualism, Bristol, U.K.

Gollan, T. H., & Acenas, L. A. (2004). What is a TOT? cognate and translation effects on tip-of-the-tongue States in Spanish-English and Tagalog-English bilinguals. *J Exp Psychol Learn Mem Cogn*, **30**(1): 246-269.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: masked priming with cognates and noncognates in Hebrew-English bilinguals. *J Exp Psychol Learn Mem Cogn* **23**(5): 1122-1139.

Grainger, J. (1988). Neighborhood frequency effects in visual word recognition and naming. *IPO Annual Progress Report* **23**: 92-101.

Grainger, J., & Dijkstra, T. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 207-220). Amsterdam: Elsevier.

Grainger, J., & Frenck-Mestre, C. (1998). Masked priming by translation equivalents in proficient bilinguals. *Lang Cogn Proc* **13**: 601-623.

Grainger, J., & Segui, J. (1990). Neighborhood frequency effects in visual word recognition: a comparison of lexical decision and masked identification latencies. *Percept Psychophys* **47**(2): 191-198.

Gratton, G., Coles, M. G., & Donchin, E. (1989). A procedure for using multi-electrode information in the analysis of components of the event-related potential: vector filter. *Psychophysiol* **26**(2): 222-232.

Green, D. W. (1986). Control, activation and resource: A framework and a model for the control of speech in bilinguals. *Brain Lang* **27**: 210-223.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Biling: Lang. Cogn* **1**: 67-81.

Greenberg, S. N., & Saint-Aubin, J. (2004). Letter detection for homographs with different meanings in deferent language texts. *Biling: Lang. Cogn* **7**: 241-253.

Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. *Percept Psychophys* **28**(4): 267-283.

Grosjean, F. (1982). Bilingualism in the world. In *Life with Two Languages: An Introduction to Bilingualism.* (pp. 1). Cambridge, MA: Harvard University Press.

Grosjean, F. (1985). The bilingual as a competent but specific speaker-hearer. *JMMD* **6**: 467-477.

Grosjean, F. (1994). Individual bilingualism. *ELL*: 1656-1660.

Grosjean, F. (1997). Processing mixed language: Issues, findings and models. In M. B. De Groot A & J. F. Kroll (Eds.), *Tutorials in Bilingualism: Psycholinguistic Perspectives* (pp. 225-254). Mahwah, NJ: Lawrence Erlbaum Associates.

Grosjean, F. (1998a). Studying bilingualism: methodological and conceptual issues. *Biling: Lang. Cogn* **1**: 131-149.

Grosjean, F. (1998b). Transfer and language mode. *Biling: Lang. Cogn* **1**(175-176).

Grosjean, F. (2000). Processing mixed language: issues, findings, and models. In W. Li (Ed.), *The Bilingual Reader* (pp. 443-469). London: Routledge.

Grosjean, F. (2001). The bilingual's language modes. In L. N. Janet (Ed.), *One mind, Two languages: Bilingual Language Processing* (pp. 1-22). Oxford: Blackwell.

Grosjean, F., Li, P., Munte, T. F., & Rodriguez-Fornells, A. (2003). Imaging bilinguals: When the neurosciences meet the language sciences. *Biling: Lang. Cogn* **6**: 159-165.

Grossi, G., Coch, D., Coffey-Corina, S., Holcomb, P. J., & Neville, H. J. (2001). Phonological processing in visual rhyming: a developmental erp study. *J Cogn Neurosci* **13**(5): 610-625.

Grubb, J. D., Bush, A. M., & Geist, C. R. (1998). Effects of second language study of phonemic discrimination and auditory event-related potentials in adults. *Percept Mot Skills* **87**(2): 447-456.

Gunter, T. C., Friederici, A. D., & Schriefers, H. (2000). Syntactic gender and semantic expectancy: ERPs reveal early autonomy and late interaction. *J Cogn Neurosci* **12**(4): 556-568.

Guo, T., & Peng, D. (2006). Event-related potential evidence for parallel activation of two languages in bilingual speech production. *Neuroreport* **17**(17): 1757-1760.

Guo, T., & Peng, D. (2007). Speaking words in the second language: From semantics to phonology in 170 ms. *Neurosci Res* **57**(3): 387-392.

Hagoort, P. (2003). Interplay between syntax and semantics during sentence comprehension: ERP effects of combining syntactic and semantic violations. *J Cogn Neurosci* **15**(6): 883-899.

Hahne, A. (2001). What's different in second-language processing? Evidence from event-related brain potentials. *J Psycholinguist Res* **30**(3): 251-266.

Hahne, A., & Friederici, A. D. (1999). Electrophysiological evidence for two steps in syntactic analysis. Early automatic and late controlled processes. *J Cogn Neurosci* **11**(2): 194-205.

Hahne, A., & Friederici, A. D. (2001). Processing a second language: late learners' comprehension mechanisms as revealed by event-related brain potentials. *Biling: Lang. Cogn* **4**: 123-141.

Haigh, C. A., & Jared, D. (2007). The activation of phonological representations by bilinguals while reading silently: evidence from interlingual homophones. *J Exp Psychol Learn Mem Cogn* **33**(4): 623-644.

Hauk, O., Davis, M. H., Ford, M., Pulvermuller, F., & Marslen-Wilson, W. D. (2006). The time course of visual word recognition as revealed by linear regression analysis of ERP data. *Neuroimage* **30**(4): 1383-1400.

Hauk, O., & Pulvermuller, F. (2004). Effects of word length and frequency on the human event-related potential. *Clin Neurophysiol* **115**(5): 1090-1103.

Hermans, D. (2004). Between-language identity effects in picture-word interference tasks: A challenge for language-nonspecific or language-specific lexical access? *Int J Biling* **8**(2): 115-125.

Hermans, D., Bongaerts, T., de Bot, K., & Schreuder, R. (1998). Producing words in a foreign language: Can speakers prevent interference from their first language? *Biling: Lang. Cogn* **1**(3): 213-229.

Hoffmann, C. (1991). Individual bilingualism. In *An Introduction to Bilingualism* (pp. 13). London/New York: Longman.

Holcomb, P. J. (1988). Automatic and attentional processing: an event-related brain potential analysis of semantic priming. *Brain Lang* **35**(1): 66-85.

Holcomb, P. J., Anderson, J., & Grainger, J. (2005). An electrophysiological study of cross-modal repetition priming. *Psychophysiol* **42**(5): 493-507.

Holcomb, P. J., & Neville, H. J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Lang. Cogn Process* **5**: 281-312.

Holcomb, P. J., & Neville, H. J. (1991). Natural speech processing: An analysis using event-related brain potentials. *Psychobiol* **19**(286-300).

Holcomb, P. J., Reder, L., Misra, M., & Grainger, J. (2005). The effects of prime visibility on ERP measures of masked priming. *Brain Res Cogn Brain Res* ***24***, 155-172.

Hoshino, N., & Kroll, J. F. (2005). *Cognate effect in picture naming: Does cross-language activation survive a change of script?* Paper presented at the Fifth International Symposium on Bilingualism, Barcelona, Spain.

Jackson, G. M., Swainson, R., Cunnington, R., & Jackson, S. R. (2001). ERP correlates of executive control during repeated language switching. *Biling: Lang. Cogn* **4**: 169-178.

Jacobs, A. M., & Grainger, J. (1992). Testing a semistochastic variant of the interactive activation model in different word recognition experiments. *J Exp Psychol Hum Percept Perform* **18**(4): 1174-1188.

Jacquet, M., & French, R. M. (2002). The BIA++: Extending the BIA+to a dynamic distributed connectionist framework. *Biling: Lang. Cogn* **5**(3): 202-205.

Jared, D., & Kroll, J. F. (2001). Do bilinguals activate phonological representations in one or both of their languages when naming words? *J. Mem. Lang* **44**: 21-31.

Jared, D., & Seidenberg, M. S. (1991). Does word identification proceed from spelling to sound to meaning? *J Exp Psychol Gen* **120**: 358-394.

Jared, D., & Szucs, C. (2002). Phonological activation in bilinguals: Evidence from interlingual homograph recognition. *Biling: Lang. Cogn* **5**(225-39).

Jemel, B., George, N., Olivares, E., Fiori, N., & Renault, B. (1999). Event-related potentials to structural familiar face incongruity processing. *Psychophysiol* **36**(4): 437-452.

Jennings, J. R., & Cole, G. H. (1991). *Handbook of Cognitive Psychophysiology*. New York: John Wiley.

Jiang, N. (1999). Testing processing explanations for the asymmetry in masked cross-language priming. *Biling: Lang. Cogn* **2**(1): 59-75.

Jin, Y.-S. (1990). Effects of concreteness on cross-language priming in lexical decision. *Percept Mot Skills* **70**: 1139-1154.

Jodo, E., & Kayama, Y. (1992). Relation of a negative ERP component to response inhibition in a Go/No-go task. *Electroencephalogr Clin Neurophysiol* **82**(6): 477-482.

Joyce, C. A., Paller, K. A., Schwartz, T. J., & Kutas, M. (1999). An electrophysiological analysis of modality-specific aspects of word repetition. *Psychophysiol* **36**(5): 655-665.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Lang. Cogn Process* **15**(2): 159-201.

Keatley, C., & De Gelder, B. (1992). The bilingual primed lexical decision task: Cross-language priming disappears with speeded responses. *European Journal of Cognitive Psychology* **4**: 273-292.

Keatley, C., Spinks, J., & De Gelder, B. (1994). Asymmetrical semantic facilitation between languages. *Mem Cognit* **22**: 70-84.

Kerkhofs, R., Dijkstra, T., Chwilla, D. J., & de Bruijn, E. R. (2006). Testing a model for bilingual semantic priming with interlingual homographs: RT and N400 effects. *Brain Res* **1068**(1): 170-183.

Kim, A., & Osterhout, L. (2005). The independence of combinatory semantic processing: evidence from event-related potentials. *J. Mem. Lang* **52**: 205-225.

Kirsner, K., Smith, M. C., Lockhart, R. S., King, M., & Jian, M. (1984). The bilingual lexicon: Language-specific units in an integrated network. *J. Verb. Learn. Verb. Behav.* **23**: 519-539.

Koelsch, S., Kasper, E., Sammler, D., Schulze, K., Gunter, T., & Friederici, A. D. (2004). Music, language and meaning: brain signatures of semantic processing. *Nat Neurosci* **7**(3): 302-307.

Kohnert, K. (2004). Cognitive and cognate-based treatments for bilingual aphasia: a case study. *Brain Lang* **91**(3): 294-302.

Kolk, H. H., Chwilla, D. J., van Herten, M., & Oor, P. J. (2003). Structure and limited capacity in verbal working memory: a study with event-related potentials. *Brain Lang* **85**(1): 1-36.

Kotz, S. A. (2001). Neurolinguistic evidence for bilingual language representation: a comparison of reaction times and event-related brain potentials. *Biling: Lang. Cogn* **4**(2): 143-154.

Kotz, S. A., & Elston-Guttler, K. E. (2004). The role of proficiency on processing categorical and associative information in the L2 as revealed by reaction times and event-related brain potentials. *J Neurolinguistics* **17**: 215-235.

Kotz, S. A., Holcomb, P. J., & Osterhout, L. (2007). ERPs reveal comparable syntactic sentence processing in native and non-native readers of English. *Acta Psychol (Amst)*.

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *J Exp Psychol Learn Mem Cogn* **20**(4): 804-823.

Kroll, J. F. (1993). Accessing conceptual representations for words in a second language. In R. Schreuder & B. Weltens (Eds.), *The Bilingual Lexicon* (Vol. 6, pp. 53-81). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Kroll, J. F., Bobb, S. C., & Wodniecka, Z. (2006). Language selectivity is the exception, not the rule: Arguments against a fixed locus of language selection in bilingual speech. *Biling: Lang. Cogn* **9**(2): 119-135.

Kroll, J. F., & Curley, J. (1988). Lexical memory in novice bilinguals: The role of concepts in retrieving second language words. In M. Gruneberg, P. Morris & R. Sykes (Eds.), *Practical Aspects of Memory* (Vol. 2, pp. 389-395). London: Wiley.

Kroll, J. F., & De Groot, A. M. B. (2005). *Handbook of Bilingualism: Psycholinguistic Approaches*. New York: Oxford University Press.

Kroll, J. F., Dijkstra, T., Janssen, N., & Schriefers, H. (2000). *Selecting the language in which to speak: Experiments on lexical access in bilingual production.* Paper presented at the 41st Annual Meeting of the Psychonomic Society, New Orleans, LA.

Kroll, J. F., & Sholl, A. (1992). Lexical and conceptual memory in fluent and nonfluent bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 191-204). Amsterdam: Elsevier.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *J Mem Lan* **33**: 149-174.

Kroll, J. F., & Tokowicz, N. (2005). Models of bilingual representation and processing. In J. F. Kroll & M. B. De Groot A (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches* (pp. 531-553). New York: Oxford University Press.

Kuperberg, G. R. (2007). Neural mechanisms of language comprehension: challenges to syntax. *Brain Res* **1146**: 23-49.

Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Brain Res Cogn Brain Res* **17**(1): 117-129.

Kutas, M., & Federmeier, D., K. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Science* **4**(12): 463-470.

Kutas, M., Federmeier, D., K., Coulson, S., King, J. W., & Munte, T. F. (2000). Language. In T. J. Cacioppo, G. L. Tassinary & G. G. Berntson (Eds.), *Handbook of Psychophysiology* (pp. 576-601). Cambridge: Cambridge University Press.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science* **207**(4427): 203-205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature* **307**(5947): 161-163.

Kutas, M., & Kluender, R. (1991). What is who violating? A reconsideration of linguistic violations in the light of event-related potentials. In H. J. Heinze, T. F. Munte & G. R. Mangun (Eds.), *Cognitive electrophysiology: basic and clinical applications.* (pp. 183-210). Boston: Birkhauser.

Lanza, E. (1992). Can bilingual two-year-olds code-switch? *J Child Lang* **19**(3): 633-658.

Lemhofer, K., & Dijkstra, T. (2004). Recognizing cognates and interlingual homographs: Effects of code similarity in language specific and generalized lexical decision. *Mem. Cogn* **35**: 533-550.

Law, S-P., & Bella, O. (2001). A case study of acquired dyslexia and dysgraphia in Cantonese: Evidence for nonsemantic pathways for reading and writing Chinese. *Cogn Neuropsy 18,* 729-748.

Law, S-P., Wong, W., & Kong, A. (2006). Direct access from meaning to orthography in Chinese: A case study of superior written to oral naming. *Aphasiology **20**,* 565-578.

Law, S-P., Wong, W., & Kong, A. (2006). Whole-word phonological representations of disyllabic words in Chinese lexicon: Data from acquired dyslexia. *Behav Neurol **16***, 169-177.

Lesch, M. F., & Pollatsek, A. (1998). Evidence for the use of assembled phonology in accessing the meaning of printed words. *J Exp Psychol Learn Mem Cogn* **24**(3): 573-592.

Levelt, W. J. (1989). *Speaking: From Intention to Articulation.* Cambridge, MA: MIT Press.

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behav Brain Sci* **22**(1): 1-38; discussion 38-75.

Levelt, W. J., Schriefers, H., Vorberg, D., Meyer, A. S., Pechmann, T., & Havinga, J. (1991). The time course of lexical access in speech production: A study of picture naming. *Psychol Rev* **98**: 122-142.

Liu, Y., & Perfetti, C. A. (2003). The time course of brain activity in reading English and Chinese: an ERP study of Chinese bilinguals. *Hum Brain Mapp* **18**(3): 167-175.

Liu, Y., Perfetti, C. A., & Hart, L. (2003). ERP evidence for the time course of graphic, phonological, and semantic information in Chinese meaning and pronunciation decisions. *J Exp Psychol Learn Mem Cogn* **29**(6): 1231-1247.

Lu, C. H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: a review of the Simon and spatial Stroop effects. *Psychon Bull Rev* **2**: 174-207.

Luck, S. J. (2005). *An Introduction to Event-Related Potentials Technique*. Cambridge Mass: The MIT Press.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiol* **31**(3): 291-308.

Luck, S. J., Vogel, E. K., & Shapiro, K. L. (1996). Word meanings can be accessed but not reported during the attentional blink. *Nature* **383**(6601): 616-618.

Lukatela, G., & Turvey, M. T. (1991). Phonological access of the lexicon: evidence from associative priming with pseudohomophones. *J Exp Psychol Hum Percept Perform* **17**(4): 951-966.

Lukatela, G., & Turvey, M. T. (1994a). Visual lexical access is initially phonological: 1. Evidence from associative priming by words, homophones, and pseudohomophones. *J Exp Psychol Gen* **123**(2): 107-128.

Lukatela, G., & Turvey, M. T. (1994b). Visual lexical access is initially phonological: 2. Evidence from phonological priming by homophones and pseudohomophones. *J Exp Psychol Gen* **123**(4): 331-353.

Luo, C. R., Johnson, R. A., & Gallo, D. A. (1998). Automatic activation of phonological information in reading: evidence from the semantic relatedness decision task. *Mem Cognit* **26**(4): 833-843.

Lupker, S. J., & Williams, B. A. (1989). Rhyme priming of pictures and words: a lexical activation account. *J Exp Psychol Learn Mem Cogn* **15**: 1033-1046.

Macizo, P., & Bajo, M. T. (2006). Reading for repetition and reading for translation: do they involve the same processes? *Cognition* **99**(1): 1-34.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychol Bull* **109**(2): 163-203.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word-recognition. *Cognition* **25**(1-2): 71-102.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). The temporal structure of spoken language understanding. *Cognition* **8**(1): 1-71.

Martin, J. H. (1991). The collective electrical behavior of cortical neurons: The electroencephalogram and the mechanisms of epilipsy. In E. R. Kandel, J. H. Schwartz & T. M. Jessell (Eds.), *Principles of Neural Science* (3rd ed., pp. 777-791). New York: Elsevier.

McCarthy, R. A., & Warrington, E. K. (1988). Evidence for modality-specific meaning systems in the brain. *Nature* **334**(6181): 428-430.

McCarthy, G., & Wood, C.C. (1985). Scalp distributions of event-related potentials: an ambiguity associated with analysis of variance models. *Electroencephalogr Clin Neurophysiol Suppl* **62**, 203-208.

McClelland, J. L. (1991). Stochastic interactive processes and the effect of context on perception. *Cognit Psychol* **23**(1): 1-44.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognit Psychol* **18**(1): 1-86.

McClelland, J. L., & Rumelhart, D. (1981). An interactive activation model of context effects in letter perception. Part 1. An account of basic findings. *Psychol Rev* **88**: 375-407.

McLaughlin, J., Osterhout, L., & Kim, A. (2004). Neural correlates of second-language word learning: minimal instruction produces rapid change. *Nat Neurosci* **7**(7): 703-704.

Meuter, R., Donald, M. W., & Ardal, S. (1987). A comparison of first- and second-language ERPs in bilinguals. *Electroencephalogr Clin Neurophysiol Suppl* **40**: 412-416.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: evidence of a dependence between retrieval operations. *J Exp Psychol* **90**(2): 227-234.

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Dev* **75**(5): 1373-1386.

Miller, J., & Hackley, S. A. (1992). Electrophysiological evidence for temporal overlap among contingent mental processes. *J Exp Psychol Gen* **121**(2): 195-209.

Milota, V. C., Widau, A. A., McMickell, M. R., Juola, J. F., & Simpson, G. B. (1997). Strategic reliance on phonological mediation in lexical access. *Mem Cognit* **25**(3): 333-344.

Misra, M. & Holcomb, P. J. (2003). Event-related potential indices of masked repetition priming. *Psychophysiol* ***40***, 115-130.

Moreno, E. M., & Kutas, M. (2005). Processing semantic anomalies in two languages: an electrophysiological exploration in both languages of Spanish-English bilinguals. *Brain Res Cogn Brain Res* **22**(2): 205-220.

Morton, J. B., & Harper, S. N. (2007). What did Simon say? Revisiting the bilingual advantage. *Dev Sci* **10**(6): 719-726.

Mueller, J. L. (2005). Electrophysiological correlates of second language processing. *Second Language Research* **21**(2): 152-174.

Muysken, P. (2000). *Bilingual speech: A Typology of Code-mixing*. Cambridge: Cambridge University Press.

Naatanen, R. (1992). *Attention and Brain Function*. Hillsdale, N. J.: Erlbaum.

Naatanen, R., & Alho, K. (1995). Mismatch negativity--a unique measure of sensory processing in audition. *Int J Neurosci* **80**(1-4): 317-337.

Naatanen, R., & Picton, T. (1987). The N1 wave of the human electric and magnetic response to sound: a review and an analysis of the component structure. *Psychophysiol* **24**(4): 375-425.

Naatanen, R., & Picton, T. W. (1986). N2 and automatic versus controlled processes. *Electroencephalogr Clin Neurophysiol Suppl* **38**: 169-186.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. H. Besner, G. W. (Ed.), *Basic Processes in Reading: Visual Word Recognition.* (pp. 264-337). Hillsdale, NJ: Lawrence Erlbaum Associates.

Neville, H. J., Mills, D. L., & Lawson, D. S. (1992). Fractionating language: different neural subsystems with different sensitive periods. *Cereb Cortex* **2**(3): 244-258.

Orfanidou, E., & Sumner, P. (2005). Language switching and the effects of orthographical specificity and response repetition. *Mem Cognit* **33**(2): 355-369.

Osterhout, L. (1997). On the brain response to syntactic anomalies: manipulations of word position and word class reveal individual differences. *Brain Lang* **59**(3): 494-522.

Osterhout, L., & Holcomb, P. (1992). Event-related potentials elicited by syntactic anomaly. *J Mem Lang* **31**(785-806).

Osterhout, L., & Holcomb, P. (1995). Event-related potentials and language comprehension. In M. R. M. Coles (Ed.), *Electrophysiological studies of human cognitive function.* (pp. 171-215). Oxford: Oxford University Press.

Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden-path sentences: evidence of the application of verb information during parsing. *J Exp Psychol Learn Mem Cogn* **20**(4): 786-803.

Paivio, A., Clark, J. M., & Lambert, W. E. (1988). Bilingual dual-coding theory and semantic repetition effects on recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **14**: 163-172.

Paivio, A., & Desrochers, A. (1980). A dual-coding approach to bilingual memory. *Canadian Journal of Psychology* **34**: 388-399.

Paradis, M. (2004). *A Neurolinguistic Theory of Bilingualism.* Amsterdam/Philadephia: John Benjamins Publishing Company.

Paulmann, S., Elston-Guttler, K. E., Gunter, T. C., & Kotz, S. A. (2006). Is bilingual lexical access influenced by language context? *Neuroreport* **17**(7): 727-731.

Pernier, J., Perrin, F., & Bertrand, O. (1988). Scalp current density fields: concept and properties. *Electroencephalogr Clin Neurophysiol* **69**(4): 385-389.

Perrin, F., & Garcia-Larrea, L. (2003). Modulation of the N400 potential during auditory phonological/semantic interaction. *Brain Res Cogn Brain Res* **17**(1): 36-47.

Pfefferbaum, A., Ford, J. M., Weller, B. J., & Kopell, B. S. (1985). ERPs to response production and inhibition. *Electroencephalogr Clin Neurophysiol* **60**(5): 423-434.

Phillips, N., A., Segalowitz, N., O'Brien, I., & Yamasaki, N. (2004). Semantic priming in a first and second language: evidence from reaction time variability and event-related brain potentials. *J Neurolinguistics* **17**: 237-262.

Phillips, N. A., Klein, D., Mercier, J., & de Boysson, C. (2006). ERP measures of auditory word repetition and translation priming in bilinguals. *Brain Res* **1125**(1): 116-131.

Picton, T. W., Bentin, S., Berg, P., Donchin, E., Hillyard, S. A., Johnson, R., Jr., et al. (2000). Guidelines for using human event-related potentials to study cognition: recording standards and publication criteria. *Psychophysiol* **37**(2): 127-152.

Picton, T. W., & Hillyard, S. A. (1988). Endogenous event-related potentials. In T. W. Picton (Ed.), *Human Event-related Potentials* (Vol. 3, pp. 361-426). New York: Elsevier Science.

Picton, T. W., Lins, O., & Sherg, M. (1995). The recording and analysis of event-related potentials. In F. Boller & J. Grafman (Eds.), *Handbook of Neuropsychology* (Vol. 10, pp. 3-73). Amsterdam: Elsevier.

Picton, T. W., & Stuss, D. T. (1980). The component structure of human event-related potentials. In H. Kornhuber & L. Deecke (Eds.), *Motivation, Motor and Sensory Process of the Brain. Progress in Brain Research* (pp. 17-49). Amsterdam: Elsevier.

Picton, T. W., van Roon, P., Armilio, M. L., Berg, P., Ille, N., & Scherg, M. (2000). The correction of ocular artifacts: a topographic perspective. *Clin Neurophysiol* **111**(1): 53-65.

Polich, J. (1993). Cognitive brain potentials. *cur dir in psych sci* **2**: 175-179.

Potter, M. C., So, K.-F., Von Eckardt, B., & Feldman, L. B. (1984). Lexical and conceptual representation in beginning and proficient bilinguals. *J. Verb. Learn. Verb. Behav.* **23**: 23-38.

Poulisse, N. (1997). Language production in bilinguals. In M. B. De Groot A & J. F. Kroll (Eds.), *Tutorials in Bilingualism: Psycholinguistic Perspectives* (pp. 201-224). Mahwah, NJ: Lawrence Erlbaum Associates.

Poulisse, N. (1999). *Slips of the tongue: Speech errors in first and second language production*. Amsterdam/Philadelphia: John Benjamins.

Poulisse, N., & Bongaerts, T. (1990). *A closer look at the strategy of transfer.* Paper presented at the AILA World congress, Thessaloniki.

Poulisse, N., & Bongaerts, T. (1994). First language use in second language production. *Applied Linguistics* **15**(1): 36-57.

Praamstra, P., & Stegeman, D. F. (1993). Phonological effects on the auditory N400 event-related brain potential. *Brain Res Cogn Brain Res* **1**(2): 73-86.

Pratarelli, M. E. (1994). Semantic processing of pictures and spoken words: evidence from event-related brain potentials. *Brain Cogn* **24**(1): 137-157.

Proverbio, A. M., Leoni, G., & Zani, A. (2004). Language switching mechanisms in simultaneous interpreters: an ERP study. *Neuropsychologia* **42**(12): 1636-1656.

Pugh, K. R., Rexer, K., & Katz, L. (1994). Evidence of flexible coding in visual word recognition. *J Exp Psychol Hum Percept Perform* **20**(4): 807-825.

Pulvermuller, F. (2001). Brain reflections of words and their meaning. *Trends Cogn Sci* **5**(12): 517-524.

Rahman, R. A., van Turennout, M., & Levelt, W. J. (2003). Phonological encoding is not contingent on semantic feature retrieval: an electrophysiological study on object naming. *J Exp Psychol Learn Mem Cogn* **29**(5): 850-860.

Rayner, K., & Pollatsek, A. (1989). *The Psychology of Reading.* Englewood Cliffs, NJ: Prentice Hall.

Regan, D. (1989). *Human Brain Electophysiology: Evoked Potentials and Evoked Magnetic Fields in Science and Medicine*. Amsterdam: Elsevier.

Ritter, P., & Villringer, A. (2006). Simultaneous EEG-fMRI. *Neurosci Biobehav Rev* **30**(6): 823-838.

Roberts, P. M., & Deslauriers, L. (1999). Picture naming of cognate and non-cognate nouns in bilingual aphasia. *J Commun Disord* **32**(1): 1-22; quiz 22-23.

Rodriguez-Fornells, A., Rotte, M., Heinze, H. J., Nosselt, T., & Munte, T. F. (2002). Brain potential and functional MRI evidence for how to handle two languages with one brain. *Nature* **415**(6875): 1026-1029.

Rodriguez-Fornells, A., Schmitt, B. M., Kutas, M., & Munte, T. F. (2002). Electrophysiological estimates of the time course of semantic and phonological encoding during listening and naming. *Neuropsychologia* **40**(7): 778-787.

Rodriguez-Fornells, A., van der Lugt, A., Rotte, M., Britti, B., Heinze, H. J., & Munte, T. F. (2005). Second language interferes with word production in fluent bilinguals: brain potential and functional imaging evidence. *J Cogn Neurosci* **17**(3): 422-433.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition* **42**(1-3): 107-142.

Romaine, S. (1989). *Bilingualism*. Oxford: Basil Blackwell.

Rossion, B., Delvenne, J. F., Debatisse, D., Goffaux, V., Bruyer, R., Crommelinck, M., et al. (1999). Spatio-temporal localization of the face inversion effect: an event-related potentials study. *Biol Psychol* **50**(3): 173-189.

Rugg, M. D. (1985). The effects of semantic priming and word repetition on event-related potentials. *Psychophysiol* **22**(6): 642-647.

Rugg, M. D. (1987). The dissociation of semantic priming, word and non-word repetition effects by event-related potentials. *Q J Exp Psychol A* **39A**: 123-148.

Rugg, M. D. (1990). Event-related brain potentials dissociate repetition effects of high- and low-frequency words. *Mem Cognit* **18**(367-379).

Rugg, M. D., & Barrett, S. E. (1987). Event-related potentials and the interaction between orthographic and phonological information in a rhyme-judgment task. *Brain Lang* **32**(2): 336-361.

Rugg, M. D., & Cole, G. H. (1995a). *Electrophysiology of Mind: Event-Related Brain Potentials and Cognition*. New York: Oxford University Press.

Rugg, M. D., & Cole, G. H. (1995b). Event-related brain potentials: An introduction. In M. D. Rugg & G. H. Cole (Eds.), *Electrophysiology of Mind: Event-Related Brain Potentials and Cognition*. New York: Oxford University Press.

Rugg, M. D., & Doyle, M. C. (1994). Event-related potentials and stimulus repetition in direct and indirect tests of memory. In H. J. Heinze, T. F. Munte & G. R. Mangun (Eds.), *Cognitive Electrophysiology* (pp. 124-148). Birkhauser: Boston.

Sabol, M. A., & De Rosa, D. V. (1976). Semantic encoding of isolated words. *J Exp Psychol Hum Lear Mem* **2**: 58-68.

Sanchez-Casas, R. M., Davis, C. W., & Garcia-Albea, J. E. (1992). Bilingual lexical processing: exploring the cognate-noncognate distinction. *European Journal of Cognitive Psychology* **4**: 293-310.

Sanchez-Casas, R. M., & Garcia-Albea, J. E. (2005). The representation of cognate and noncognate words in bilingual memory. In J. F. Kroll & A. M. B. De Groot (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches*. New York: Oxford University Press.

Sanchez-Casas, R. M., Suarez-Buratti, B., & Igoa, J., M. (1992). *Are bilingual lexical representations interconnected?* Paper presented at the Fifth conference of the European society for cognitive psychology, Pairs.

Sanders, L. D., & Neville, H. J. (2003). An ERP study of continuous speech processing. II. Segmentation, semantics, and syntax in non-native speakers. *Brain Res Cogn Brain Res* **15**(3): 214-227.

Scarborough, D. L., Gerard, L., & Cortese, C. (1984). Independence of lexical access in bilingual word recognition. *J Verb Learn Verb Behav* **23**(1): 84-99.

Schmitt, B. M., Munte, T. F., & Kutas, M. (2000). Electrophysiological estimates of the time course of semantic and phonological encoding during implicit picture naming. *Psychophysiol* **37**(4): 473-484.

Schmitt, B. M., Rodriguez-Fornells, A., Kutas, M., & Munte, T. F. (2001). Electrophysiological estimates of semantic and syntactic information access during tacit picture naming and listening to words. *Neurosci Res* **41**(3): 293-298.

Schreuder, R., & Weltens, B. (1993). *The Bilingual Lexicon* (Vol. 6). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Schwanenflugel, P. J., & Rey, M. (1986). Interlingual semantic facilitation: Evidence for a common representational system in bilingual. *J Mem Lan* **25**: 605-618.

Schwartz, A. I. (2003). *Word and sentence-based processes in second language reading.* The Pennsylvania State University, University Parl.

Schwartz, A. I., & Kroll, J. F. (2006a). Bilingual lexical activation in sentence context. *J Mem Lan* **55**(2): 197-212.

Schwartz, A. I., & Kroll, J. F. (2006b). Language Processing in Bilingual Speakers. In M. Traxler & M. A. Gernsbacher (Eds.), *Handbook of Psycholinguistic* (2 ed.). London: Elsevier.

Sebastian-Galles, N., Rodriguez-Fornells, A., de Diego-Balaguer, R., & Diaz, B. (2006). First- and second-language phonological representations in the mental lexicon. *J Cogn Neurosci* **18**(8): 1277-1291.

Segalowitz, N. (1997). Individual differences in second language acquisition. In M. B. De Groot A & J. F. Kroll (Eds.), *Tutorials in Bilingualism: Psycholinguistic Perspectives.* Mahwah, NJ: Lawrence Erlbaum Associates.

Segalowitz, N., & Hulstijn, J. (2005). Automaticity in bilingualism and second language learning. In J. F. Kroll & M. B. De Groot A (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches* (pp. 371-388). New York: Oxford University Press.

Shallice, T. (1993). Multiple semantics: whose confusions? *Cogn Neuropsychol* **10**: 251-261.

Sholl, A., Sankaranarayana, A., & Kroll, J. F. (1995). Transfer between picture naming and translation: a test of asymmetries in bilingual memory. *Psychol Sci* **6**: 45-49.

Simon, G., Bernard, C., Largy, P., Lalonde, R., & Rebai, M. (2004). Chronometry of visual word recognition during passive and lexical decision tasks: an ERP investigation. *Int J Neurosci* **114**(11): 1401-1432.

Skutnabb-kangas, T. (1984). *Bilingualism or Not.* Clevedon: Multilingual Matters.

Smith, M. C. (1997). How do bilinguals access lexical information? In M. B. De Groot A & J. F. Kroll (Eds.), *Tutorials in Bilingualism* (pp. 145-186). Mahwah, NJ: Lawrence Erlbaum Associates.

Smith, M. C. (1991). On the recruitment of semantic information for word fragment completion: Evidence from bilingual priming. *J Exp Psychol Learn Mem Cogn* **17**(234-44).

Smith, M. C., & Kirsner, K. (1982). Language and orthography as irrelevant features in colour-word and picture-word Stroop interference. *Q J Exp Psychol A* **34**(Pt 1): 153-170.

Sunderman, G., & Kroll, J. F. (2006). First language activation during second language lexical processing: An investigation of lexical form, meaning, and grammatical class. *SSLA* **26**(3): 387-422.

Sutton, S., Braren, M., Zubin, J., & John, E. R. (1965). Evoked-potential correlates of stimulus uncertainty. *Science* **150**(700): 1187-1188.

Swaab, T. Y., Baynes, K., & Knight, R. T. (2002). Separable effects of priming and imageability on word processing: an ERP study. *Brain Res Cogn Brain Res* **15**(1): 99-103.

Talamas, A., Kroll, J. F., & Dufour, R. (1999). Form related errors in second language learning: a preliminary stage in the acquisition of L2 vocabulary. *Biling: Lang. Cogn* **2**: 45-58.

Thierry, G., Cardebat, D., & Demonet, J. F. (2003). Electrophysiological comparison of grammatical processing and semantic processing of single spoken nouns. *Brain Res Cogn Brain Res* ***17***, 535-547.

Thierry, G., Doyon, B., & Demonet, J. F. (1998). ERP mapping in phonological and lexical semantic monitoring tasks: A study complementing previous PET results. *Neuroimage* **8**(4): 391-408.

Thierry, G., Martin, C. D., Downing, P., & Pegna, A. J. (2007). Controlling for interstimulus perceptual variance abolishes N170 face selectivity. *Nat Neurosci* **10**(4): 505-511.

Thierry, G., & Price, C. J. (2006). Dissociating verbal and nonverbal conceptual processing in the human brain. *J Cogn Neurosci* **18**(6): 1018-1028.

Thierry, G., & Wu, Y. J. (2004). Electrophysiological evidence for language interference in late bilinguals. *Neuroreport* **15**(10): 1555-1558.

Thierry, G., & Wu, Y, J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Science, USA* ***104***, 12530-12535.

Thorpe, S., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *Nature* **381**(6582): 520-522.

Tokowicz, N., & MacWhinney, B. (2005). Implicit and explicit measures of sensitivity to violations in second language grammar: An event-related potential investigation. *SSLA* **27**: 173-204.

Treffers-Daller, J. (1997). Variability in code-switching styles: Turkish-German code-switching patterns. In R. Jacobson (Ed.), *Code-switching Worldwide* (pp. 177-197). Berlin: Mouton de Gruyter.

Tucker, D. M., Liotti, M., Potts, G. F., Russell, G. S., & Posner, M. I. (1994). Spatiotemporal analysis of brain eletrical fields. *Hum Brain Mapp* **1**: 134-152.

Tyler, L. K. (1984). The structure of the initial cohort: evidence from gating. *Percept Psychophys* **36**(5): 417-427.

Tzelgov, J., & Eben-Ezra, S. (1992). Components of the between-language semantic priming effect. *European Journal of Cognitive Psychology* **4**: 253-272.

Unsworth, S. J., & Pexman, P. M. (2003). The impact of reader skill on phonological processing in visual word recognition. *Q J Exp Psychol A* **56**(1): 63-81.

Van Hell, J. G. (1998). *Cross-language processing and bilingual memory organization.* University of Amsterdam, Amsterdam.

Van Hell, J. G., & Dijkstra, T. (2002). Foreign language knowledge can influence native language performance in exclusively native contexts. *Psychon Bull Rev* **9**(4): 780-789.

van Herten, M., Kolk, H. H., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Brain Res Cogn Brain Res* **22**(2): 241-255.

Van Heste, T. (1999). *Visual woordherkenning bij tweetalige personen [Visual word recognition in bilinguals], Unpublished master's thesis.* University of Leuven, Belgium.

Van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neiborhood effects in bilingual word recognition. *J. Mem. Lang* **39**: 458-483.

Van Orden, G. C. (1987). A ROWS is a ROSE: spelling, sound, and reading. *Mem Cognit* **15**(3): 181-198.

Van Petten, C. (1993). A comparison of lexcial and sentence-level context effects in event-related potentials. *Lang. Cogn Process* **8**(4): 485-531.

Van Petten, C., & Rheinfelder, H. (1995). Conceptual relationships between spoken words and environmental sounds: event-related brain potential measures. *Neuropsychologia* **33**(4): 485-508.

van Schie, H. T., Wijers, A. A., Kellenbach, M. L., & Stowe, L. A. (2003). An event-related potential investigation of the relationship between semantic and perceptual levels of representation. *Brain Lang* **86**(2): 300-325.

van Turennout, M., Hagoort, P., & Brown, C. M. (1997). Electrophysiological evidence on the time course of semantic and phonological processes in speech production. *J Exp Psychol Learn Mem Cogn* **23**(4): 787-806.

Van Wijnendaele, I., & Brysbaert, M. (2002). Visual word recognition in bilinguals: phonological priming from the second to the first language. *J Exp Psychol Hum Percept Perform* **28**(3): 616-627.

Vissers, C. T., Chwilla, D. J., & Kolk, H. H. (2006). Monitoring in language perception: The effect of misspellings of words in highly constrained sentences. *Brain Res* **1106**(1): 150-163.

Weber-Fox, C., & Neville, H. J. (1996). Maturational constrainst on functional specializations for language processing: ERP and behavioral evidence in bilingual speakers. *J Cogn Neurosci* **8**: 231-256.

Weber-Fox, C., & Neville, H. J. (2001). Sensitive periods differentiate processing of open- and closed-class words: an ERP study of bilinguals. *J Speech Lang Hear Res* **44**: 1338-1353.

Wernreich, U. (1953). *Languages in contact. Findings and problems*. New York: Humanities Press.

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level processing of concrete and abstract words: an electrophysiological investigation. *J Cogn Neurosci* **12**(6): 1024-1037.

West, W. C., & Holcomb, P. J. (2002). Event-related potentials during discourse-level semantic integration of complex pictures. *Brain Res Cogn Brain Res* **13**(3): 363-375.

Wheeldon, L. R., & Monsell, S. (1992). The locus of repetition priming of spoken word production. *Q J Exp Psychol A* **44A**: 723-761.

Winkler, I., Kujala, T., Tiitinen, H., Sivonen, P., Alku, P., Lehtokoski, A., et al. (1999). Brain responses reveal the learning of foreign language phonemes. *Psychophysiol* **36**(5): 638-642.

Zhang, Q., Damian, M. F., & Yang, Y. (2007). Electrophysiological estimates of the time course of tonal and orthographic encoding in Chinese speech production. *Brain Res* **1184**: 234-244.

Zhang, Q., Weekes, B., & Yang, Y. (2007). Electrophysiological estimates of the time course of orthographic and metrical encoding in Chinese speech production. *Brain Lang* **103**(1): 124-125.

Zhang, Q., & Yang, Y. (2007). Electrophysiological estimates of the time course of semantic and metrical encoding in Chinese speech production. *Neuroscience* **147**(4): 986-995.

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychol Bull* **131**(1): 3-29.

Appendix 1

Consent Form

School of psychology
Bangor University
Informed Consent Form

Names and positions of principal investigators

Guillaume Thierry (PhD) - Lecturer in Neuropsychology
Mark Roberts - Research assistant in Psychology
Yanjing Wu - PhD Student in Psychology

The experiment that you accept to take part in is part of a research project concerned with the way people process Languages, especially second language. It is not a test of the skill of individuals and it is similar to tasks that have been used for many years in research laboratories and pose no known discomfort or risk. Nevertheless, you are free to withdraw from the experiment now or at any time with no penalty.

Your data will be stored, analysed and published in a completely confidential manner, preserving anonymity. Data storage is coded so that people not involved in the experiment will not be able to retrieve any personal information, nor view your data.

We will be happy to answer any question regarding the experiment and its significance after it is finished. You may keep your copy of this consent form.

I, ________________ agree to participate in this experiment.

Signed ________________ Date ________________

Any complaints concerning the conduct of this research should be addressed to Professor C.F Lowe, Head of Department, School of Psychology, University of Wales, Bangor, Gwynedd, LL57 2AS. In the case of Health Service Patients, complaints should in addition be addressed to Chief Executive of the relevant trust.

Appendix 2

Sample of the Stimuli Rating Questionnaire (Chinese version)*

朋友你好,
首先,非常感谢你能够帮助我做以下检测.请注意阅读检测要求.

单词意义联系检测

请给出你认为以下每组单词在其意思上的联系程度.
如果你看不出两个单词有任何意义方面的联系(比如: 鸭子-木匠) 请添"1"
如果你觉得两个单词有很勉强的联系 (比如: 大脑-皮肤) 请添"2"
如果你觉得两个单词有联系但不直接 (比如: 房子-岩石) 请添"3"
如果你觉得两个单词有较为直接的联系 (比如: 厨房-盘子) 请添"4"
如果你觉得第一个单词和第二个有非常直接的联系 (比如: 医生-护士) 请添"5"

注意事项:
1. 所谓的联系程度是指意义上的,不要考虑读音,比划,等非意义因素.
2. 在做选择的时候尽量不要考虑太深远 (考虑多了恐怕任何单词都有联系了),以是否能够看到直接的联系为评判标准.
3. 如果可能给与明确的评判 (1:"毫无联系"或 5:"直接联系"),尽量不要使用中间评判 (2,3,4)
3. 请将评判后的数字写在"/"后面

信件-信封/
香蕉-桔子/
数字-气体/
筷子-食物/
帽子-膝盖/
黑板-老板/
洋葱-领带/
铅笔-纸张/
地板-房顶/
护照-护士/
背壳-饼干/
牛肉-猪肉/
兔子-课桌/
学生-学校/
海员-海洋/
金钱-财富/
土地-土壤/
狐狸-语言/
香肠-香烟/

* This is a sample abstracted from the stimuli rating questionnaire for study 1. Remind that the Chinese and the English version of it were evaluated respectively by a group of Chinese monolinguals and a group of English monolinguals independent of participants involved in the current studies.

Appendix 3

Sample of the Stimuli Rating Questionnaire (English version)

Dear friends,

First of all, thank you for taking part in the following questionnaire. Please read carefully the instructions.

Semantic relatedness rating questionnaire

Please rate the semantic relatedness in the following word pairs.

Put "1" if you cannot see relation between the two words in any aspect (e.g., duck-carpenter)

Put "2" if you think the relation is quite vague (e.g., brain-skin)

Put "3" if you think there is an indirect relation (e.g., house-rock)

Put "4" if you think the relation is quite obvious (e.g., kitchen-plate)

Put "5" if you think the two words are directly related (e.g., doctor-nurse)

Please note

1. Considering only the semantic relatedness (i.e., in terms of the meanings)

2. Trust your first intuition which is usually the most implicit and genuine opinion of yours. Deep consideration might result in uncertainties.

3. Whenever possible, please provide a clear evaluation (e.g., 1 for unrelated and 5 for related), and avoid making indecisive judgment (e.g., 2, 3, and 4)

3. Please put the number after the "/"

letter-envelop/
banana-orange/
number-gas/
chopstick-food/
hat-knee/
blackboard-boss/
onion-tie/
pencil-paper/
floor-roof/
passport-nurse/
shell-cookie/
beef-pork/
rabbit-desk/
student-school/
sailor-sea/
money-wealth/
land-soil /
fox-language/
sausage-cigarette/

Appendix 4

Lexical Features of the Stimuli

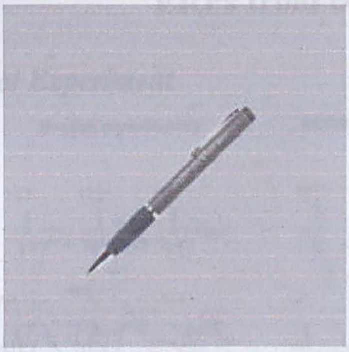
The table below presents all important parameters of the stimuli that were used in this thesis, including (from left to right) lexical frequency (Kucera and Francis as cited in Coltheart, 1981), concreteness/imageability[1], number of letters, number of phonemes, ratings for the semantic relatedness (by both Chinese and English)[2], and the standard deviation of each value (after "/").

	Condi[3]	LFRQ	CNC/IMG	NLET	NPHN	SRC	SRE
Study 1	S+R+	73/82	554/63	5.7/1.6	4.7/2.0	4.03/0.7	4.34/0.5
	S+R-	73/86	554/76	4.8/1.6	3.9/1.6	3.93/0.6	4.28/0.3
	S-R+	73/97	551/83	5.8/1.5	4.7/1.9	1.27/0.2	1.50/0.2
	S-R-	75/90	556/64	4.9/1.6	4.0/1.7	1.26/0.3	1.37/0.2
Study 2	O	71/66	495/89	5.96/2.1	4.9/1.9	1.23/0.5	1.67/0.2
	P	70/85	493/112	5.76/1.9	4.9/2.0	1.16/0.5	1.60/0.2
	S	69/52	493/92	5.32/1.6	4.4/1.9	4.24/0.3	4.62/0.4
	U	70/90	494/114	5.54/2.3	4.7/2.4	1.18/0.2	1.51/0.2
Study 3	E	41/53	592/36	4.74/1.1	3.92/1.4	1.12/0.6	1.38/0.3
	C	38/33	595/40	5.42/1.4	4.05/1.4	1.25/0.4	1.29/0.3
	S	41/40	591/33	5.13/1.5	3.81/1.5	4.04/0.4	4.21/0.5
	U	39/46	592/34	5.31/1.6	4.03/1.8	1.27/0.1	1.41/0.2

[1] Words in study 1 and 2 were matched on concreteness, as pictures in study 3 on imageability (see Coltheart, 1981).
[2] On a Lickert scale from 1 (completely unrelated) to 5 (strongly related), the minimum/maximum averaged rating to include a related/unrelated item is 3.
[3] Labels used in this table have the same connotations as those used in table 4.1, table 4.2, and table 4.3 in the Method section.

Appendix 5

Samples of Pictures used in Study 3

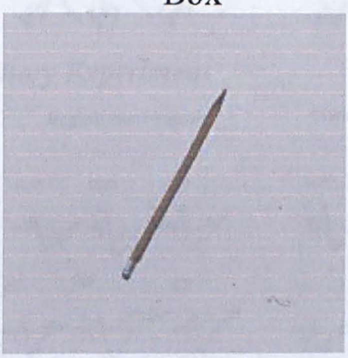


Pen

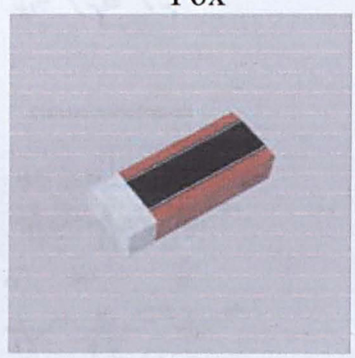
Piano

Box

Fox



Pencil



Eraser

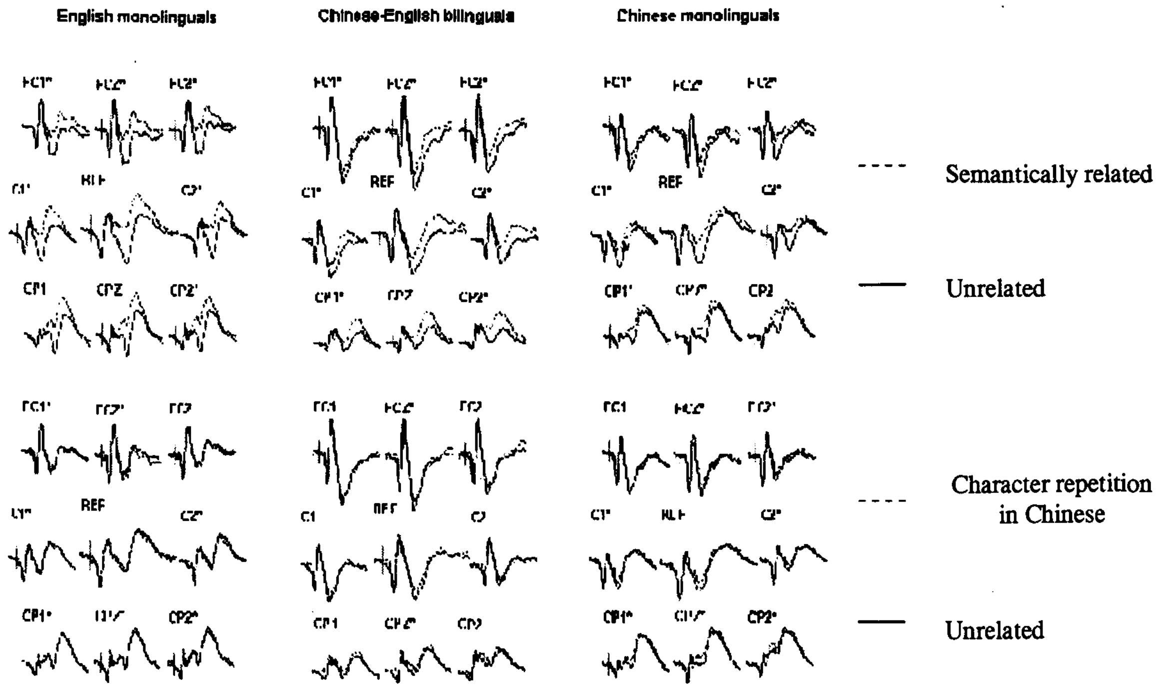
Leaf

Hammer

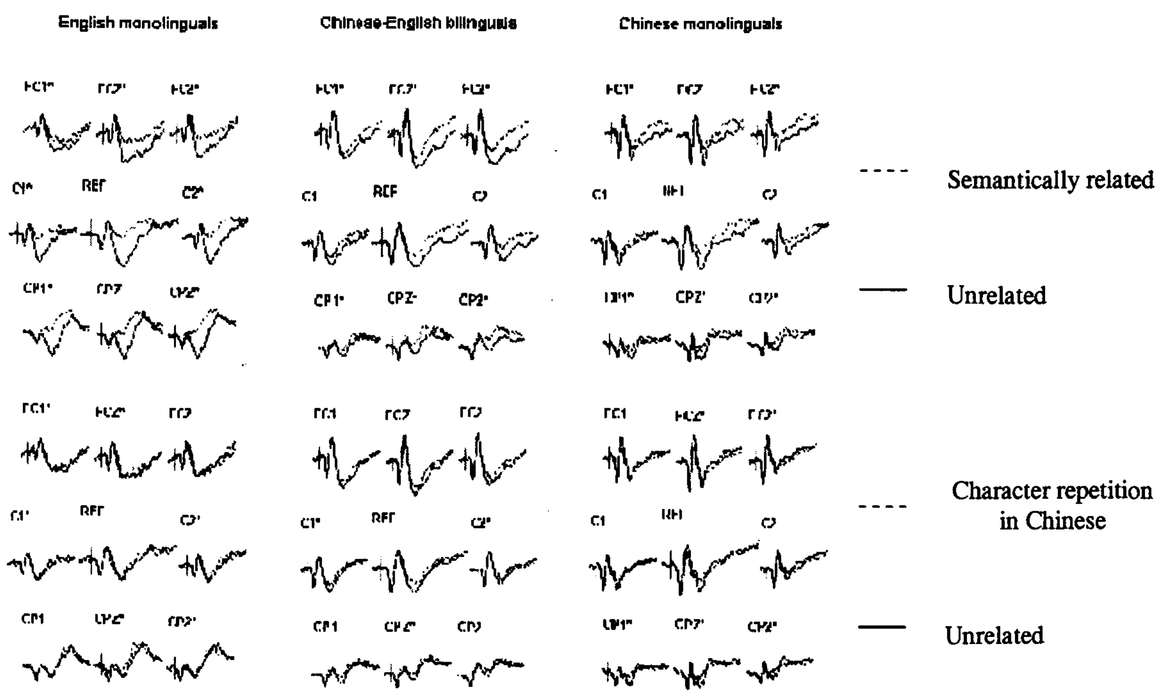
Appendix 6

ERPs from central nine electrodes* in Study 1

Visual Experiment



Auditory Experiment



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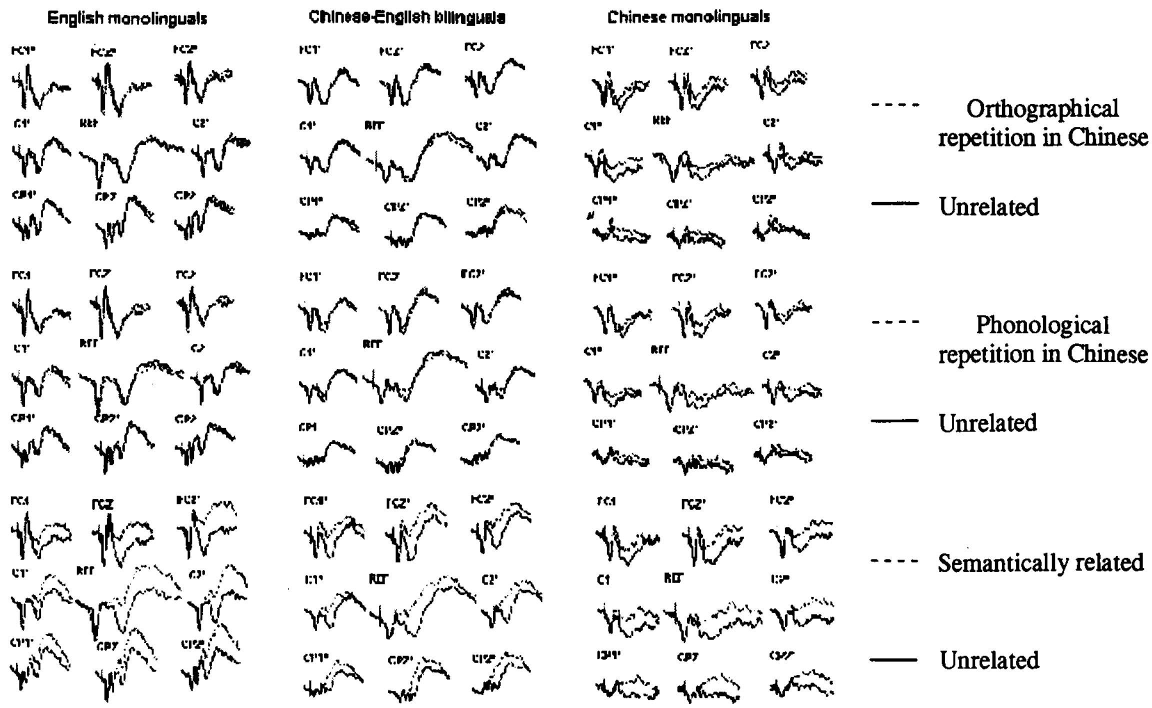
* These electrodes are FC1, FCZ, FC2, C1, CZ, C2, CP1, CPZ, and CP2, on which the statistics were performed.

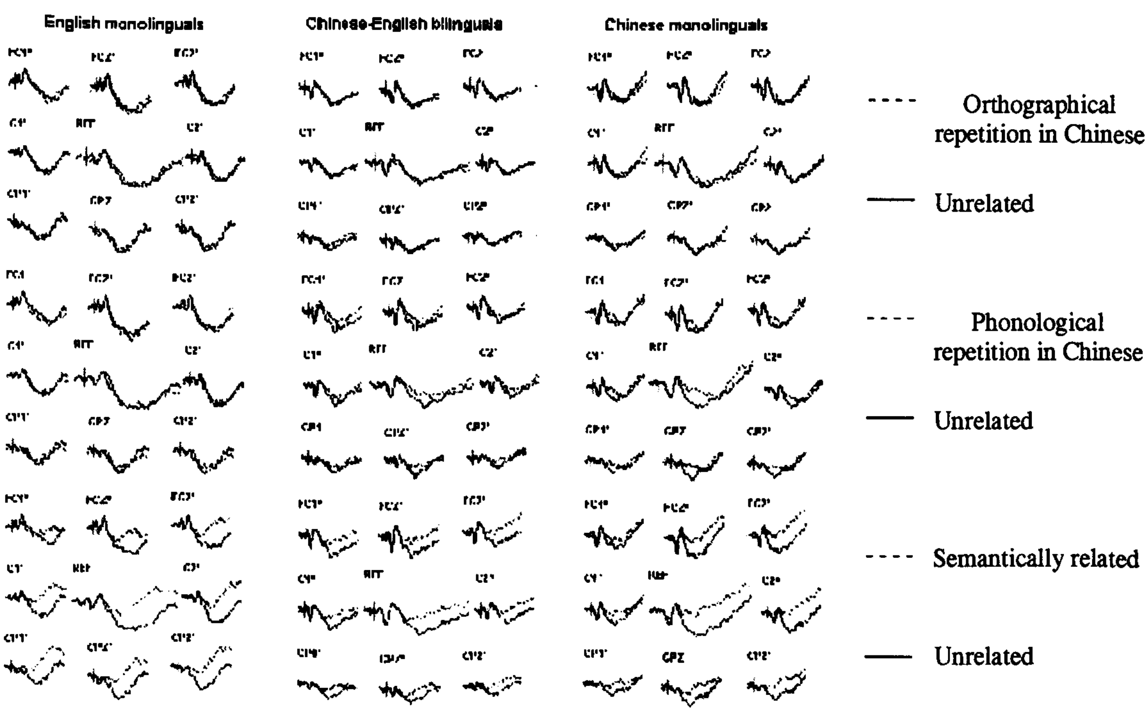
Appendix 7

ERPs from central nine electrodes in Study 2

Visual Experiment



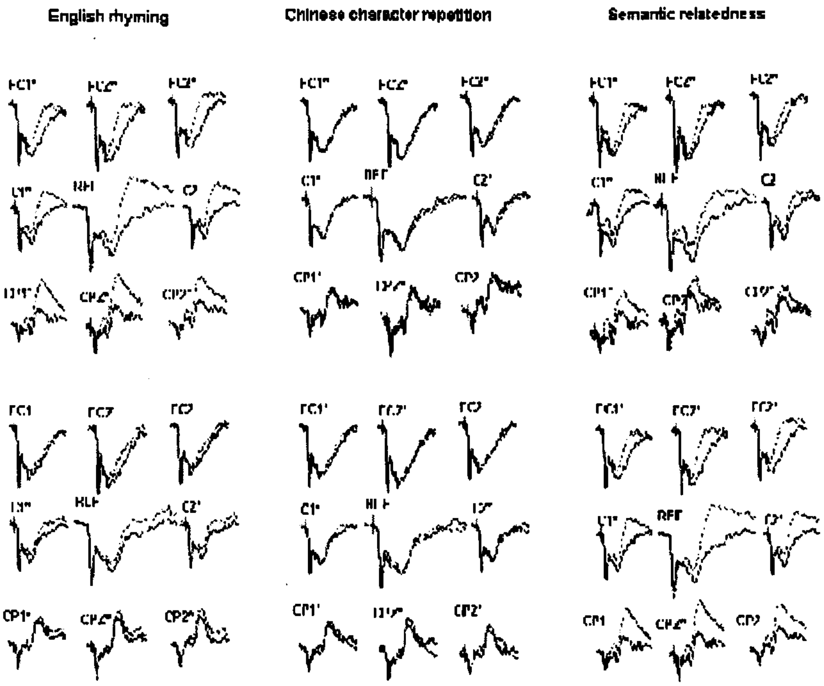
Auditory Experiment



Appendix 8

ERPs from central nine electrodes in Study 3

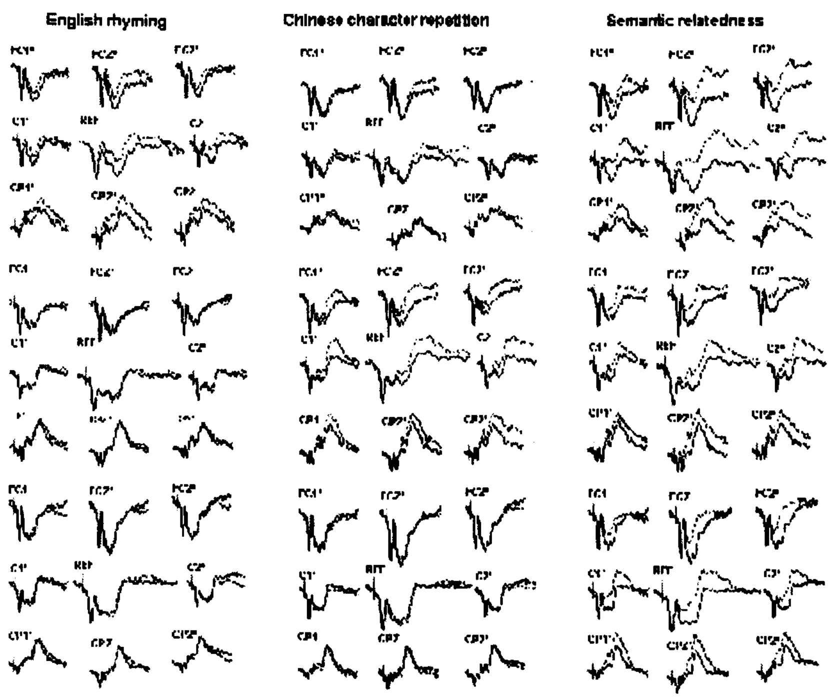
English Monolinguals



English rhyming task

Semantic relatedness task

Chinese Bilinguals



English rhyming task

Chinese character repetition task

Semantic relatedness task

Appendix 9

Additional Information on the Participants

The table below presents additional information on the participants: gender ratio (male/female), mean age and standard deviations, and English proficiency (e.g., IELTS score and standard deviations).

	Participants	Gender Ratio	Mean Age and SD	English Proficiency and SD
Study 1	English monolinguals	5/10	20.2/1.1	Native
	Chinese-English bilinguals	6/9	21.1/3.2	6.12/0.08
	Chinese monolinguals	7/8	18.8/0.4	N/A
Study 2	English monolinguals	4/11	19.8/1.5	Native
	Chinese-English bilinguals	7/8	21.3/3.5	6.32/0.05
	Chinese monolinguals	6/9	19.1/0.8	N/A
Study 3	English monolinguals	6/9	20.4/1.3	Native
	Chinese-English bilinguals	9/6	21.8/2.8	6.35/0.03
	Chinese monolinguals	5/10	19.9/0.7	N/A

Appendix 10

Stimuli of Study One

Prime	S+R+	Prime	S+R-	Prime	S-R+	Prime	S-R-
sheep	goat	grape	peach	hornet	vest	castle	coke
bus	car	death	war	economy	experience	pizza	story
letter	envelope	green	grass	belief	information	glass	lip
hill	mountain	sister	brother	operation	gesture	chest	message
sweet	honey	rain	cloud	document	civilization	mushroom	speaker
commerce	business	black	night	company	princess	wedding	wall
map	geography	fly	wing	romance	waste	cream	coin
factory	worker	chopstick	meal	genius	weather	pan	wire
summer	winter	mouth	nose	pistol	handkerchief	ticket	oil
ocean	seaman	check	cash	lift	light	soap	street
wrist	watch	knife	fork	density	angle	clock	seat
carpenter	wood	floor	roof	navy	poster	dictionary	drama
calendar	date	exam	mark	culture	file	leg	travel
flying	plane	love	rose	jewelry	leader	beach	baby
education	professor	paper	pencil	method	square	heater	silk
voice	sound	man	woman	blank	air	bridge	army
star	planet	writing	essay	diary	sunset	notebook	tank
water	river	capital	government	summary	president	elephant	palm
printer	typewriter	cock	duck	circus	road	ear	wife
bull	cow	coffee	tea	blackboard	boss	bean	rubber
tooth	dentist	hamburger	salad	address	tunnel	suitcase	copper
agriculture	farm	god	heaven	tiger	teacher	rabbit	desk
spring	autumn	money	wealth	network	tennis	language	fox
book	shelf	food	rice	strange	doctor	gun	biology
post	mail	bottle	drink	butter	gold	fountain	wheel
soil	land	win	loss	jade	corn	goldfish	bag
city	town	question	answer	airport	machine	worm	window
pub	alcohol	bath	shower	underground	carpet	sports	monkey
boy	girl	investigation	research	novel	child	hammer	plant
stamp	postmark	dinner	cook	finance	metal	keyboard	gate
science	technology	picture	photo	grammar	hair	number	gas
breakfast	lunch	coat	jacket	peanut	flower	flat	flame
project	work	intelligence	brain	hell	basement	hat	knee
concert	musician	orange	banana	passport	nurse	baseball	leather
mother	father	blue	sky	mobile	arm	flag	ball
school	student	video	film	ham	train	boat	university
treatment	medicine	sea	ship	card	truck	pillow	joke
garden	park	currency	bank	strawberry	lawn	sock	stone
battery	electricity	onion	potato	flood	kettle	program	paint
album	camera	fire	smoke	sausage	cigarette	brush	certificate
wine	beer	oyster	scallop	crystal	fruit	biscuit	shell
tree	leaf	foot	shoe	leader	tie	building	ankle
panda	bear	dream	sleep	pen	piano	snake	lake
king	queen	snow	ice	movie	telephone	monitor	pool
report	newspaper	music	song	mask	bread	telegram	cup
patient	disease	microphone	speaker	interview	noodle	clipper	seed
table	chair	apple	pear	sugar	sand	chips	bomb
dive	jump	journal	magazine	turkey	torch	theater	nail
beef	pork	virus	bacteria	volcano	rocket	publication	bin
eye	tear	mouse	rat	mercury	cement	game	door

Appendix 11

Stimuli of Study One

Prime	S+R+	Prime	S+R-	Prime	S-R+	Prime	S-R-
绵羊	山羊	葡萄	桃子	马蜂	马甲	城堡	可乐
汽车	轿车	战争	死亡	经济	经验	比萨	故事
信件	信封	绿色	草地	信仰	信息	杯子	嘴唇
山丘	山峰	姐妹	兄弟	手术	手势	胸膛	消息
甜蜜	蜂蜜	下雨	云彩	文件	文明	蘑菇	音箱
商业	商务	黑色	夜晚	公司	公主	婚礼	墙壁
地图	地理	飞翔	翅膀	浪漫	浪费	奶油	钱币
工厂	工人	筷子	饮食	天才	天气	炒锅	电线
夏天	冬天	嘴巴	鼻子	手枪	手绢	车票	石油
海洋	海员	支票	现金	电梯	电灯	肥皂	街道
手腕	手表	餐刀	叉子	密度	角度	钟表	座位
木匠	木头	地板	房顶	海军	海报	字典	戏剧
日历	日期	考试	成绩	文化	文件	大腿	旅行
飞行	飞机	爱情	玫瑰	首饰	首领	海滩	婴儿
教育	教授	纸张	铅笔	方法	方块	暖气	丝绸
声音	声响	男人	女人	空白	空气	桥梁	军队
恒星	行星	写作	杂文	日记	日落	笔记	坦克
河水	河流	首都	政府	总结	总统	大象	手掌
打印	打字	公鸡	鸭子	马戏	马路	耳朵	妻子
公牛	母牛	咖啡	茶叶	黑板	老板	豆子	橡胶
牙齿	牙医	汉堡	沙拉	地址	地道	箱子	铜器
农业	农民	上帝	天堂	老虎	老师	兔子	桌子
春天	夏天	金钱	财富	网络	网球	语言	狐狸
书籍	书架	食物	米饭	陌生	医生	枪支	生物
邮政	邮件	瓶子	饮料	黄油	黄金	喷泉	轮子
土壤	土地	胜利	失败	玉器	玉米	金鱼	袋子
城市	城镇	问题	答案	机场	机器	虫子	窗户
酒吧	酒精	浴缸	蓬头	地铁	地毯	体育	猴子
男孩	女孩	学习	研究	小说	小孩	锤子	植物
邮票	邮戳	晚餐	厨师	金融	金属	键盘	大门
科技	科学	图画	照片	语法	头发	数字	气体
早餐	午餐	大衣	夹克	花生	花朵	公寓	火焰
工程	工作	智力	大脑	地狱	地下	帽子	膝盖
乐队	乐手	橘子	香蕉	护照	护士	棒球	皮毛
母亲	父亲	蓝色	天空	手机	手臂	旗帜	皮球
学校	学生	录影	胶卷	火腿	火车	小船	大学
医疗	医药	大海	轮船	卡片	卡车	枕头	笑话
花园	公园	货币	银行	草莓	草地	袜子	石头
电池	电器	洋葱	土豆	水灾	水壶	程序	油漆
相册	相机	火灾	烟雾	香肠	香烟	刷子	证书
白酒	啤酒	牡蛎	扇贝	水晶	水果	饼干	贝壳
树木	树叶	脚丫	鞋子	领导	领带	建筑	脚踝
猫熊	黑熊	做梦	睡觉	钢笔	钢琴	毒蛇	湖水
国王	女王	下雪	结冰	电影	电话	荧幕	台球
报告	报纸	音乐	歌曲	面具	面包	电报	杯子
病人	病患	话筒	喇叭	面试	面条	发卡	种子
桌子	椅子	苹果	鸭梨	砂糖	砂子	薯条	炸弹
跳水	跳跃	期刊	杂志	火鸡	火炬	剧院	指甲
猪肉	牛肉	病毒	细菌	火山	火箭	出版	纸篓
眼睛	眼泪	老鼠	耗子	水银	水泥	游戏	房门

Appendix 12

Stimuli of Study Two

Prime	O	Prime	P	Prime	S	Prime	U
biography	leaflet	sense	olive	hell	heaven	monitor	defense
blame	dirty	wage	cock	win	loss	wedding	zoology
behaviour	ranks	hungry	chance	science	research	dictionary	drama
precaution	handbag	goat	sun	money	wealth	chest	information
repetition	weight	clock	china	question	answer	pillow	joke
frank	tax	jungles	experience	government	capital	gun	biology
taste	nap	jealous	memory	candy	sweet	leg	travel
flavor	investigation	method	hair	exam	mark	pizza	story
landing	surrender	comparison	pen	war	fight	brush	certificate
appearance	snake	care	popular	dream	sleep	baseball	sunset
carry	growth	experience	surprise	dinner	cook	boat	university
stress	overlap	strength	history	music	song	radio	silk
emphasis	harmony	threat	smile	writing	essay	telegram	cup
profession	agenda	particle	danger	pilot	plane	bridge	army
caution	double	lie	card	microphone	speaker	suitcase	copper
framework	imitate	mosquito	civilization	fire	smoke	number	gas
asymmetry	title	symbol	fortune	blue	sky	ear	wife
rubbings	expedition	desire	budget	check	cash	sports	monkey
collection	tibet	drawing	chemistry	bottle	drink	clock	seat
account	conference	calendar	victory	food	lunch	onion	tie
expert	walk	grave	sight	rain	cloud	slipper	wheel
mediation	warm	property	gesture	virus	bacteria	program	paint
imbalance	tune	tomorrow	name	ocean	seaman	soap	street
awareness	province	font	nature	post	mail	castle	coke
contend	angle	sugar	murder	sister	brother	ticket	balance
vague	pattern	tide	message	water	flow	notebook	tank
vision	sleep	rocket	file	floor	roof	goldfish	sock
specialty	leader	textbook	visitor	operation	patient	flat	flame
accent	cook	glove	leader	bath	shower	rabbit	desk
interest	commander	crystal	nerve	newspaper	magazine	pan	wire
sheet	mint	manual	guard	fly	wing	snake	lake
ammunition	spring	reader	poison	hamburger	salad	beach	quick
persuade	novel	report	storm	chips	fish	glass	lip
publication	colleague	goal	lumber	grass	green	hat	knee
role	corner	list	minister	shoes	foot	hammer	beauty
abbreviation	match	vest	aunt	light	electricity	bean	rubber
optimistic	instrument	industry	princess	burning	heat	cookie	shell
fortress	jam	prediction	jade	table	chair	curtain	nail
progression	bank	bathroom	corn	math	physics	fence	bin
cartoon	hairpin	sausage	village	hot	summer	mushroom	weed
parking	lake	today	metal	rose	love	elephant	hand
lackey	claw	exchange	nurse	coffee	tea	language	fox
bladder	shoulder	island	missile	honey	sweet	game	door
bounce	bullet	secret	bee	victory	fail	building	revolution
saving	cattle	submission	head	time	watch	worm	exchange
sticker	clay	aim	wood	winter	cold	train	independence
doctor	rice	opposition	cigarette	nose	mouth	brick	aspect
ammunition	marble	machine	egg	banana	orange	stone	clean
spoon	key	conservation	mobile	teacher	education	ball	management
divination	carrot	shark	sofa	exam	test	technology	anxiety

Appendix 13

Stimuli of Study Two

Prime	O	Prime	P	Prime	S	Prime	U
传记	传单	感觉	橄榄	地域	天堂	屏幕	防守
埋怨	埋没	工资	公鸡	赢得	输掉	婚礼	动物
行列	行为	肌饿	机会	科学	研究	字典	戏剧
提防	提包	山羊	太阳	金钱	财富	胸膛	信息
重复	重量	钟表	中国	问题	答案	枕头	笑话
直率	税率	荆棘	经验	政府	首都	手枪	生物
午觉	味觉	嫉妒	记忆	糖果	甜蜜	大腿	旅行
调味	调查	方法	头发	考试	成绩	比萨	故事
降落	降服	对比	钢笔	战争	打斗	刷子	证书
长相	长虫	留心	流行	做梦	睡觉	棒球	日落
提留	提升	经验	惊讶	晚餐	做饭	小船	大学
重读	重叠	力量	历史	音乐	歌曲	雷达	丝绸
强调	协调	威胁	微笑	写作	文章	电报	杯子
行程	行业	微粒	危险	驾驶	飞机	桥梁	军队
慎重	双重	欺骗	卡片	喇叭	话筒	箱子	铜器
模版	模仿	蚊子	文明	火灾	烟雾	数字	气体
对称	职称	符号	福气	蓝色	天空	耳朵	妻子
拓版	拓展	欲望	预算	支票	现金	体育	猴子
西藏	收藏	画柑	化学	瓶子	饮料	钟表	座位
会计	会议	日历	胜利	食物	午餐	洋葱	领带
行家	行走	墓地	目光	下雨	云彩	拖鞋	轮子
调和	暖和	资产	姿势	病毒	细菌	程序	油画
失调	音调	明天	名字	海洋	水手	香皂	大街
省觉	省份	字体	自然	邮政	信件	城堡	可乐
角斗	角度	沙糖	杀手	姐妹	兄弟	票具	平衡
模糊	模子	潮汐	信息	河水	流动	笔记	坦克
视觉	睡觉	火箭	文件	房顶	地板	金鱼	袜子
特长	首长	课本	客人	手术	病人	公寓	火焰
腔调	烹调	手套	首长	洗澡	淋浴	兔子	课桌
利率	统率	水晶	神经	报纸	杂志	炒锅	电线
薄纸	薄荷	手册	守卫	飞翔	翅膀	毒蛇	湖水
弹药	弹簧	读者	毒药	汉饱	沙拉	沙滩	迅速
游说	小说	报告	暴风	薯条	炸鱼	玻璃	嘴唇
发行	同行	目标	木材	草地	绿色	帽子	膝盖
角色	角落	目录	牧师	鞋子	脚丫	锤子	美丽
简称	相称	马夹	蚂蚁	光学	电子	豆子	橡胶
乐观	乐器	工业	公主	燃烧	发热	饼干	贝壳
要塞	堵塞	预测	玉器	桌子	板凳	窗帘	指甲
进行	银行	浴室	玉米	数学	物理	栅栏	纸篓
卡通	卡子	香肠	乡村	炎热	夏天	蘑菇	海藻
停泊	湖泊	今天	金属	玫瑰	爱情	大象	手掌
爪牙	爪子	互相	护士	咖啡	茶叶	语言	狐狸
膀胱	膀臂	岛屿	导弹	蜂蜜	甜美	游戏	房门
反弹	子弹	秘密	蜜蜂	胜利	失败	建筑	革命
储蓄	牲畜	投搞	头脑	时间	手表	虫子	交换
粘贴	粘土	目标	木头	冬天	寒冷	火车	独立
大夫	大米	相对	香烟	鼻子	嘴巴	砖头	方面
弹药	弹球	机器	鸡蛋	香蕉	橘子	石头	干净
钥羹	钥匙	守恒	手机	老师	教育	皮球	管理
占卜	箩卜	鲨鱼	沙发	考试	测验	科技	忧郁

Appendix 14

Stimuli of Study Three

Prime	E	Prime	C	Prime	S	Prime	U
beach	peach	arrow	tongue	baby	cradle	ant	circle
hand	sand	axe	orange	bamboo	panda	monk	toe
book	cook	balloon	bus	blackboard	chalk	baseball	eye
box	fox	butter	gold	castle	wall	basketball	beef
table	cable	can	bone	check	cash	cauliflower	alligator
cake	lake	card	truck	chili	ginger	spider	brush
cat	hat	cashew	belt	mushroom	carrot	sink	butterfly
clock	sock	cassette	tie	exam	test	calendar	pipe
coat	boat	champagne	cigarette	chopsticks	bowl	ruler	toast
curtain	fountain	comb	duck	church	priest	coin	tent
dam	jam	cup	neck	coconut	pineapple	cheese	match
deer	beer	desert	sofa	coffee	sugar	dolphin	dentist
dice	ice	doctor	student	feather	bird	dinosaur	cabbage
door	floor	mask	noodle	film	camera	drawer	football
drill	pill	fist	pillow	fire	smoke	aubergine	lock
egg	leg	garlic	ocean	forest	wood	envelope	brain
zipper	paper	goat	hill	fork	knife	goldfish	tower
bell	shell	yellow	cucumber	frog	mosquito	bra	hammer
glass	grass	ham	train	hamburger	salad	hanger	pump
green	queen	hornet	vest	horse	cow	heart	spring
hair	chair	ink	flood	feet	shoes	heater	map
head	bread	jade	corn	judge	prisoner	ladder	rainbow
house	mouse	kettle	rice	lemon	grape	leaf	square
king	wing	lamp	phone	lettuce	tomato	monitor	island
pin	bin	leek	elephant	lighting	rain	notebook	broom
light	knight	lift	computer	stamp	letter	peas	violin
wine	line	mailbox	oven	magazine	newspaper	squirrel	railroad
lip	ship	mobile	arm	microphone	speaker	raincoat	tennis
clown	crown	nurse	soldier	honey	candy	stair	doll
moon	spoon	patrol	stone	necklace	ring	scissor	cage
bullet	wallet	peanut	flower	nose	mouth	crab	flag
nail	snail	pen	piano	pants	jacket	short	bat
pear	bear	perfume	banana	eraser	pencil	fax	kitchen
plate	gate	pigeon	boot	pepper	salt	volleyball	elbow
fan	pan	pirate	seal	plane	tank	fossil	juice
bed	red	glove	watch	plum	apple	sweater	window
sea	tea	rabbit	skirt	potato	onion	squid	umbrella
sheep	jeep	rope	bottle	present	candle	shark	missile
gun	sun	sausage	soap	audio	television	snooker	dog
tail	sail	strawberry	lawn	star	earth	lobster	toilet
tear	ear	referee	tailor	river	bridge	underwear	pork
silk	milk	torch	finger	shelf	desk	tissue	key
tree	bee	underground	carpet	shirt	button	iceberg	tire
wheel	heel	volcano	rocket	shower	bath	tiger	road
monkey	hockey	watermelon	suit	sky	cloud	kite	slipper

Appendix 15

Stimuli of Study Two

Prime	O	Prime	P	Prime	S	Prime	U
海滩	桃子	箭头	舌头	婴儿	摇篮	蚂蚁	圆圈
手掌	沙子	斧子	橘子	竹子	猫熊	和尚	脚趾
图书	厨师	气球	汽车	黑板	粉笔	棒球	眼睛
盒子	狐狸	黄油	黄金	城堡	墙壁	篮球	牛肉
桌子	电线	罐头	骨头	支票	现金	菜花	鳄鱼
蛋糕	湖水	卡片	卡车	辣椒	生姜	蜘蛛	刷子
小猫	帽子	腰果	腰带	蘑菇	萝卜	水槽	蝴蝶
钟表	袜子	磁带	领带	考试	测验	日立	水管
大衣	小船	香宾	香烟	筷子	饭碗	尺子	土司
窗帘	喷泉	梳子	鸭子	教堂	牧师	钱币	帐篷
水坝	果酱	杯子	脖子	椰子	菠萝	奶酪	火柴
小鹿	啤酒	沙漠	沙发	咖啡	砂糖	海豚	牙医
色子	结冰	医生	学生	羽毛	小鸟	恐龙	白菜
房门	地板	面具	面条	胶卷	相机	抽屉	足球
钻头	药片	拳头	枕头	火焰	烟雾	茄子	门锁
鸡蛋	大腿	大蒜	大海	森林	木头	信封	大脑
拉锁	纸张	山羊	山峰	叉子	餐刀	金鱼	毛巾
铃铛	贝壳	黄色	黄瓜	青蛙	蚊子	胸罩	锤子
玻璃	小草	火腿	火车	汉堡	沙拉	衣架	水泵
绿色	女王	马蜂	马甲	马匹	奶牛	心脏	春天
头发	椅子	墨水	洪水	脚丫	鞋子	暖气	地图
头脑	面包	玉器	玉米	法官	囚犯	梯子	彩虹
房子	老鼠	水壶	水稻	柠檬	葡萄	树叶	方块
国王	翅膀	电灯	电话	生菜	番茄	荧幕	岛屿
别针	纸篓	大葱	大象	闪电	雨水	笔记	扫把
灯光	骑士	电梯	电脑	邮票	信件	豆子	提琴
白酒	线条	油箱	烤箱	杂志	报纸	松树	铁道
嘴唇	轮船	手机	手臂	话筒	喇叭	雨衣	网球
小丑	皇冠	护士	战士	蜂蜜	糖果	楼梯	娃娃
月亮	勺子	石油	石头	项链	戒指	剪刀	笼子
子弹	钱包	花生	花朵	鼻子	嘴巴	螃蟹	旗帜
指甲	蜗牛	钢笔	钢琴	裤子	夹克	短裤	蝙蝠
鸭梨	黑熊	香水	香蕉	橡皮	铅笔	传真	厨房
盘子	大门	鸽子	靴子	辣椒	盐巴	排球	肘子
电扇	炒锅	海盗	海豹	飞机	坦克	化石	汁液
睡床	红色	手套	手表	李子	苹果	毛衣	窗户
大海	茶叶	兔子	裙子	土豆	洋葱	鱿鱼	雨伞
绵羊	吉普	绳子	瓶子	礼物	蜡烛	鲨鱼	导弹
枪支	太阳	香肠	香皂	音响	电视	台球	小狗
尾巴	帆船	草莓	草地	恒星	地球	龙虾	厕所
眼泪	耳朵	裁判	裁缝	河流	桥梁	内衣	猪肉
丝绸	牛奶	手电	手指	书架	课桌	纸巾	钥匙
树木	蜜蜂	地铁	地毯	衬衫	扣子	冰山	轮胎
轮子	鞋跟	火山	火箭	蓬头	浴缸	老虎	马路
猴子	冰球	西瓜	西服	天空	云彩	风筝	脱鞋