Changing views on word recognition in bilinguals

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Abstract

For a long time, bilingualism was believed to involve the requirement of two separate word processing systems that function independently and that can be accessed selectively. These assumptions are both intuitively appealing and have guided empirical research on multiple language proficiency for decades. However, a number of recent studies have challenged these ideas, both for spoken word recognition and for written word recognition. We first review some of these studies, and then present a computational model that processes words within an integrated lexicon. We end by listing a number of real challenges and false trails this new framework is likely to raise.

Changing views on word recognition in bilinguals

Given that half of the world population has some elementary knowledge of a second language and that more people understand English as a second language (L2) than as a first language (L1), one would expect bilingualism to be a core issue in psycholinguistic research. For instance, one would expect that all models of word recognition incorporate the possibility of multiple language proficiency. The fact that this is not the case illustrates a basic assumption about bilingualism (Grosjean, 1989), namely that mastery of a second language does not have implications for native language processing. When it comes to L1, bilinguals are considered to be equal to monolinguals. Reading in English is not supposed to be different in English-Dutch bilinguals than in English monolinguals, except maybe in cases of balanced bilinguals who were born in a bilingual environment and from a very young age learned to use both languages interchangeably. In this article, we first review some traditional views of bilingual word recognition that were based on this assumption. Then, we describe a series of recent experiments that question the assumption and, instead, put forward a theoretical framework of a language system that processes words on the basis of their similarity to stored representations in an integrated lexicon, and not on the basis of the language they belong to. Our evidence is based on spoken and written word recognition. The reader may want to know, however, that similar findings have been published on spoken word production (Colomé, 2001; Costa, Miozzo, & Caramazza, 1999; Hermans, Bongaerts, De Bot, & Schreuder, 1998) and sentence parsing (Altarriba, Kroll, Sholl, & Rayner, 1996; Fernandez, 2002; Hernandez, Bates, & Avila, 1994).

Views based on independent lexicons and language-specific access

The presumed independence of L1 and L2 word recognition is most prominently present in those models that postulate independent lexicons for the two languages of a bilingual. In most of these models, the lexicons are simply assumed to be functionally independent (i.e., they do not influence each other's functioning), but in some they are also localised in different parts of the brain. One such proposal, for instance, has been that L2 processing depends on the right cerebral hemisphere whereas L1 processing is localised in the left brain half, certainly when L2 has been acquired after the age of 10 (Krashen, 1973; Evans, Workman, Mayer, & Crowley, 2002). This proposal was based on Lenneberg's (1967) claim that language acquisition is governed by the maturation of the left and the right cerebral hemispheres. Because the maturation is not completed until around puberty, it has been suggested that a second language that is learned after the maturation of the nervous system makes greater use of the right hemisphere. Another, less strong claim has been made by Gomez-Tortosa, Martin, Gaviria, Charbel, and Ausman (1995). They reported on a bilingual patient who exhibited selective impairment in one language after surgical resection of an arteriovenous malformation in the left hemisphere, and suggested that the impaired language must have been represented in a region closer to the surgical area than the nonimpaired language. Brain imaging studies have refuted the strong claim of a right hemisphere dominance for L2, but seem unable to decide whether or not the activation patterns of L1 and L2 overlap completely or diverge in a significant way (refs to be added).

Other researchers have concentrated less on the neuroanatomical separation of L1 and L2, but defended a functional independence of both languages. In their view, even if L1 and L2 are processed in the very same brain areas, at the functional level they can still be considered as two independent language systems, at least as far as word form recognition is concerned. Such a model has been defended, for instance, by Paradis (1980, 1997). He put forward a three-store hypothesis of word recognition, in which a distinction is made between word forms (orthographic and phonological forms with their syntactic properties), word meanings (which are often language-dependent), and conceptual features (the nonlinguistic mental representations underlying human thought). In Paradis's model, the first two types of representations are language-specific, whereas the last is shared by the two languages. In addition, Paradis ventured that L1 may depend more on implicit, procedural memory because it has been acquired spontaneously, whereas L2 depends more on explicit, declarative memory if it has been acquired largely through school instruction.

Another important model that defended the functional autonomy of L1 and L2 word recognition, was proposed by Kroll and colleagues (Kroll & Stewart, 1994; Kroll & de Groot, 1997) [1]. In the original version of the Revised Hierarchical Model (Figure 1), separate lexicons were postulated for L1 and L2. These two lexicons were connected to one another and to a common semantic system where word meanings were stored. The model is asymmetric, because for unbalanced bilinguals the connections from L2 word forms to their L1 translations are stronger than the other way around, because L2 words are often learned by associating them with their L1 translation (e.g., "*paard*" in Dutch, L2, means "*horse*" in English, L1"). In contrast, the connections between L1 words and their meanings are assumed to be stronger than the connections between L2 words and their meanings, implying that in the initial stages of L2 acquisition, the meaning of L2 words may be accessed through their translation equivalent (e.g., the meaning of "*paard*" is found via the associated lexical form "*horse*"). As L2 proficiency increases, so does the strength of the connections between L2 word forms in the lexicon and the semantic system, and gradually the meaning of L2 words can be retrieved directly. Differences in the meaning of words in L1 and L2 are captured by assuming that the meaning of words is not unitary, but consists of a bundle of semantic features (Kroll & de Groot, 1997). In such a view, it is perfectly possible that a word in L2 activates a pattern of features that does not have a complete overlap with any pattern of features activated by a word in L1 (e.g., the English word "*web*" is used in many more contexts than the Dutch translation "*web*",).

By itself, independence of lexicons does not imply language-selective access. Theoretically, it is perfectly possible that both lexicons of a bilingual are activated simultaneously to the extent that the input matches representations within each lexicon (Van Heuven, Dijkstra, & Grainger, 1998). However, in practice most researchers suggesting independent lexicons also have assumed that each lexicon could be activated or inhibited as a function of the context language. This seems necessary to understand why a bilingual reading a text in one language is not constantly confused by words that exist in the other language as well. For instance, the first four sentences of this paragraph contain a series of words that exist in Dutch as well, mostly with a different meaning (i.e., the words "*of, are, most, have, as*"; two other words that are shared in English and Dutch are *in* and *is*, but these have the same meaning). The ubiquitous presence of such interlingual homographs makes one wonder how a Dutch-English bilingual can read this text without constantly being directed towards L1.

[1] Because of the evidence summarised later in this article, Kroll has recently dropped the assumption of independent lexicons (e.g., Kroll & Dijkstra, 2002). However, the original model still prevails in many introductory texts.

A language switch mechanism was first proposed by Penfield and Roberts (1959) who argued that the functional separation of languages takes place by an automatic switch at the neurophysiological level (see Albert & Obler, 1978, for a review of the language-switch research). Kolers (1966) asked participants to read passages in one or two languages. Comprehension was unaffected by mixing the languages, but speed of reading was slower in the mixed-language condition. According to Kolers, the meanings of words are represented in a language-free form in long term memory, while a time-consuming language switch at the encoding level ensures language-specific lexical access. By guiding sensory information to the appropriate lexical system, the language switch thus enables the bilingual to avoid interference from the inappropriate language in a strictly monolingual situation (see also Amrhein, 1999). However, as we will see in the subsequent sections, the idea of an input switch has not been confirmed by later empirical studies. First, we present evidence from spoken word recognition; then, we present evidence from visual word recognition.

Evidence against language-selective access : spoken word recognition

In auditory word recognition, the input reaches the listener sequentially over time. Many words take a few hundred milliseconds to pronounce, and very often these words are recognised before the complete signal has been presented. According to the cohort model (Marlsen Wilson, 1987), speech input activates a cohort of words that start with the input sounds. So, the sounds */sp/* activate the lexical candidates *space, span, spaghetti, speak, spear, spoon, spoiler*, and so on. Gradually, the candidate list or chort is pruned as more information comes in until only one candidate remains (e.g. the candidate *spaghetti* after the input */spag/*). Evidence for this model was provided by a series of experiments examining the eye movements of participants who received spoken instructions (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Allopenna, Magnuson, & Tanenhaus, 1998). When participants saw a visual display of a number of familiar items (e.g., a candy, an apple, a candle, and a fork) and were given the instruction “Now, pick up the candy”, quite often they shifted their gaze towards the candle (the name of which starts with the same sounds) before looking at the candy. This has been interpreted as evidence that the initial sounds */kae/* activate the two matching words *candy* and *candle*.

Spivey and Marian (1999) hypothesised that if bilinguals have a language-selective input switch, this phenomenon should only be observed with within-language distractors but not with between-language distractors. So, a Russian-English bilingual getting the L1 instruction “Poloji marku nije krestika” (“Put the stamp below the cross”) should not be hindered by the presence of a *marker* on the table. Similarly, in a condition where all instructions and interactions are in English, these bilinguals should not be hindered by the presence of a *stamp* (*marka*) when they are asked to pick up the *marker*. However, this is not what the authors found. Both with Russian instructions and with English instructions, participants looked more at between-language distractors than at control items with a name that did not start with the same sounds as the target, neither in English nor in Russian. Subsequent research (Marian, Spivey, & Hirsch, in press) showed that the interference effect of between-language items is present even on trials that contain a within-language distractor (e.g., the English instruction “pick up the spear” for a display with a *speaker*, a *spear*, *matches [spichki*], and an *apple*). The finding of a distractor effect from L2 on L1 in situations where the participants were strictly addressed in L1, is very strong evidence that knowledge of words in L2 cannot be suppressed and has impact on L1 spoken word recognition. It may be important to note that although they were highly proficient in L2, all participants in Marian and Spivey's study had learned English rather late in life (in their early teens).

Evidence against language-selective access: visual word recognition

Many studies have demonstrated that visual word recognition in L2 is affected by the native language of the reader (e.g., Wang, Koda, & Perfetti, 2003). However, the opposite is true as well: Bilinguals do not recognise written words exactly the same as monolinguals. Early evidence that knowledge of L2 may have impact on the recognition of printed L1 words, was published by Bijeljac-Babic, Biardeau, and Grainger (1997). They investigated the inhibition effect of high-frequency orthographic neighbours (Segui & Grainger, 1990). When a low-frequency target word (e.g., *GREED*) was preceded by a briefly presented, masked prime word, it is took longer to process this word when it was preceded by a high-frequency word that differed in only one letter position (i.e., an orthographic neighbour, such as *green*) than when it was preceded by a high frequency word that had no orthographic overlap (*black*). Such a within-language effect was predicted on the basis of the interactive activation model (McClelland & Rumelhart, 1981), which sees word identification as the result of competition between orthographically similar words. Bijeljac-Babic et al. showed that the inhibition effect occurs not only for L1 intralingual neighbours but also for cross-lingual L2 neighbours. Thus, highly proficient French-English bilinguals not only took 28 ms longer to decide that *MIEL* [honey] was a French word if it had been preceded by the French prime *mien* [my] than if it had been preceded by the French prime *hier* [yesterday]. They also required 43 ms more time to decide that the same L1 word *MIEL* was a French word when it was preceded by the L2 prime *mile* than when it was preceded by the control prime *meet*. In contrast, French monolinguals only showed the inhibition effect for the French primes, not for the English primes. Beginning French-English bilinguals showed an intermediate effect for the English primes.

Van Heuven, Dijkstra, and Grainger (1998) examined how the recognition of target words in L1 or L2 is affected by similar word forms both within the target language and within the other language. In one experiment, they looked at the effects of L1 on L2. Dutch-English bilinguals and English monolinguals decided whether strings of letters formed English words or non-words (English lexical decision task). For the English monolinguals, word identification time depended on the number of English orthographic neighbours. Participants took longer to decide that a letter string was a word when it had few neighbours (e.g., *deny*, with the neighbours *defy*, *demy*, *dewy*, *dene*, and *dent*) than when it had many (e.g., *dish*, with the neighbours *bish*, *fish*, *pish*, *wish*, *dash*, *dosh*, *disc*, *disk*, *disp*, *diss*, *dist*). In contrast, the Dutch-English bilinguals were more influenced by the number of Dutch neighbours than by the numbers of English neighbours. They took longer to accept an English L2 word with many Dutch L1 neighbours (e.g., *poor*, with the Dutch neighbours *boor, door, goor, hoor, koor, moor, noor, voor, zoor, poer, pook, pool, poos, poot*) than an English word with few Dutch neighbours (e.g., *bath* with only the very low-frequency Dutch word *bats* as neighbour). This is the typical and well-accepted effect of the better-known L1 on the later-acquired L2.

However, in other experiments with Dutch-English bilinguals, van Heuven et al. not only noticed that the identification latency for English L2 words depended on the number of Dutch L1 neighbours, but also that the identification latency for Dutch L1 words was influenced by the number of English L2 neighbours. Native Dutch-speaking university students needed longer presentation times before they could identify a Dutch word with many English neighbours (*bons* [bump]) than an equivalent Dutch word with a few English neighbours (*bouw* [building, structure]). Although van Heuven et al.'s participants were rather proficient in English, they were by no means balanced bilinguals who could express themselves as easily in English as in Dutch. In addition, in one of their experiments, van Heuven et al. manipulated the proficiency level of the participants, and that had no significant impact. This suggests that the influences of L2 on L1 visual word recognition begin at proficiency levels lower than generally assumed.

A similar finding was reported by Dijkstra, Timmermans, and Schriefers (2000), who presented Dutch-English bilinguals with lists of English and Dutch words. The participants were to press a button only if an English word appeared. If the presented word belonged to Dutch, they were instructed to wait for the next word (i.e., a go / no-go paradigm). Dijkstra et al. were particularly interested in the comparison between words that only exist in English (e.g., *home*) and words that exist both in English and in Dutch but have a different meaning in both languages (so-called interlingual homographs, such as *room*, which means *cream* in Dutch). The idea was that if participants only activated words in their English lexicon, they should not be influenced by whether or not the letter string formed a word with a different meaning in Dutch. Still, Dijkstra et al. obtained a reliable homograph effect: Participants needed more time to decide that a homograph was an English word (657 ms) than that a non-homograph was an English word (577 ms), even though the English reading of the homograph was much more frequent than the Dutch reading and even though all test words were readily recognised as valid English words (more than 97% correct responses). Even more interesting, however, was the observation that the effect was not only significant from L1 reading on L2 performance, but also from L2 reading on L1 performance. When the participants pressed on a button when the letter string formed a word in Dutch and refrained from responding when it was a word in English, Dijkstra et al. also obtained a reliable homograph effect. Participants took longer to accept a letter string as an existing Dutch word when it was an English homograph (*room*) than when it was not (e.g., *nis* [niche]). The effect was particularly strong (over 200 ms) when the English reading of the homograph was more frequent than the Dutch reading (as is the case for *room*), but still amounted to 31 ms for homographs that had a higher frequency in Dutch than in English (e.g. *hoop* [hope] vs. *mond* [mouth]).

To get more insight in why bilinguals cannot inhibit one of their languages at will, Brysbaert, Van Dyck, and Van de Poel (1999) started from the recent finding that visual word recognition heavily depends on the phonology represented by the written stimulus. In addition, it has been shown that the phonological recoding of the visual stimulus happens prelexically (i.e., before the word form representation in the lexicon is activated) and automatically (see, e.g., Frost, 1998). The strongest evidence for these claims comes for the masked priming paradigm. Perfetti and Bell (1991) showed that a briefly presented target word like *FLOOR* has more chances of being identified when it is preceded by the masked homophonic nonword prime *flore* than when it is preceded by the graphemic control prime *floop*, even when the primes are presented so briefly that the participants cannot perceive them consciously. The fact that this phonological priming effect is observed with nonword primes indicates that the effect is not due to word-word interactions within the lexicon, but that the phonology is activated on the basis of direct letter-sound correspondences. Later research showed that the phonological priming effect is equally large when the stimulus materials make phonological coding unhelpful (or even detrimental) in the majority of trials (because on those trials the prime does not share any sound with the target word, as in *thase-FLOOR,* or is a pseudohomophone of another word, as in *braune-FLOOR*; Brysbaert, 2001; Xu & Perfetti, 1999). The presence of the phonological priming effect even in strongly discouraging conditions suggests that people cannot strategically control either the activation of phonology or the reliance on it.

Brysbaert et al. (1999) hypothesised that the automatic and prelexical activation of phonological information must have implications for bilingual visual word recognition. Different languages based on the same, Roman, alphabet, often use the same letter combinations to represent different sounds. For instance, the grapheme "ou" represents the /u/ phoneme in French but the /Au/ phoneme in Dutch. Similarly, the "oo" grapheme stands for /u:/ in English but for /o:/ in Dutch. Assuming that phonological coding happens automatically in L1, this implies that frequently the wrong phonemes will be activated for a person reading in L2, unless the grapheme-phoneme conversion system is able to integrate the cross-language inconsistencies in the mappings, just like it is able to cope with within-language inconsistencies (e.g., *bead* vs. *head*). In a series of experiments, Brysbaert and colleagues (Brysbaert et al., 1999; Van Wijnendaele & Brysbaert, 2002) showed that the system solves the problem by activating the phonology simultaneously according to the L1 mappings and the L2 mappings (see Lange, 2002, for a similar within-language finding). Because of this co-activation, it is possible to prime a target word in one language with a homophone of the other language. Thus, for an English-Dutch bilingual, the English (L1) target word "*coat*" can be primed by the Dutch (L2) homophone prime "*koot*" [pastern] (The actual experiments happened with Dutch-French and French-Dutch bilinguals and French stimuli.) As participants were unaware of the presence of the masked primes, Brysbaert and colleagues concluded that the automatic, simultaneous activation of phonemes according to the different languages known to an individual is an inherent aspect of visual word recognition in bilinguals. It implies not only that L2 reading in a bilingual will be different from L1 reading in a monolingual, but also that L1 reading in a bilingual will be different from L1 reading in a monolingual (due to the parallel activation of phonemes according to the L2 correspondences).

Modelling language non-selective access: The BIA and BIA+ models

Having found strong evidence for language non-selective access in bilinguals, we are now faced with the challenge of trying to understand how the human brain copes with multiple language input, if it cannot strategically control the flow of information through two independent word recognition systems. As indicated in the first section of this paper, one of the attractions of language selective access was that it could easily "explain" why bilinguals experience relatively little interference from the non-target language while using one of their languages.

In 1998, Dijkstra and colleagues (Dijkstra & van Heuven, 1998; Dijkstra, van Heuven, & Grainger, 1998; van Heuven, Dijkstra, & Grainger, 1998) presented the first example of a computational model of bilingual word recognition that includes an integrated lexicon for L1 and L2, and a language non-selective access mechanism. They called this model the Bilingual Interactive Activation (BIA) model (see Figure 2). It was an extension of McClelland and Rumelhart's (1981) monolingual Interactive Activation model, and as such contained levels of representation for features, letters, and for words. When a letter string was presented to the BIA model, this visual input affected particular features at each letter position, which subsequently excited letters that contained these features and at the same time inhibited letters for which the features were absent. The activated letters next excited words in both languages in which the activated letter occurred at the position in question, while all other words were inhibited. At the word level, all words inhibited each other, irrespective of the language to which they belonged. Dijkstra and colleagues showed that this model could successfully simulate (1) Bijeljac-Babic et al.'s (1997) inhibition effect of cross-language high-frequency, orthographic neighbour primes (mile – MIEL), (2) van Heuven et al.'s (1998) findings related to the number of within-language and between-language neighbours, and (3) Dijkstra et al.'s (2000) results with interlingual homographs in the go/no-go paradigm.

In spite of BIA's successful performance, subsequent empirical findings pointed to a series of shortcomings, which forced Dijkstra and van Heuven (2002) to extend the model. For a start, the BIA model did not contain phonological and semantic representations. This made it impossible to account for the between-language phonological priming effects, and to simulate the many findings of word translations that are so well captured by the Revised Hierarchical Model. The original BIA model also contained two language nodes above the word level, that received activation from the word nodes belonging to that language, and inhibited the activation of the word nodes belonging to the other language. However, it soon became clear that the representational and functional aspects of these language nodes were not well specified (e.g., whether or not they could receive activation unrelated to the language processing, such as activation originating from the context in which the person was operating), and that the language nodes had often fulfilled a kind of an easy solution that was not really required.

To remedy the shortcomings of BIA, Dijkstra and van Heuven presented the BIA+ model, shown in Figure 3. It consists of two clearly separated systems: a word identification system and a task schema system. The word identification system incorporates the BIA model as a special case (except that the language nodes no longer feed back to the word level, and that interlingual homographs are represented differently) and extends it with phonology and semantics. In this way, bilingual word recognition is affected not only by cross-linguistic orthographic similarity effects, but also by cross-linguistic phonological and semantic overlap. Because the language nodes can no longer influence the activation levels of the word nodes, this takes away their function as language filters dependent on experimental factors and non-linguistic contextual pre-activation. They remain in the model because they are needed to answer the question to which language a particular word belongs. The influence of non-linguistic context effects, such as the effects arising from instruction, task demands, or participant expectancies, is limited to the task schema part of the model. This part has been added to the model, on the basis of the conviction that the performance of a task not only requires an early preconscious, automatic level of processing, but also an attention-sensitive level at which the percepts are selected with reference to task demands (e.g., a lexical decision) and various other contextual factors (e.g., focus on speed vs. focus on accuracy). The task schema specifies the series of operations to be carried out to perform the specific task at hand (see also Green, 1998; Norman & Shallice, 1986).

Real challenges and false trails

The main challenges that lie ahead, mainly involve the actual implementation of the different parts of the BIA+ model in a fully operational, computational model. The achievement of this will involve major efforts both within the bilingual and the monolingual research tradition. For instance, the inclusion of a semantic system in a word recognition model seems straightforward, but only recently do we start to have an idea of how semantic information might be incorporated within such a model of word recognition and how it can be implemented in a computer model. In general, two approaches have been taken, with roughly comparable results. The first involves eliciting the semantic features of concepts that are then integrated within self-organising semantic networks (e.g., McRae, de Sa, & Seidenberg, 1997; Tyler & Moss, 2001; Vinson & Vigliocco, 2002). The second approach is to define the semantic space of a particular word as the vector of words that co-occur with that word in text corpora (Burgess & Lund, 1996; Landauer & Dumais, 1997).

Another challenge is how to combine an integrated, language non-specific lexicon with the recurrent reports of different brain areas associated with language processing in L1 and in L2, and the various case studies showing that language revalidation after brain damage is not always equal in L1 and L2. For instance, Fabbro (2001a) reported on the revalidation of 20 bilingual aphasia patients. Of these, 13 (65%) showed similar improvement in both languages, 4 (20%) had less improvement in L2, and 3 (15%) continued to perform less well in L1 than in L2. In particular, the finding of worse performance in L1 than in L2 after brain damage seems difficult to understand within the framework of a unitary lexicon. One explanation that is currently pursued (Fabbro, 2001b; Gollan & Kroll, 2001; Paradis, 1997) is that selective loss of a language may have less to do with the destruction of that language in the brain, than with pathological inhibition of the language. Bilingualism requires finely tuned control mechanisms that prevent the language users from language mixing, but allows them to easily switch between the two languages if they wish so (see the task schema part of BIA+). It seems likely that this delicate balance may be disturbed due to brain damage, the more because excessive, pathological language mixing is also observed in bilingual aphasia patients (Abutalebi, Miozzo, Cappa, 2000; Fabbro, Skrap, & Aglioti, 2000; Munoz, Marquardt, & Copeland, 1999; Perecman, 1984).

Equally important to defining the real challenges for future research on bilingualism, however, is to avoid the false convictions that have prevented progress in the past. One of these convictions is that the multitude of words known by a multilingual must result in word confusions if one is not willing to accept an input switch. This issue has recently been addressed by Dijkstra (in press) on the basis of simulations with the BIA model. Because word confusions are most likely among short words (which have a higher chance of resembling one another), Dijkstra limited his analysis to words of 3, 4, and 5 letters. In Dutch, there are some 2,600 such uninflected words with a frequency of at least 1 per 42 million. In English, there are about 3,600 of these words, and in French about 2,800. Assuming a person was perfectly trilingual for these languages, Dijkstra calculated that each word in Dutch has 4.5 orthographic neighbours in Dutch, increased by another 2.7 in English, and 1.5 in French. Surprisingly, Dijkstra noticed that it only took 5% longer for the model to identify a Dutch word when the model contained all three languages than when it only consisted of Dutch. One of the reasons for this is that when target words have many competing neighbours, these competitors will also interfere with each other (through lateral inhibition) and not just with the target. In addition, languages are likely to include language-specific cues (script, sequences of letters, sounds, diacritic markers) that are rapidly taken up by the word identification system to reduce the number of word competitors (Grainger & Beauvillain, 1987; Grosjean, 1988; Kroll & Dijkstra, 2001;Mathey & Zagar, 2000).

Another preconception that has been strong in people's mind is that due to capacity limitations, performance of a bilingual in each of the languages will necessarily be inferior to that of a comparable monolingual for that language. In this view, our emphasis in the first sections that L1 processing in a bilingual is in subtle ways different from L1 processing in a monolingual, may easily be misinterpreted as meaning that it is in subtle ways inferior. There is, however, no evidence for this, at least not for healthy individuals of comparable socio-economic backgrounds. A more subtle suggestion is that children who have to learn to read a language different from the one they speak at home, are likely to remain at a lower reading level than children who use the same language at home and in school. A review by Bialystok's (2002) shows that this is unlikely to be the case, when parents in a bilingual environment make an extra effort to create a language environment that is rich enough, as there seems to be a tendency in a bilingual family to limit the vocabulary both in L1 and in L2.

Conclusion

Research on bilingualism has witnessed a major paradigmatic shift in the last 10 years. Whereas a decade ago, researchers used to think of a bilingual as a person with two independent word form recognition systems and a language-selective input switch, today evidence is rapidly accumulating that both ideas are wrong. In the first stages of auditory and visual word recognition, there is no evidence for selective input. Word candidates from the different languages compete with one another very much like within-language candidates compete. This not only questions the assumption of language-selective input, but also the assumption of functionally independent lexicons. We have discussed the BIA and the BIA+ models as examples of computational models that offer us a way of theorising about multiple language proficiency within a framework of an integrated lexicon. Although the new perspective raises a whole series of new questions, ultimately we believe it provides us with a more realistic approach to the issue of bilingual word recognition, because it does not require two strong claims that were implicitly present in the older models. The first of these is that new skills recruit new, "non-used" circuits in the brain; the second that different parts of the brain can be switched on an off at will. To our knowledge, neither of these claims has received empirical support.

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Figure 1 : The Revised Hierarchical Model of Kroll & Stewart (1994)

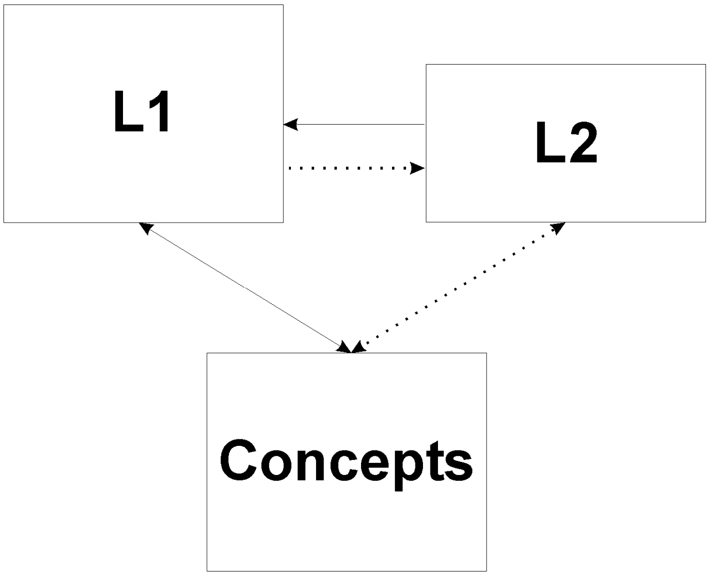

Figure 2 : The BIA model of Dijkstra and colleagues

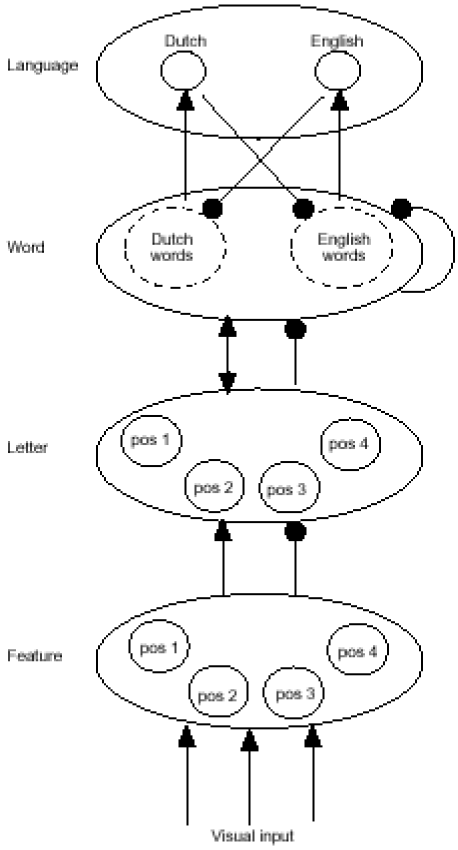

Figure 3 : The BIA+ model of Dijkstra & van Heuven (2002)