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**Models of Bilingual Representation and Processing:**

**Looking Back and to the Future**

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**Abstract**

Early research on the representation and processing of information in bilingual memory debated whether the two languages were stored and accessed together or separately in memory. In this chapter we argue that the question that motivated the initial research and model development on this topic failed to address a set of critical issues. These include distinctions between levels of language representation, differences in components of processing associated with unique task goals in comprehension vs. production, and the consequences of developmental aspects of language experience. We examine the legacy of the debate about shared vs. separate representations in a review of models that focus on each of the issues we have identified. Finally, in the course of our review, where the evidence is available, we consider the implications of recent neuroimaging research for constraining models of bilingual representation and processing.

## **Models of Bilingual Representation and Processing:**

### **Looking Back and to the Future**

Perhaps the most enduring question in psycholinguistic studies of bilingualism is whether bilinguals have a single system of memory representation and processing devoted to all of the languages they use, or separate systems, one for each language (e.g., Kolers, 1963; McCormack, 1977; Weinrich, 1953). Life experience offers ample support for each alternative. Bilinguals appear to be able to function in each of their languages when required to do so, without frequent or random intrusions of the other language, yet they can also code switch with other bilingual speakers in a manner that suggests simultaneous activity of both languages. In the early literature on this topic, an answer to the question of whether the languages were functionally independent failed to emerge despite an increasing number of empirical studies that tested predictions based on the two alternatives. With hindsight, it is easy to see why the question was ill formed, how the models proposed were underspecified, and why the resulting evidence was difficult to interpret. The question of whether bilinguals have shared or separate language representations requires that assumptions be made about a number of features of the cognitive architecture. These features include levels of representation, the distinction between representation and process, the manner in which cognitive representations and processes are recruited to perform different tasks, and the ways in which representations and processes change at different stages of learning and in response to different learning contexts.

The first problem with early bilingual models is that they failed to consider distinctions among levels of representation. A priori, there is no reason why the answer to the question of how the two languages are represented needs to be the same for orthography, phonology, semantics, and syntax. Indeed, the question may be answered differently for different aspects of

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language representation and for bilinguals whose particular languages constrain the possibilities of shared representation and whose language learning histories determine the context in which the two languages are acquired.

A second issue is that the questions of what is represented and how that information is processed were conflated in much of the early research. Thus, the assumption that the two languages were stored in independent memory systems was generally associated with a selective view of language processing that suggested that there might be a language switch that effectively enabled one language and shut the other down as needed (e.g., Macnamara & Kushnir, 1971). As Van Heuven, Dijkstra, and Grainger (1998) point out, these questions can be viewed independently of one another. It is possible to have shared memory representations with selective access or separate representations with parallel and nonselective access. One question is about the representation or code, the other is about the process of accessing that information.

A third respect in which the early bilingual models failed to adequately characterize cognitive activity concerns their scope. Few distinctions were made to address the distinct demands of comprehension, production, or memory. Models were considered to be general and predictions were tested for comprehension, production, and memory as if they were the same. Tests of particular models might therefore succeed or fail depending on the relation of the nature of evidence to the hypothesized mechanism.

Finally, although early research focused on different types of bilingualism (e.g., Weinrich, 1953), later models, for the most part, did not consider the consequences of the bilingual's learning history or the developmental changes associated with increasing skill in the second language (see De Groot & Poot, 1997; Kroll & Stewart, 1994; MacWhinney, 1997, Mägiste, 1984, and Potter, So, Von Eckardt, & Feldman, 1984, for exceptions).

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We can illustrate the problem in the early models using an example drawn from an often cited paper by Kirsner, Smith, Lockhart, King, and Jain (1984). Our example is not intended to single out these authors. To the contrary, this paper made an important contribution by demonstrating that it was possible to obtain cross-language semantic priming even when the two languages are mixed and orthographically distinct. Kirsner et al. contrasted five models of the bilingual lexicon, using a scheme initially proposed by Meyer and Ruddy (1974). These models are shown in Figure 1. In each of the five configurations, words in the bilingual's two languages

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Insert Figure 1 about here  
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have separate representations or share the same representation. The grouping of words vertically reflects their semantic relations whereas the horizontal connections depict lexical connections across translation equivalents. In Model A, there are separate representations for words in each language and lexical connections only within but not across languages. Kirsner et al. rejected this extreme version of the separate model on the grounds that it would prevent translation. Model B maintains separate lexical nodes for words in each language but includes translation links across languages. Model D, like Models A and B, assumes separate lexical representations. However, now there are not only the translation links of Model B, but also cross-language connections to associated words. Model C is an extreme version of the integrated model, with shared lexical nodes and therefore shared semantic relations within and across languages. The final alternative, Model E, assumes shared conceptual representations but separate lexical representations for each language. This model has been taken by some (e.g., Kroll & Sholl, 1992; Potter et al., 1984) as a solution to the apparent controversy surrounding the issue of separate vs. shared language representation. If only semantic, but not lexical, representations are shared, then tasks that reflect

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lexical level processing will tend to support independence across the two languages whereas tasks that reflect semantic processing will tend to support the common interdependent alternative.

The pattern of cross-language priming results obtained by Kirsner et al. (1984) allowed them to reject all but Models D and E, which they were unable to distinguish on the basis of the observed data. But the point of this example for present purposes is that the family of models shown in Figure 1 fails to address each of the issues identified above. Although lexical and semantic representations are distinguished, no information is specified concerning the form of those representations. The models do not identify orthographic and phonological aspects of lexical form, nor do they provide adequate detail that might allow the models to handle cases in which precise translation equivalents do not exist. Likewise, no assumptions are made about the selectivity of lexical access, although the arrangement of separated vs. integrated lexical representations would appear to suggest selective vs. nonselective access. The priming focus of the Kirsner et al. paper suggests that the models are intended to capture aspects of comprehension, but the arrangement in Model E was initially proposed by Potter et al. (1984) to account for bilingual performance in language production tasks. Thus, distinctions are not drawn between initial access from word to concept in comprehension and later lexicalization from concept to word in production. Finally, the architecture and processing within the lexicon in this family of alternatives appears to reflect an ultimate arrangement for proficient bilinguals that ignores their learning history, structural differences between their two languages, and their relative language dominance. How the relations between word and concept develop as second language learners become more proficient in the second language and how the proficient state of the lexicon may reflect dynamic changes in language use and activity is not addressed.

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In response to the problems described above, contemporary models have become more specialized, focusing on particular aspects of the codes that may be shared across languages, on the way in which lexical or grammatical information is accessed in bilinguals under specific task conditions, such as reading, listening, speaking, or remembering, and on the processes that characterize the cognitive changes that enable second language learners to become proficient bilinguals. These cognitive changes include the component processes that allow the development of skilled performance in the second language (e.g., see Segalowitz & Hulstijn, this volume) as well as the control mechanisms that permit attention to be allocated appropriately to the desired language and language task (e.g., Bialystok, this volume; Green, 1986, 1998; Michael & Gollan, this volume). In this context, the issue of independence or interdependence of bilingual language systems has not been abandoned, but instead recast to accommodate what we now know about language processing and the cognitive mechanisms that support it.

In this chapter we provide an overview of models that have brought research on the representation and processing of two languages to its contemporary state. Our review is necessarily selective due to the length limitations of the present text and the availability of other recent reviews of related material in this volume (e.g., chapters by Costa, Dijkstra, La Heij, Sánchez-Casas, and Thomas & Van Heuven) and others (e.g., De Groot, 2002; Dijkstra & Van Heuven, 2002; Gollan & Kroll, 2001; Kroll & De Groot, 1997; Kroll & Dijkstra, 2002; Kroll & Dussias, in press; Kroll & Sunderman, 2003; Kroll & Tokowicz, 2001). We focus specifically on models that address the issues raised above, namely what aspects of representation are shared and to what extent access to them is selective, how cross-language interactions change in the face of different task demands, and how the course of second language (L2) acquisition affects the form of representations and connections across the two languages. Furthermore, we restrict our

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discussion to models of lexical representation and to accounts of online processing because a disproportionate number of studies have addressed the bilingual lexicon. (For a review of models and evidence regarding syntactic processes see Frenck-Mestre, this volume; Kroll & Dussias, in press; MacWhinney, 1997, this volume; Pienemann, this volume). Questions about memory retrieval outside the timeframe of initial comprehension or production are also of interest but beyond the scope of the present review. (For a review of research on bilingual memory, see Durgunoglu & Roediger, 1987; Francis, this volume; Marian & Neisser, 1999; Paivio, 1991; Schrauf & Rubin, 1998).

Finally, where there are available data, we consider the theoretical implications of the recent neuroimaging evidence for models of bilingual representation and processing (see Abutalebi, Cappa, & Perani, this volume, for a comprehensive review of the imaging research). Interestingly, recent cognitive neuroscience approaches to bilingualism have returned to the question of whether the bilingual's two languages are represented in a separate or integrated memory system by asking whether and where there is distinct neural activity associated with each language. In some respects, the theoretical implications of this approach are potentially regressive with respect to model development. However, the new imaging evidence has also served the important function of reviving interest in how the timing and context of second language learning impacts the organization of the two languages in the brain. We briefly consider the implications of this new approach in our review.

### **A review of models: Levels of representation, processing tasks, development**

We now turn to a review of specific models. Our review is organized into three sections. The first considers models that illustrate the ways in which assumptions have been made about different levels of representation. The second examines models that have been proposed to



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address particular language processing tasks, such as comprehension or production. The final section focuses on developmental issues and their consequences for proficient bilingual performance.

### **Levels of representation**

An advance in modeling the bilingual lexicon came from the recognition that different aspects of the lexical code may distinctly constrain the form of cross-language interactions. The development of computational models of word recognition in the monolingual domain (e.g., Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981; Seidenberg & McClelland, 1989) generated a number of alternative candidates that, with some modification, appeared to provide a reasonable extension to the bilingual case. Grainger and Dijkstra (1992) and Dijkstra and Van Heuven (1998) first proposed such an extension of the Interactive Activation Model, called the BIA or Bilingual Interactive Activation Model. The BIA model, a localist connectionist model, is at present the bilingual model of word form that has been studied most extensively. We describe it only briefly because two chapters in the present volume examine the model, its associated evidence, recent extensions, and its relation to distributed models (Dijkstra, this volume; Thomas & Van Heuven, this volume). We then examine the Distributed Feature Model (De Groot, 1992b), a model focused specifically on semantic representation.

**Word form.** The BIA model (see Figure 1 in Thomas & Van Heuven, this volume) borrows the basic architecture of McClelland and Rumelhart's (1981) Interactive Activation model, such that processing is initiated by visual input from text and proceeds in a bottom-up manner from letter features to letters to words. The BIA model assumes that the lexicon is integrated across languages and that lexical access is parallel and nonselective. Thus, during early stages of word recognition, patterns of activation and inhibition within and across levels of

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representation are hypothesized to be language blind. However, unlike models of word recognition for monolinguals, the bilingual model requires that there be a basis upon which words can eventually be correctly selected in the intended language. In the BIA model, the mechanism introduced to achieve language selection is the layer of language nodes. The language nodes, as represented in the original BIA model, inhibit words in the nontarget language. Their top-down influence is not thought to alter the early activation of words in each of the two languages, but to increase the later likelihood of selecting a word from the intended language (see Dijkstra & Van Heuven, 2002, for a revision of this mechanism in the BIA+ model).

Unlike earlier bilingual models, the BIA model proposes a precise mechanism for the way in which orthographic forms are activated in two languages when a bilingual recognizes visually presented words. For languages whose orthographies are similar, there will be parallel activation that results in competition at the lexical and sublexical levels. This property of the model has been investigated by exploiting the presence of words whose form overlaps across languages. These include *cognates*, translation pairs that share word form and meaning, *interlingual homographs*, words that are similar in form in both languages but not translation equivalents, and *orthographic neighbors*, words in each language whose lexical form is only slightly different than the target word. If lexical access is nonselective across languages, then the consequences of cross-language activity should influence recognition performance. If lexical access is selective, then the presence of other-language form relatives should be irrelevant and processing should proceed in the same way as for a monolingual reader. Thus, according to the selective view, a word like *room*, which is an interlingual homograph in English and Dutch (in which the word *room* means cream), would be processed in each language as if it were an

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unambiguous word. In contrast, according to the nonselective view, both language senses of the word would be active and compete, similar to the competition observed for lexically ambiguous words within a language. Over a large number of studies and using a range of experimental paradigms, convincing support for the nonselective alternative has been reported (see Dijkstra, this volume, for details and Thomas & Van Heuven, this volume, for a description of how the model has been implemented). A particularly compelling aspect of the evidence on word recognition is that the activity of the second language influences the native language even when the task is performed in the native language alone (e.g., Van Hell & Dijkstra, 2002).

Although the initial evidence for the BIA model focused on orthographic interactions across languages, more recent evidence on phonology suggests that phonological codes are also active in both languages during word recognition (e.g., Brysbaert, Van Dyck, & Van de Poel, 1999; Dijkstra, Grainger, & Van Heuven, 1999; Jared & Kroll, 2001; Jared & Szucs, 2002; Marian & Spivey, 1999; Schwartz, Kroll, & Diaz, 2003). For example, Schwartz et al. showed that the time for English-Spanish bilinguals to name cognates was a function of the match between the orthographic and phonological similarity of their forms in the two languages. These findings and others suggest that it is not orthography alone but the interaction between orthography and phonology across the bilingual's two languages that determines the course of visual word recognition. The inclusion of cross-language phonological activity requires an extension to the BIA model that has recently been described by Dijkstra and Van Heuven (2002) in a model now called the BIA+ and by Van Heuven (2000) (see the SOPHIA model in Figure 3 of the chapter by Thomas & Van Heuven, this volume). The new models introduce both lexical and sublexical phonology to account for the observed patterns of orthographic and phonological interaction. Finding cross-language phonological interactions also accommodates the observation

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that nonselectivity is not restricted to languages whose visual form is similar (e.g., see Gollan, Forster, & Frost, 1997, for an example of priming between Hebrew and English).

The specificity of the BIA model allows clear predictions to be tested about the form of cross-language interactions during visual word recognition. However, by accounting for only one aspect of lexical form, the model fails to fully characterize word recognition in and out of meaningful context. Just as the new extensions in the BIA+ and SOPHIA models include phonological representations, they also now include semantic representations to address this issue. Only a small number of studies have investigated the effects of semantic and syntactic context on cross-language activation during lexical access (e.g., Altarriba, Kroll, Sholl, & Rayner, 1996; Elston-Güttler, 2000; Schwartz, 2003; Van Hell, 1998). The answer to the question of whether context can modulate the parallel activation of information about words in both languages and, if so, at what level in the system, will be critical to the development of the next generation of models. The preliminary evidence on this issue suggests that at least under some circumstances, it is possible to modulate the presence of cross-language interactions. Both Van Hell (1998) and Schwartz (2003) found evidence that in the context of a highly constrained sentence context, cross-language activity was reduced. However, for the same materials, in low constraint sentences and out of context, there was clear evidence for cross-language influences. An intriguing aspect of these results is that the language of the context itself does not appear to determine selectivity. If lexical access was fundamentally selective, then we might expect that the language of the sentence would be an effective cue to selection. Yet, in each of these studies, the low constraint sentence context did not override nonselectivity. Like cross-language semantic priming studies in which the language of the prime has been manipulated (e.g., De Bruijn, Dijkstra, Chwilla, & Schriefers, 2001), these results suggest a limited role for language-specific

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cues per se, at least in comprehension.

Although most of the evidence for language nonselectivity has been based on behavioral measures, a few recent studies have examined neural activity during bilingual word recognition. De Bruijn et al. (2001) found similar N400 effects in an ERP study for target words semantically related to an interlingual homograph regardless of the language bias preceding the homograph. In ERP research, the N400 has been taken as an index of lexical and semantic processing. Finding similar results regardless of language context would appear to support the nonselective account provided by the BIA model. In contrast, a recent ERP and fMRI study by Rodriguez-Fornells, Rotte, Heinze, Nössel, and Münte (2002) claimed that selectivity was possible in a language decision task in which bilingual participants could use phonological information to avoid cross-language interference (but see Grosjean, Li, Münte, & Rodriguez-Fornells, in press, for a critique of these results). Marian, Spivey, and Hirsch (2003) also examined the parallel activation of the two languages by comparing cross-language interactions in an eye movement paradigm and using fMRI measures. Their results fall somewhere between the two alternatives, with some evidence for shared areas of brain activation and other evidence for differences. They suggest that the presence of both similarities and differences is consistent with a timecourse account in which the same cortical mechanisms are likely to be activated for both languages during early stages of processing but as processing proceeds, patterns of activation may become more distinct. It will remain to be seen how well the developing body of neuroimaging evidence fits with the nonselective account that appears so compelling on the basis of the behavioral data.

**Meaning.** We turn now to the representation of meaning because a complete model of the bilingual lexicon will require that the semantics be specified (see Francis, 1999, and this volume, for a comprehensive review of research on semantic and conceptual representation in

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bilinguals). Much of the research on language processing in bilinguals has assumed that the same semantic representations are accessed for both languages (e.g., Costa, Miozzo, & Caramazza, 1999; La Heij et al., 1990; Potter et al., 1984) because past research has appeared to support that assumption. For example, in a bilingual variant of primed lexical decision, semantically related words prime each other even when the prime and target appear in different languages (e.g., Altarriba, 1990; Chen & Ng, 1989; Keatley, Spinks, & De Gelder, 1994; Meyer & Ruddy, 1974; Schwanenflugel & Rey, 1986; Tzelgov & Eben-Ezra, 1992). Although the pattern of cross-language priming often reveals an asymmetry, with more priming from the first language, L1, to the second, L2, the presence of cross-language priming at all, especially under conditions that minimize the likelihood of translation, suggests that some shared meaning is accessed across languages. Similarly, in a Stroop-type picture-word production task, interference is observed when a distractor word is semantically related to the picture's name regardless of the language in which it appears (e.g., Costa et al., 1999; Hermans, 2000; Hermans, Bongaerts, De Bot, & Schreuder, 1998).

The reliance on out-of-context tasks in which participants translate concrete nouns or name pictured objects may have contributed to the assumption of shared semantics because these circumstances may be the most likely to evoke the same meaning in both of the bilingual's languages. It also made it reasonable to ignore distinctions between semantic and conceptual representations and the more general implications of lexical semantics that would be relevant in ordinary sentence contexts. In contrast, research on linguistic relativity focuses on just those circumstances that are most likely to evoke different meanings across languages, for example, when there are not precise translation equivalents or when the linguistic or cultural context biases the appropriate sense of meaning (see Pavlenko, 1999, and this volume, for a discussion of

linguistic relativity).

To accommodate the possibility of both shared and separate semantics under different circumstances, De Groot and colleagues (De Groot, 1992a; De Groot, 1992b; De Groot, 1995; De Groot, Dannenburg, & Van Hell, 1994; Van Hell, 1998; Van Hell & De Groot, 1998) proposed a model of bilingual semantics called the Distributed Feature Model (see Figure 2). A key assumption in the model is that the degree to which semantic representations are shared across languages is a consequence of the word's lexical category. Representations for concrete nouns and cognates are assumed to be quite similar across languages whereas representations for abstract nouns and noncognates are assumed to be more distinct. In some respects, the Distributed Feature Model uses word type to model lexico-semantic representations in a manner that resembles the way in which older models used the learning history of the bilingual to model compound vs. coordinate representations (e.g., Lambert, 1969). In one case, attributes of the language representation determine the architecture of the system. In the other, attributes of the language user constrain the nature of the representations and their relations (see the discussion of compound vs. coordinate bilingualism in a later section of this chapter).

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The Distributed Feature Model predicts that the degree of overlap across translation equivalents will determine the time it takes speakers to translate from one language to the other or to recognize whether two words are the correct translation equivalents of one another. To the extent that translation requires semantic processing (De Groot et al., 1994; La Heij, Kerling, & Van der Velden; 1996; but see Kroll & Stewart, 1994), then the speed of access to semantic representations should influence performance. In a series of studies, De Groot and colleagues

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(De Groot, 1992a; De Groot, 1992b; De Groot, 1995; De Groot et al., 1994; Van Hell, 1998; Van Hell & De Groot, 1998) confirmed these predictions. Using a range of tasks that included translation production, translation recognition, lexical decision, and word association, these experiments showed that the time to recognize and produce translation equivalents is faster when the word pairs are concrete nouns or cognates. Van Hell and De Groot also demonstrated that word associations were more similar across languages for concrete words and cognates than for abstract words and noncognates.

The Distributed Feature Model assumes that the semantic system itself is shared across the bilingual's two languages. The features that comprise the pool of semantic primitives are hypothesized to be available to either language (see Illes et al., 1999, for neuroimaging evidence that the same areas of the brain are active when bilinguals make concreteness judgments about words in each of their languages). How those features combine within a language then determines the similarity of particular concepts. Earlier research on concreteness effects within a single language showed that concrete words have higher contextual availability than abstract words (e.g., Schwanenflugel & Shoben, 1983). Abstract words appear to depend more on provided context for their meaning than concrete words. The Distributed Feature Model extends this idea to the bilingual case. If the context in which words are processed differs across languages and cultures, then the meaning of abstract words will depend more on the context in which their sense is instantiated than the meaning of concrete words.

In a recent study with Dutch-English bilinguals who performed a semantic rating task on translation pairs (i.e., how similar are these two words?), Tokowicz, Kroll, De Groot, and Van Hell (2002) found that indeed concrete translation equivalents were more likely to share meaning than abstract translation equivalents, although no distinction between cognate and noncognate



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translations was found. A further difference reported by Tokowicz et al. was that words with more than one translation equivalent were rated as less semantically similar to their translation equivalents than words with only one translation equivalent. This finding suggests that the existence of alternate translations influences how adequate each individual translation is considered to be. Indeed, Tokowicz (2000) found that the time to produce translation equivalents in a translation production task was slower for words considered to have multiple translation equivalents than for words with only a single dominant translation. These results suggest that bilinguals can have (nearly) identical concepts for some words and different concepts for other words. The consequence of differences in the degree of overlap in meaning for the nature of cross-language processing will depend on the nature of the task and also the bilingual's level of proficiency and context of acquisition (e.g., Dufour & Kroll, 1995; Finkbeiner, 2003; Jiang, 2000; Silverberg & Samuel, 2003).

### **Processing tasks**

Even with a model of bilingual representation that provides an adequate characterization of lexical form and meaning, we would need to make additional assumptions about the ways in which the goals associated with different tasks utilize those representations. The same lexicon may underlie word recognition and word production, but the manner in which lexical processes are initiated and the demands on processing resources associated with each task, may differentially constrain performance (see Kroll & Dijkstra, 2002, for a comparison of bilingual comprehension and production). Here we consider two models that address the issue of how the task determines the nature of the information that is retrieved and the manner in which processing is controlled. One is a model of lexical production to account for the way in which a bilingual initiates a spoken word in response to the requirement to name a picture, translate a

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word, or speak a thought. The other is a model of the control processes that are hypothesized to be recruited so that only the intended language is selected for comprehension or production.

**Production.** Far less research on the bilingual lexicon has examined production relative to comprehension. Although code-switching has been studied extensively by linguists and sociolinguists (see Myers-Scotton, this volume), it is only recently that the methods developed by psycholinguistics to study speech production within the native language (e.g., Levelt, 1989; Levelt, Roelofs, & Meyer, 1999; Peterson & Savoy, 1998) have been extended to the bilingual case (e.g., Colomé, 2001; Costa & Caramazza, 1999; Costa et al., 1999; De Bot & Schreuder, 1993; Gollan & Silverberg, 2001; Hermans et al., 1998; Miller & Kroll, 2002). Our purpose in the present discussion is not to provide a comprehensive review of this work (see the chapters by Costa and La Heij, this volume). Rather, we hope to illustrate how the components of a model of lexical access in production will necessarily address some different issues than a model of comprehension.

We adopt a model of spoken production proposed first by Poulisse and Bongaerts (1994) and later extended by Hermans (2000) (see Figure 3). The model characterizes the bilingual lexicon in the face of the requirement to speak a word in one language or the other. Like models in the monolingual domain (e.g., Levelt et al., 1999), the production model shown in Figure 3 assumes that there are three levels of representation that are engaged in translating an idea into a spoken word. First, the idea must be represented conceptually. If the event that initiates speaking is a pictured object, as shown in the model, then this first step will involve recognizing the object and accessing its meaning. In this model, there is also a language cue represented at the conceptual level. The language cue signals information about the language in which the utterance is to be spoken. If lexical access in production is language selective, then the intention to speak a

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word in one of the bilingual's language rather than the other might suffice to turn the remaining steps in the production process into the monolingual case. However, recent experiments suggest that even when bilinguals know that they will be speaking only one of their two languages, that knowledge is not sufficient to effectively switch off the activation of other language alternatives (e.g., Colomé, 2001; Costa, Caramazza, & Sebastián-Gallés, 2000; Kroll, Dijkstra, Janssen, & Schriefers, in preparation).

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Insert Figure 3 about here  
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Following conceptual processing, a set of lemmas is hypothesized to be activated in each of the bilingual's two languages. Although there is some debate about what information is stored at the lemma level, particularly with regard to grammatical category, there is general agreement that at this level, abstract lexical representations for words in each language are activated. Unlike the assumptions of an integrated lexicon in comprehension models such as BIA or BIA+, the assumption here is that the syntactic constraints specified at the lemma level will require that lemmas are necessarily distinct for words in each of the bilingual's languages. At the final level depicted in the model, the phonology of the spoken word is specified. Like the assumption of the Distributed Feature Model for semantics, the production model assumes that each language draws on a common pool of phonological features. Thus, although there may be distinct aspects of the phonology associated with each language, the assumption is that the phonological system itself is shared so that common phonological elements in each language will activate the same or similar representations.

A key question about production concerns the sequencing of these representations prior to the production of a spoken word or sentence. In research on monolingual production, this

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issue has been at the center of a debate about the nature of lexical access and the interactions between syntax and semantics (e.g., Dell, 1986; Levelt et al., 1999; Vigliocco & Hartsuiker, 2002). In the bilingual domain, the issue is potentially even more complicated because the language of speaking also has to be determined. If representations are activated for both languages in parallel, then the question of whether they compete for selection is critical because proficient bilinguals will have at least two words available for each concept. In the model shown in Figure 3 there is activation of candidates in both languages at the lemma level, but the assumption is that selection occurs at this level (e.g., see Hermans et al., 1998) and that phonology is specified only for the language the person intends to speak. The recent evidence suggests that there is in fact activation to the level of the phonology for words in both languages (e.g., Colomé, 2001; Costa et al., 2000; Kroll et al., in preparation). The theoretically difficult question is whether all activated information competes for selection or whether the language cue can effectively guide the selection process. The interested reader can consult the chapters by Costa, La Heij, and Meuter in this volume for an in-depth discussion of this particular issue.

The point for present purposes is that how the very same representations may be engaged will differ depending on whether the task requires comprehension or production. In production, the initiating event consists of conceptual activity. The corresponding sequence of processing from concepts to words will necessarily engage feedback from semantics that may or may not be available during comprehension, for which the sequence from words to concepts is more likely to be driven by properties of the stimulus input rather than its meaning. In the production model illustrated here, the language cue is hypothesized to be encoded as part of the conceptual representation of the event that initiates production. In a comprehension model such as BIA or BIA+, the language nodes are not activated until relatively late in the processing sequence. Given

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these differences, it is perhaps surprising that the empirical evidence suggests that lexical access is language nonselective for both comprehension and production. However, it is important not to conclude that the apparent similarities arise from the same mechanism. Particularly in production, it should be possible in theory to use context and available cues to bias selection. A number of recent studies suggest that this may be the case (e.g., Bloem & La Heij, 2003; Miller & Kroll, 2002).

**Control.** Like many cognitive models, those that characterize the bilingual lexicon have been designed without much concern for how the cognitive system actually manages to produce actions in response to task goals. The problem is especially acute in light of the evidence for language nonselectivity in both comprehension and production. If candidates in both of the bilingual's languages are routinely available in comprehension and in production regardless of the intention to use one language only, then a mechanism must be in place to modulate the resulting competition and to control performance. A number of recent models have addressed the control problem by finding solutions within the lexicon itself (e.g., the language nodes served this purpose in the original BIA model) or by positing a mechanism that falls outside the lexicon but uses the output of the lexical system to achieve proficient performance. Green (1998) proposed the Inhibitory Control (IC) model, shown in Figure 4, to accomplish this goal. The model is described in some detail by Meuter (this volume) so our review will touch only on its central points.

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Insert Figure 4 about here  
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Like other models of production, the IC model assumes that a conceptual representation is generated at the onset of planning. That conceptual activity in turn activates both the lexico-

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semantic system and the supervisory attentional system or SAS. The role of the SAS is to control the activation of task schemas for particular language processing goals. Thus the task schema for naming a picture in the L1 would differ from the schema for naming a picture in L2 or translating a word from L1 to L2. The IC model further assumes that lemmas are tagged for language membership. A critical function of the task schemas is to activate lemmas in the intended language and to inhibit lemmas in the unintended language. Because the level of competition created by this process will require attentional resources, the degree of inhibitory control required for a bilingual to perform a particular task will be related to the relative activation of lemmas in each language. For example, if lexical candidates in the more dominant L1 are active when a bilingual is attempting to name a picture in L2, then the inhibitory processes required to modulate the competition from L1 to L2 will be greater than those required when the task is performed in the L1 itself.

An important source of evidence regarding inhibitory control comes from experiments on deliberate language switching (see Meuter, this volume, for a review of this literature). Research on language switching has shown that switch costs are greater when bilinguals are required to switch into L1 relative to L2 (e.g., Meuter & Allport, 1999). The asymmetry in switch costs appears at first counterintuitive because one might think that the more dominant L1 will always be automatically available. However, from the perspective of the IC model, the result makes a good deal of sense because switch costs will be greatest when the processing on the trial just prior to the switch induces a great deal of competition and therefore requires significant inhibition. It is precisely this mechanism that is hypothesized to occur when a bilingual performs a task such as picture naming or number naming in the L2. If L1 lemmas compete prior to the selection of the word to be produced in L2, then the inhibition of the L1 lemmas will produce a

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cost when L1 is the target language to produce on the subsequent trial.

A complete understanding of how attentional and task processes influence performance will be an important feature of the next generation of models of the bilingual lexicon (see Dijkstra & Van Heuven, 2002, and also Von Studnitz & Green, 2002, for an illustration of how this mechanism might work in comprehension). As Meuter (this volume) notes, it's not entirely clear how to think about the scope of the inhibitory mechanism proposed within the IC model. Identifying the factors that determine the range of inhibition will be critical as it seems unreasonable to think that the entire language is inhibited at once. Furthermore, the IC model, as depicted in Figure 4, makes few assumptions about the architecture of the lexicon itself, an issue that we have considered in some detail in the previous sections of this chapter. It will be important to understand how assumptions about representation and processing within the lexicon constrain, and are constrained by, the attentional mechanisms that serve as an interface to the more general cognitive system and to action.

An aspect of the IC model that has only recently been investigated concerns the implications of inhibitory control for the achievement of L2 proficiency. If the mental juggling that appears to be required by using two languages can only be effectively controlled by the allocation of sufficient attentional resources, then individuals who already possess high memory capacity may be advantaged second language learners. A number of recent studies investigating individual differences in memory and attentional resources for second language acquisition suggest that this may be the case (see Michael & Gollan, this volume). Furthermore, in the case of highly skilled translators and interpreters, it seems clear that they possess extraordinary cognitive resources that enable their remarkable performance (see Christoffels & De Groot, this volume). What is less clear is the direction of causality. We don't yet know whether individuals

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with high cognitive abilities are more likely to become skilled bilinguals or whether the process of becoming bilingual has the positive consequences of enhancing cognitive skills more generally. The evidence on young bilingual children (see Bialystok, this volume) provides compelling support for the view that bilingualism itself may confer a set of cognitive benefits that extend beyond language processing to executive control functions. However, little is known about whether the advantages observed in early childhood endure into adulthood or whether late acquisition of a second language has similar consequences.

What is evident in this discussion is that models of bilingual processing and its control will require an account that considers not only representation and control but also developmental aspects of language acquisition. In the final section of our review we turn to models of bilingual representation and processing that have focused on these developmental issues.

### **Developing L2 proficiency**

**Early vs. late acquisition: Compound vs. coordinate bilingualism.** We now consider how the context in which L2 is acquired may affect semantic and lexical representations and their interconnections. Although some researchers have viewed L2 acquisition from the perspective of the critical period hypothesis (e.g., Lambert, 1972), our review considers aspects of L2 acquisition that are not typically the focus of research on that topic (see Birdsong and DeKeyser & Larson-Hall, this volume, for current reviews of the critical period hypothesis). Depending on the acquisition context of the bilingual, a distinction has been made between *compound* and *coordinate* bilinguals. Generally defined, compound bilinguals are individuals who learn two languages simultaneously, in the same context, whereas coordinate bilinguals are individuals who learn their two languages in succession, in separate contexts. However, it should be noted that there has been disagreement in past research concerning the definitions of



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compound and coordinate bilingualism, and whether this distinction is a continuum or rather a dichotomy (Lambert, 1969).

One of the hypothesized differences between compound and coordinate bilinguals regards the similarity of concepts referred to by L1 and L2 words. It was believed that compound bilinguals had one set of concepts that could be referenced by either language, whereas coordinate bilinguals had two sets of concepts, each set uniquely available to one of the two languages. This distinction has not only been applied to semantic aspects of the language, but also to syntactic, phonological, and cultural aspects (e.g., Lambert, Havelka, & Crosby, 1958).

To test the compound/coordinate distinction, Lambert (1961) used the semantic differential to determine whether translation equivalents shared meaning in the two languages. In this task, the bilingual rates a word relative to adjectives (e.g., how cold is a house?) and then does the same for the translation equivalent. The theoretical prediction was that compound bilinguals would rate translation equivalents more similarly than coordinate bilinguals. Lambert found that compound bilinguals did give similar ratings to translation equivalents, but that the ratings of coordinate bilinguals depended on their particular acquisition context—coordinates who learned L1 and L2 in the same cultural context rated translations similarly, whereas coordinates who learned the two languages in different cultural contexts rated translations dissimilarly. These findings show that the experience of the learner is important above and beyond the manner of learning. Although the evidence on the semantic differential revealed differences between compound and coordinate bilinguals, there were also questions as to whether these differences reflected the most critical aspects of the learning context.

More recent research has examined the neural consequences of the language-learning context. Whereas psycholinguistic research has moved away from the question of whether the

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two languages are stored together or separately in favor of asking what circumstances elicit behavior that appears similar or different, neuroimaging studies of bilingualism have returned to the question to ask whether the same neural tissue is activated during processing of the two languages. In some instances, the diffusion of activation as well as the activated areas is considered important. A number of studies have reported that early bilinguals are more likely than late bilinguals to activate the same brain regions when processing L1 and L2 (e.g., Kim, Relkin, Lee, & Hirsch, 1997). However, because early/late bilingualism is often confounded with proficiency, Abutalebi et al. (this volume) conclude that age of acquisition is not as important as the degree of proficiency attained for determining whether the same neural substrates serve the two languages—when individuals are highly proficient in their two languages, the languages appear to use the same neural networks, whereas distinct networks are used when bilinguals are not very proficient in L2, at least when tested using language production tasks (e.g., Chee, Tan, & Thiel, 1999; Illes et al., 1999; Klein, Milner, Zatorre, Meyer, & Evans, 1995; but see Perani et al., 2003 for evidence that the language acquired first may be associated with reduced brain activation during lexical retrieval tasks).

In contrast to the conclusion of neuroimaging studies suggesting that proficiency may be more important than the context of acquisition, studies of brain laterality show that early bilinguals have more bilateral hemispheric involvement for the native language than monolinguals and late bilinguals, even when the late bilinguals are proficient in L2 (see Hull & Vaid, this volume, for the results of a meta-analysis including a large number of bilingual laterality studies). This finding suggests that learning a second language early in life leads to a qualitative difference in how language is processed by the brain above and beyond language

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proficiency. Note that although the conclusions of the imaging and laterality studies may seem contradictory on the surface, they are not necessarily at odds with one another because the neuroimaging evidence concerns similarity between areas used by the two languages whereas the laterality evidence concerns the areas used by the brain to process L1.

Another factor that may be critical in determining the nature of meaning representations for words in the two languages is age of acquisition (AoA). There is ample evidence suggesting that even when word frequency is controlled, words that are learned earlier in life have a processing advantage over words that are learned later in life (e.g., Gerhand & Berry, 1998; Morrison & Ellis, 1995; Morrison, Ellis, & Chappell, 1997). Izura and Ellis (2002) reported a similar finding for the effect of AoA in L2. Regardless of L1 AoA, L2 words that were learned early have a processing advantage over L2 words learned later. This result suggests that the age at which a word is acquired will influence the connections between that word and its corresponding meaning. It also suggests that for late L2 learning, the AoA of an L2 word does not simply inherit the AoA of its translation equivalent. The implication for bilinguals who learn their languages later than early childhood is that L2 words will not be as strongly connected to their meanings as L1 words. Some support for that conclusion was reported in a recent study by Silverberg and Samuel (2003) in which they compared semantic priming effects in bilinguals who differed in both the context of acquisition and in their proficiency in L2. Only early bilinguals who were highly proficient in the L2 produced significant semantic priming whereas late bilinguals failed to show these effects regardless of their L2 proficiency. The consequences of both factors, context of acquisition and degree of L2 proficiency, will be important foci in future research on this topic.

**Developing lexical and conceptual representations in the second language.** In the

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final portion of our review we consider how the connections between words and their meanings develop with increasing proficiency in the L2. Results from several studies in the cognitive literature led to the conclusion that words were likely stored separately from concepts in memory (e.g., Anderson & Bower, 1973; Potter, 1979; Snodgrass, 1980). One particularly important finding was that it takes around 200-300 ms longer to name a picture than to read a word aloud (e.g., Cattell, 1886; Fraisse, 1960; Potter & Faulconer, 1975). In a classic study, Potter et al. (1984) used this empirical observation as a means to evaluate two models of bilingual memory representation—the *Word Association* and *Concept Mediation Models*.

According to the Word Association Model (see Figure 5a), an L1 word is directly associated to its second language equivalent. To gain access to concepts, L2 words must first activate their L1 equivalents. By comparison, the Concept Mediation Model (see Figure 5b) hypothesizes that words in each language are directly associated to concepts, but that translation equivalents are not directly connected to each other. The concepts in both models are proposed to be amodal, and it is further assumed that pictures have direct access to the same concepts.

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Insert Figure 5 about here  
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To test these models, Potter et al. (1984) compared the time it took bilinguals to translate words from L1 to L2 and to name pictures in L2. The logic Potter et al. used assumed that picture naming always requires conceptual processing. If translation from L1 to L2 resembles picture naming, then one can conclude that translation is also conceptually mediated. Of interest, is that the two models make different predictions about the relation between picture naming in L2 and translation from L1 to L2. The Word Association Model predicts that L2 picture naming should take more time than translation because two additional steps are necessary (concept

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retrieval and L1 word retrieval). Potter et al. reasoned that these two extra steps are also responsible for the difference in the amount of time it takes to name pictures and words in L1. Therefore, they estimated the magnitude of the difference between picture naming and translation time predicted by the Word Association Model to be in the 200-300 ms range. In contrast, the Concept Mediation Model predicts that the two tasks should take approximately the same amount of time because they involve similar component processes.

The results of a first experiment, with highly proficient Chinese-English bilinguals showed that L2 picture naming took about the same amount of time to perform as L1 to L2 translation, and therefore favored the Concept Mediation Model. The surprising result was that in a second experiment, a group of less proficient English-French bilinguals produced the same pattern, suggesting that they also conceptually mediate the second language. Potter et al. (1984) concluded that the Concept Mediation Model more accurately characterized the memory representations of both less and more proficient bilinguals than the Word Association Model.

The results of Potter et al. (1984) study are counterintuitive because we might have expected that the less proficient bilinguals would be more likely to rely on translation equivalents than the more proficient bilinguals. However, two aspects of the design may have inadvertently affected the conclusions. First, the items used in the experiment with the less proficient English-French participants were intentionally selected to be well known by novices in the second language, and items that were not known by half of the participants were removed from the analyses. As we will later discuss, this selection criterion may have biased the results in favor of the concept mediation pattern.

A second critical aspect of the Potter et al. (1984) study concerns the selection of the less proficient bilinguals. In this study they were a group of highly motivated students about to go to

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France on a study abroad program. Although the data show clearly that this group was far less proficient than the English-Chinese bilinguals to whom they were compared (e.g., they were slower and more error prone), it is possible that they were beyond an initial stage of lexical acquisition that is characterized by reliance on word-to-word associations across the two languages.

To determine whether the Word Association Model characterizes second language learners at the earliest stages of acquisition, Kroll and Curley (1988) and Chen and Leung (1989) used a methodology similar to the one used by Potter et al. (1984), but included participants who were of lower proficiency in L2 than Potter et al.'s less proficient group. These studies showed that for learners at early stages of acquisition, translation from L1 to L2 was indeed performed more quickly than L2 picture naming, confirming the prediction of the Word Association Model. Both studies also replicated the results of the Potter et al. study for more proficient bilinguals. Therefore, these data suggest that there is a transition from a stage of acquisition in which there is reliance on translation equivalents between L1 and L2 to a stage in which direct concept mediation is possible.

To account for this developmental sequence, Kroll and Stewart (1994) proposed the Revised Hierarchical Model. The model (see Figure 6) integrates the connections depicted in the Word Association and Concept Mediation Models. Unlike the earlier models, the Revised Hierarchical Model makes two critical assumptions about the strength of connections between words and concepts in bilingual memory. The first is that L1 words are assumed to be more strongly connected to concepts than are L2 words. The second is that L2 words are assumed to be more strongly connected to their corresponding translation equivalents in L1 than the reverse. The resulting asymmetries are thought to reflect the consequences of L2 acquisition in late

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learners who possess a fully developed lexicon for words in L1 and their associated concepts. Like other claims about transfer from the L2 to L1 (e.g., MacWhinney, 1997), the Revised Hierarchical Model proposes that during early stages of L2 acquisition, the learner exploits the existing word-to-concept connections in L1 to access meaning for new words in L2. Thus, a strong lexical connection from L2 to L1 will be established during learning. Over time, there may be feedback that establishes L1 to L2 connections at this level, but they will be weaker than those for L2 to L1 because the learner does not need to use L2 in the same way. As learners become more proficient in L2, they will begin to develop the ability to directly conceptually process L2 words, but the connections between words and concepts are assumed to remain stronger for L1 than for L2 for all but the most balanced bilinguals.

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One consequence of the asymmetries represented within the Revised Hierarchical Model is a predicted asymmetry in translation performance, such that translation from L1 to L2, in the forward direction of translation, will be conceptually mediated whereas translation from L2 to L1, in the backward translation, can proceed directly via the lexical connections from L2 words to their translation equivalents. Therefore, forward translation will take longer to perform than backward translation and will be more likely to engage semantics. As L2 proficiency increases, the connection from L2 words to concepts will strengthen, resulting in a decrease in the magnitude of the translation asymmetry and a corresponding increase in the degree to which backward translation is also conceptually mediated.

To test the hypothesis that only forward translation involves conceptual mediation, Kroll and Stewart (1994) had relatively proficient Dutch-English bilinguals translate words from L1 to

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L2 and L2 to L1. They manipulated the semantic context of the translation lists. One list was semantically mixed whereas the other list was semantically categorized (e.g., all fruits, all animals, etc.). Only translation from L1 to L2 was affected by the semantic context in which translation was performed. Translation from L1 to L2 was slower for words presented in semantically-categorized lists than for the same words presented in semantically-mixed lists; translation from L2 to L1 was unaffected by this manipulation. These findings provided initial support for the claim that only L1 to L2 translation necessarily involves concept mediation.

A number of studies have examined the developmental predictions of the Revised Hierarchical Model. Talamas, Kroll, and Dufour (1999) had more and less proficient bilinguals perform a translation recognition task (De Groot, 1992a) in which a pair of words was presented and participants indicated whether the two words were translations of each other. The critical items were nontranslation foils that were related to one another by virtue of being form-related (e.g., man-hambre [hunger] instead of man-hombre [man]) or meaning-related (e.g., man-mujer [woman] instead of man-hombre [man]) to the correct translation. The results showed that the less proficient bilinguals suffered more form than meaning interference, whereas the reverse was true for the more proficient bilinguals. The results are thus consistent with a developmental shift from form to meaning with increasing proficiency in the L2.

In a study similar to Talamas et al. (1999), Sunderman (2002) also used a translation recognition task to investigate the development of L2 in a group of native English speakers learning Spanish as adults. In that study, three types of “no” trials were compared: form related (man-mano [hand]), meaning related (man-mujer [woman]), and form related to the translation (man-hambre [hunger]). The results showed that all participants, regardless of proficiency, were slower to reject word pairs that were form or meaning related relative to unrelated controls.



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However, only the less proficient participants were slower to respond to the foils that were form related to the correct translation (e.g., man-hambre). Although the presence of semantic effects for all groups failed to replicate the Talamas et al. results (see also Altarriba & Mathis, 1997), the differential effect of the form related translation foil suggests, as the Revised Hierarchical Model predicts, that access to the translation equivalent may play a particularly important role early in L2 learning (see MacWhinney, this volume, for related arguments about the scope of transfer during L2 acquisition).

Additional support for the developmental predictions of the Revised Hierarchical Model comes from a study by Kroll, Michael, Tokowicz, and Dufour (2002). In that study, learners in a summer intensive language program and proficient bilinguals performed the same bilingual tasks. The results showed that L1 to L2 translation generally took longer to perform than L2 to L1 translation, but that the asymmetry was smaller for the more proficient group than for the learners, supporting the prediction of the Revised Hierarchical Model that the two directions of translation become more similar with increased L2 proficiency.

There have also been a number of studies in which results contrary to the predictions of the Revised Hierarchical Model have been found. In one such study, De Groot and Poot (1997) tested learners at three proficiency levels (low, average, and high) on a translation production task. The concreteness or imageability of the translated words was manipulated such that some items were *concrete* (i.e., represented entities that were perceptible; e.g., table) whereas other items were *abstract* (i.e., represented entities that were imperceptible; e.g., beauty). Because the hypothesized difference between these two word types is in meaning, any difference in translation time was taken to indicate conceptually-mediated translation. De Groot and Poot found that there was a concrete-abstract difference for bilinguals in all three proficiency groups

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and therefore concluded that translation is always conceptually mediated and bilinguals do not need to rely on L1 for access to meaning. Furthermore, the results showed that translation in both directions was influenced by concreteness to a similar extent and they therefore concluded that both directions of translation are conceptually mediated, inconsistent with the predictions of the Revised Hierarchical Model. These results are important because the performance of learners of different proficiency levels was directly compared. However, because the results of this study are counter to much of the research on language production, we must interpret them carefully. In particular, more recent research has revealed that concrete words are likely to have fewer translations across languages than abstract words (Schönplflug, 1997; Tokowicz & Kroll, 2003; Tokowicz et al., 2002). Furthermore, Tokowicz and Kroll reported that the existence of an alternate translation slows translation speed considerably. Therefore, the effects of concreteness on translation may come from multiple sources and must be interpreted carefully.

Altarriba and Mathis (1997) reported another study that found results counter to the predictions of the Revised Hierarchical Model. In this study, naïve learners were trained on four color words in Spanish. After scoring 100% accuracy on several quizzes testing their knowledge of the Spanish color words, they were tested on a Stroop-type interference task using the color words they had just learned. The findings showed that the learners indeed showed interference in L2. Because they were at the very earliest stages of learning a new language (they had learned only a few words), these results were contrary to the predictions of the Revised Hierarchical Model. However, it is not clear that these results are representative of what one would find with second language learners in a more typical learning situation (i.e., with more word pairs studied over a longer period of time). What is interesting about these results is that they demonstrate the capabilities of the language learning situation under unique circumstances—when a small

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number of items are learned with extensive training, the results mimic those of proficient bilinguals. This finding provides evidence that individual items can become conceptually mediated; the bounds of this learning have yet to be demonstrated.

Perhaps the most compelling evidence supporting the prediction of the Revised Hierarchical Model that L1 to L2 translation is conceptually mediated but L2 to L1 translation is not, comes from a study that examined transfer from picture naming to translation (Sholl, Sankaranarayanan, & Kroll, 1995). If only translation from L1 to L2 is conceptually mediated, then only L1 to L2 translation should benefit from prior study during which concepts are named as pictures, a task also believed to be conceptually mediated (e.g., Potter & Faulconer, 1975). This is precisely the result reported by Sholl et al. Translation from L1 to L2 was facilitated when concepts had been named previously as pictures in L2 or L1. In contrast, translation from L2 to L1 was unaffected by prior picture naming.

The conclusions of Sholl et al. (1995) were subsequently challenged by a study reported by La Heij et al. (1996) in which Dutch-English bilinguals were asked to translate words in each direction and to name words in each language. The critical conditions of the La Heij et al. study consisted of picture primes that were related to the target word to be translated or named. Like the results of Kroll and Stewart (1994), there was little effect of the semantic context on word naming. However, unlike the results of Kroll and Stewart and Sholl et al., there were significant semantic effects of picture primes in both directions of translation, suggesting that both directions of translation are conceptually mediated. Because the Dutch-English bilinguals in the La Heij et al. study were very similar to the Dutch-English participants in the Kroll and Stewart study, it seems unlikely that the nature of the participants' bilingualism is responsible for the different pattern of results across these studies.

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In a study similar to the one by Sholl et al. (1995), Francis, Tokowicz, and Kroll (2003) showed that translation from L1 to L2 was facilitated by previous translation only in the *same* direction whereas translation from L2 to L1 was facilitated by previous translation in *either* direction, further suggesting that the two directions of translation may engage different component processes. The results of the Francis et al. study also suggest that as bilinguals become more proficient, the two directions of translation become more similar, because the asymmetrical priming disappears and both directions of translation are primed by previous translation in either direction. Finally, the results suggest that, within an individual, there may be some words that are conceptually mediated and others that are not. The “easier” items in the Francis et al. study, as defined by relatively higher word frequency, showed symmetrical priming regardless of the bilingual group’s proficiency. This result may help to explain some of the apparently conflicting results in the studies reviewed above. In the La Heij et al. (1996) experiments, items were chosen intentionally to be high frequency, and therefore likely to be known by all participants, and were repeated throughout the experiment. In the Kroll and Stewart (1994) study, the items were generally much lower in frequency and presented only once to a given participant. The pattern of results reported by Francis et al. suggests that both the proficiency of the bilingual participants as well as the nature of the items will determine the likelihood of observing asymmetries in performance. These findings highlight the developmental nature of becoming bilingual—transitions from less to more proficient are not limited to the individual bilingual but also are relevant for individual words.

### **Conclusions**

In this chapter we provided a review of the state of bilingual models of representation and processing. Although our review was limited to the lexicon, a topic on which there has been a

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disproportionate amount of research in recent years, many of the issues covered will also apply to other domains of language processing. Early models of the bilingual lexicon were general and largely failed to provide an adequate characterization of how information in each language might be represented. Later models responded to that criticism by providing a more specific account but within a relatively narrow focus. Concerns about control mechanisms, about the manner in which processing changes in the face of task demands, and about the consequences of the ways in which proficiency develops in the second language will all be crucial to the next stages of model development. With the exception of the BIA model (see also Grosjean, 1997; Thomas, 1997), few models have been implemented computationally. Likewise, it is only recently that a range of evidence has been available to test behavioral predictions of bilingual models and to then assess their neurocognitive underpinnings. We anticipate that the next period of research and model construction will be informed by all of these perspectives. Although in the future it may become more difficult to answer the question of whether the bilingual's two languages are maintained in separate or shared memory systems, we are confident that research on bilingual representation and processing will provide important insights not only into the nature of bilingualism, but more fundamentally into the relation between language and cognition.

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Author Notes

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Figure Captions

**Figure 1.** Five models of the bilingual lexicon (adapted from Kirsner et al., 1984).

**Figure 2.** The Distributed Feature Model (adapted from Van Hell & De Groot, 1998).

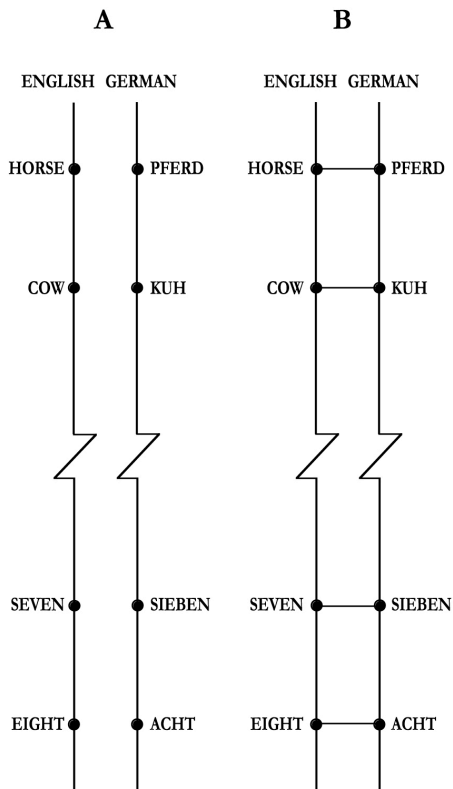
**Figure 3.** A model of bilingual language production (adapted from Poulisse & Bongaerts, 1994 and Hermans, 2000).

**Figure 4.** The Inhibitory Control Model (adapted from Green, 1998).

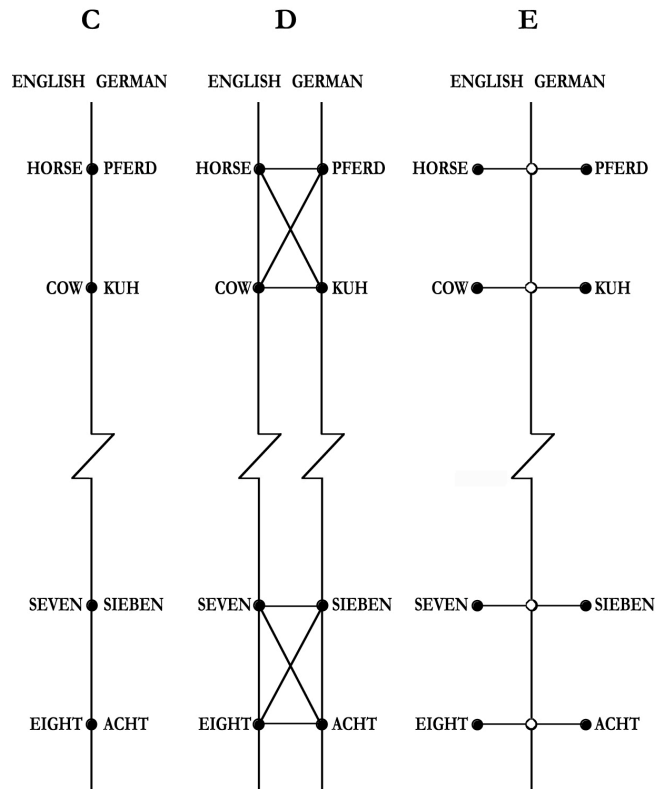
**Figure 5.** The Word Association (a) and Concept Mediation (b) Models (adapted from Potter et al., 1984).

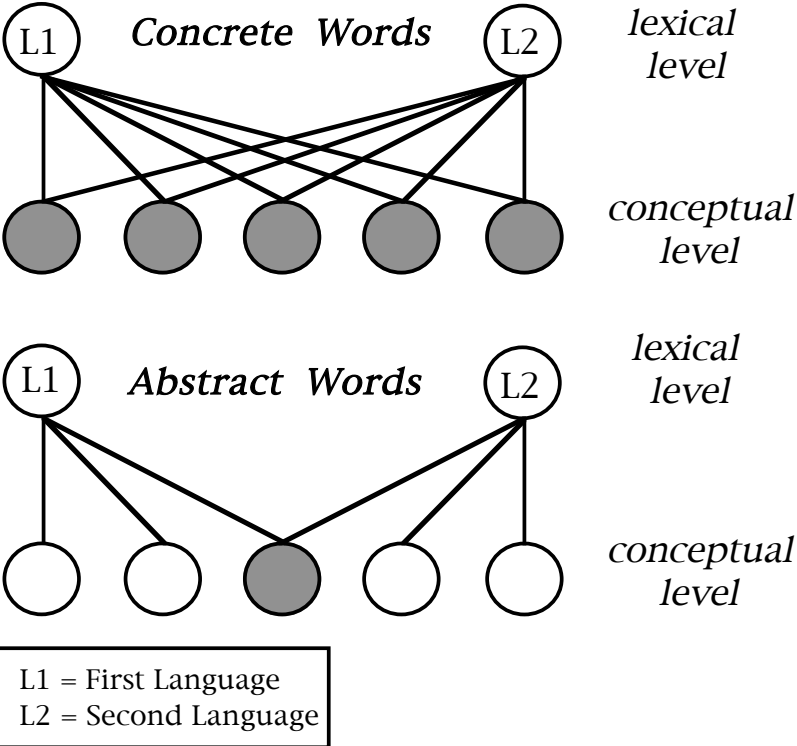
**Figure 6.** The Revised Hierarchical Model (adapted from Kroll & Stewart, 1994).

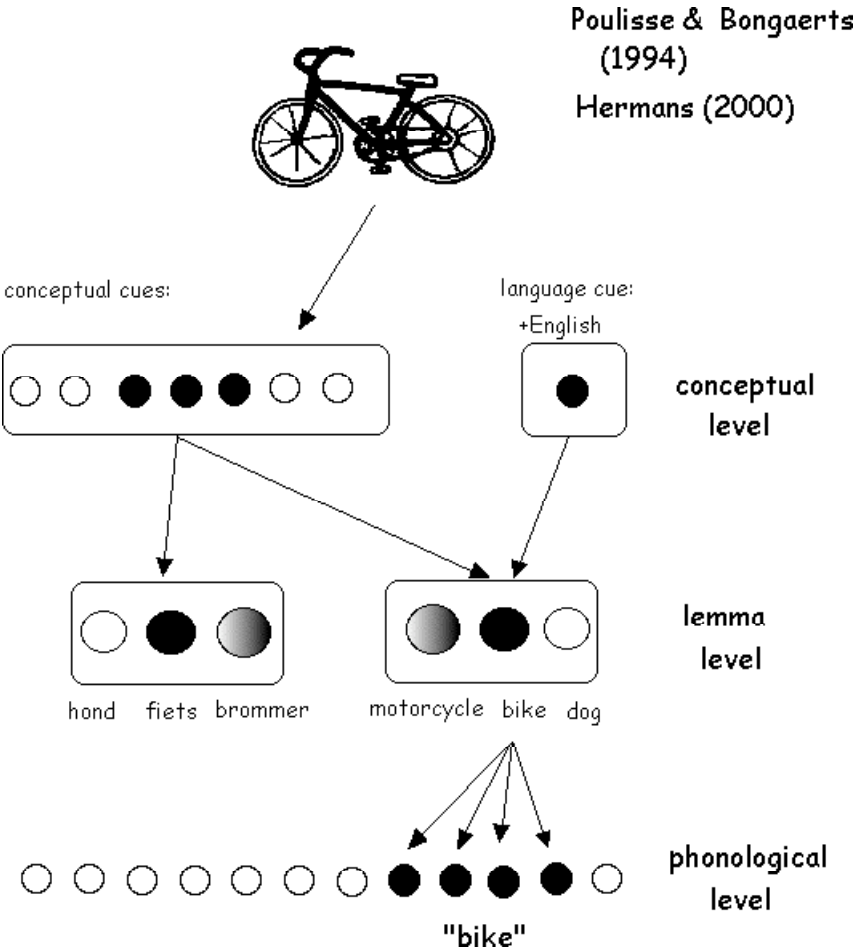
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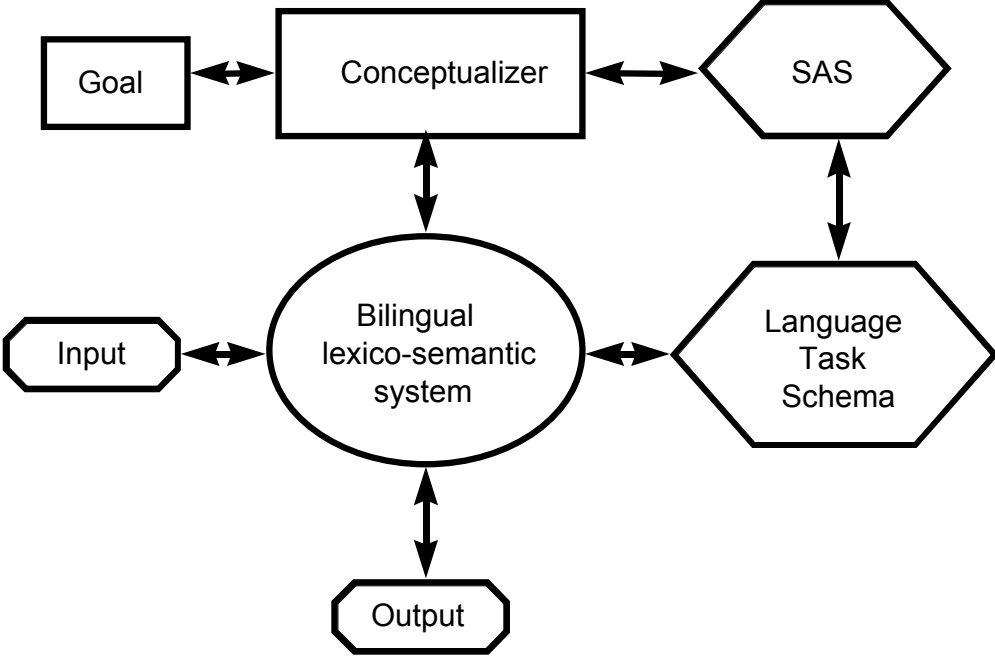
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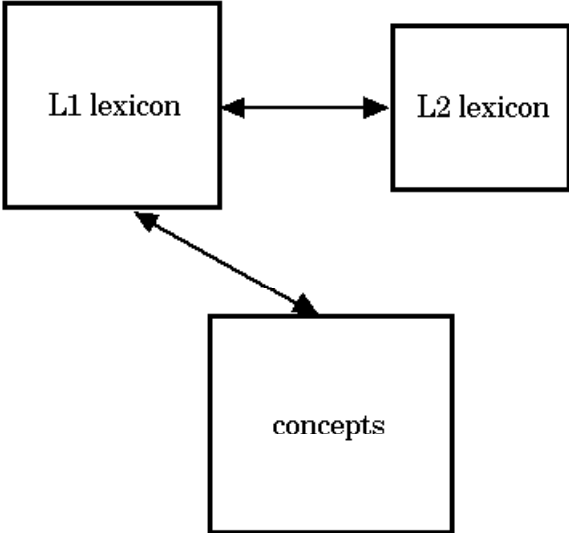




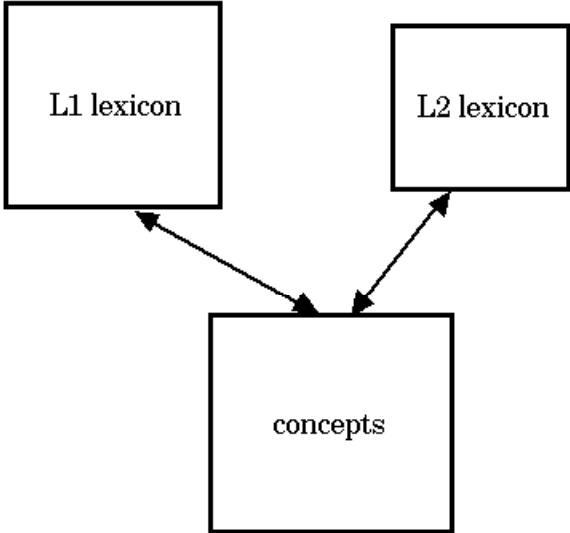








**a. Word Association Model**



**b. Concept Mediation Model**

