Chapter 4

Reading

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Although the speed with which a reader absorbed in an engrossing book turns page after page suggests otherwise, reading (like listening; see Chapter 2) is a complex skill that involves many different constituent processes that together operate on an extensive and multifaceted knowledge base. The knowledge base that enables reading consists of memory units that represent the written and spoken forms of complete words and their constituent parts. In addition, it consists of memory units that represent the meanings of words, grammatical and general world knowledge, and knowledge regarding reading strategies. The processes operating on this knowledge base include letter and word recognition, grammatical analysis, and text integration. Fluent readers perform these processes in a highly effective, fine-tuned orchestration that enables them to process around four words per second. Considering the fact that their vocabularies consist of tens of thousands of words, this is an amazing feat. Apparently, on average each quarter of a second they manage to make the proper connection between a printed word form and its representation in this vast memory store, meanwhile retrieving each word's meaning and performing the higher-level operations of grammatical analysis and text integration. This feat is all the more impressive in the case of bilinguals and multilinguals literate in more than one language. Knowing and using more than one language implies double (or triple, or quadruple etc.) sets of the knowledge units of the types distinguished above. Having multiple sets of knowledge units in memory plausibly implies noisier processing because not only units belonging to the currently targeted language but also those of the contextually inappropriate one(s) may respond to the input.

The aim of this chapter is to introduce the reader to psycholinguistic studies on bilingual reading and the insights that have emerged from them. Following Section 4.1, which presents a general outline of the reading process, Sections 4.2 and 4.3 discuss visual word recognition in bilinguals. Because reading is about reconstructing the message contained by the text and much of this message is communicated by the text's words, word recognition is arguably reading's most central constituent

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process. A basic idea in Sections 4.1 through 4.3 is the conception of mental processing during reading as the activation of memory units that store information relevant to reading. The main question addressed in Sections 4.2 and 4.3 are the following: If bilinguals encounter a written word, is the ensuing activation in the memory system – which contains two linguistic subsystems – restricted to the contextually appropriate subsystem or does coactivation occur in the contextually inappropriate subsystem, even when the input is monolingual? In agreement with common convention, the contextually appropriate and inappropriate language subsystems will be referred to as the "target language" and the "nontarget language," respectively. Section 4.2 presents the results of various types of studies that examined this question, while Section 4.3 presents a couple of models of bilingual visual word recognition that have been developed to account for the results obtained in these studies. Finally, Section 4.4 discusses sentence processing in bilinguals. Specifically, it poses the question of how bilingual readers resolve a particular type of syntactic ambiguity and how they process semantic and syntactic anomalies in sentences.

4.1 An Outline of the Reading Process

As mentioned, a core component of the reading process is word recognition. Word recognition is the outcome of activation dynamics in "sublexical" and "lexical" memory units in the mental lexicon, the component of long-term memory that stores word knowledge. Sublexical memory units represent units smaller than the word, such as visual features and letters, while lexical memory units represent whole words. When the reader sees a word, the memory representations of its constituent parts are activated first and then send their activation on to higher-level representations in the word-recognition system. The activation is transmitted along connections formed between these various types of memory representations during past reading practice. This transmission of activation along memory connections is usually called "spreading activation." Plausibly, common "subsyllabic" clusters of letters (i.e., letter clusters smaller than a syllable) and whole syllables are also represented as such in the recognition system and activated when the reader encounters them in print, through spreading activation from lower representation levels. In their turn, all of these activated sublexical "orthographical" memory representations ("orthographical" because we are dealing with units that represent script or "orthography" here, not speech) activate the corresponding sublexical phonological memory representations, which represent their sounds (e.g., Frost, 1998). The moment the activation in a lexical memory unit (usually called a "lexical representation" or "word representation") surpasses some critical level, called the "recognition threshold," the encountered word is recognized. At this moment, the further information associated with this word, among which are its meaning and syntactic specifications, becomes available for further processing.

The meaning of a sentence is not simply the aggregate of the meanings of all the words it contains and sentence comprehension therefore entails more than just assembling the meanings rendered available by the process of word recognition expounded above. The vast majority of all words have more than one meaning and writers (and speakers) have only one of these in mind when using a particular word in a specific linguistic expression. Therefore, in reconstructing the meaning of a written sentence, for every word that it contains the reader must select the contextually appropriate meaning and suppress the contextually inappropriate ones (assuming that multiple meanings automatically become available upon word recognition; this in itself is a debatable issue; see Simpson, 1994). The selected meanings then have to be integrated during sentence comprehension. The grammar of a sentence also contributes to its meaning ("The rat attacked the weasel" means something different from "The weasel attacked the rat.") So in assigning meaning to a sentence, grammatical analysis, or "parsing," must also take place. During parsing the grammatical structure of the sentence is uncovered and the constituent parts are identified as subject, object, verb, and so on. Grammatical analysis is driven by the syntactic information that is stored in word representations and becomes available upon word recognition.

While all these constituent processes take place, a mental representation of the prior text must be kept in memory and an understanding of the text part that is currently focused on must be integrated with this text representation, thus extending it. Among various operations that take place during this integration process, anaphora – words that refer to persons and things expressed before, such as "he" and "they" – must be resolved, that is, the reader must locate their antecedents in the text representation stored in memory. A consultation of the mental text representation is also required to connect noun phrases that start with a definite article with their antecedent. This is because the use of the definite (instead of the indefinite) article signals that the person or entity mentioned next has been introduced in an earlier text portion and must therefore already be represented in the stored text representation.

To conclude this brief outline of the types of mental operations a reader is involved in while enjoying the engrossing book mentioned in the introduction, a final process to mention is the retrieval of "world knowledge," or "background knowledge," from memory. It is a well-known fact that a text is like an iceberg, with only a portion of the message it aims to convey explicitly contained by the text, the rest of its meaning only implied. The authors of a good text have anticipated their audience, making an assessment about what they are likely to know already and then deciding what information to provide explicitly and what to take for granted. Text comprehension therefore requires that the information that *is* there triggers the readers to access their general knowledge store and retrieve the information that fills in the textual gaps.

To summarize, reading involves: (1) the activation of different types of sublexical memory units, both orthographic ones and, via these, the corresponding phonological units; (2) the activation of word (or "lexical") representations beyond some critical level, at which point the word's meaning and syntactic information become available; (3) sentence comprehension processes during which the meaning of the sentence is assembled from (parts of) the meanings of the words it contains, the outcome of parsing procedures, and background knowledge; (4) the construction of a mental text representation that must be updated continuously and that enables the reader to resolve anaphora, among other things.

This outline of the reading process, complex as it already is, is still a simplification of the full process because it ignores the fact that many people master more than one language. As mentioned, knowing and using more than one language plausibly implies noisier processing operations due to parallel activation in the two or more language subsystems. Section 4.2 reviews studies that examine the occurrence of such parallel activation during word recognition in bilinguals. The occurrence of coactivation of elements of the nontarget language during word recognition is known as "language-nonselective word recognition." Selective activation of knowledge units belonging to the target language during word recognition is known as "language-selective word recognition."

4.2 Word Recognition in Bilinguals

In trying to find out whether bilingual visual word recognition is language selective or language nonselective, many researchers have examined the effects of form and meaning similarity between words in a bilingual's two languages on word recognition. This approach has led to the frequent use of three types of word stimuli in the pertinent studies: "interlexical homographs," "interlexical neighbors," and "cognates." Interlexical homographs (henceforth also simply called "homographs") are words that exist in two languages but have totally different meanings in these languages. In other words, they share form but not meaning between a pair of languages. They are like ambiguous words within a language, where one and the same form has two completely distinct meanings (e.g., "bank" in English, which means a financial institution or an embankment). Interlexical neighbors (henceforth also: "neighbors") are like interlexical homographs, except that the forms of interlexical neighbors overlap largely but not completely between the languages (e.g., Dutch "mand," *basket*, is an interlexical neighbor of English "sand"). Finally, cognates are words that share both (orthographic and/or phonological) form and meaning between a pair of languages (although not necessarily completely). Phrased differently, a pair of cognate words is a translation pair with similar forms (e.g., the Dutch-English pair "appel-apple"). In this section evidence of language-(non)selective bilingual word recognition as obtained in experiments using these three types of stimuli will be presented. In addition, some evidence of language-nonselective phonological activation during bilingual word recognition will be presented.

4.2.1 Interlexical homograph studies

Beauvillain and Grainger (1987) were among the first to study the processing of interlexical homographs in bilinguals. They used a version of the "lexical-decision" task that is often used in word-recognition research. In a lexical-decision task the participants are presented with letter strings on a screen, one string at a time, and have to decide for each of these whether or not it is a word. The participants notify their decision by pressing a "yes" or a "no" button. The nonword stimuli are typically "pseudowords," that is, letter strings that obey the orthography of the target language and thus only differ from words in that they lack meaning (e.g., "plenk" or "flup" are English-like pseudowords). In a version of this task called "primed lexical decision," prior to the presentation of the target (the word to which the participant must respond) a "prime" word is presented and the effect of the prime on target processing is measured. A common finding is that a target that is semantically related to the preceding prime (e.g., prime: "flower"; target: "tree") is responded to faster than a target that follows an unrelated prime (prime: "power"; target: "tree"). This "priming effect" is often attributed to a process of activation spreading along a connection between the representations of prime and target in the mental lexicon that speeds up the recognition of the target word as a result of pre-activation: The moment the target is presented, less activation still has to be accumulated in its representation for the recognition threshold to be exceeded.

Beauvillain and Grainger (1987) used a cross-language version of this primed lexical-decision task. They presented English-French bilinguals with stimulus pairs, each consisting of a French prime word and an English target word (or an English-like pseudoword), prime and target appearing successively on a screen. The participants were instructed to read the prime and to perform a lexical decision on the target. Most of the primes were exclusively French words, but some were words in both French and English; that is, they were French-English interlexical homographs (such as "coin," meaning *corner* in French). The question of interest was whether the homograph's English meaning would be activated in addition to its French meaning, despite the fact that the participants were told that all primes were words in French. Such would prove to be the case if a target semantically related to the prime's English meaning (e.g., the target "money" following the prime "coin") was responded to faster than when the same target followed a non-homographic control prime (say French "chien," *dog*). Such a priming effect indeed occurred, but only when the interval between prime and target was short (150 ms), not when it was longer (750 ms). These findings suggest that, even though the majority of the primes were only words in French, both meanings of the homographic primes were initially activated and only later was the contextually inappropriate English meaning suppressed. In other words, under the specific circumstances of this experiment, bilingual word recognition was language nonselective.

The data pattern obtained by Beauvillain and Grainger (1987) does not suffice, however, to reject a language-selective account of bilingual word recognition. As mentioned, while the target language in this experiment was English, all the primes were French words. With the experimental materials thus containing words from both of the participants' languages, it is hardly surprising that both language subsystems were activated. In terms of Grosjean's "language-mode theory" (Grosjean 1997, 2001; see also Chapter 1), which assumes differential activation states of a bilingual's language system depending upon specific characteristics of the communicative setting, the dual-language nature of the stimulus materials in Beauvillain and Grainger's experiment likely put the participants in a "bilingual mode," where both language subsystems are activated.

A stronger test of language-selective vs. language-nonselective bilingual word recognition would involve the presentation of stimulus materials from only one of the bilinguals' two languages (in contextual circumstances that are as unilingual as possible; Grosjean, 1998; Wu & Thierry, 2010). In many of the more recent interlexical-homograph studies this research strategy was adopted, the question being whether, with all the stimulus materials in one language, the other language might nevertheless be activated. In most of these studies the lexical-decision task was used, while a couple of them used the "word-naming" task. In a word-naming task the participants simply read printed words aloud and response times and accuracy are registered.

In a subset of these unilingual studies the priming methodology was used, but with primes and targets now in one and the same language (although it should be kept in mind that homographs belong to two languages). In some of these priming studies (e.g., Kerkhofs, Dijkstra, Chwilla, & De Bruijn, 2006) the prime word preceding a target was always an isolated word, as in Beauvillain and Grainger (1987). In other priming studies the prime word was embedded in a sentence context (e.g., Elston-Güttler, Gunter, & Kotz, 2005). Because words are not normally encountered in isolation but as part of larger linguistic structures such as sentences and paragraphs, this latter procedure resembles natural language processing more closely than the former.

However, the majority of the unilingual studies did not use the priming methodology. Instead, on each trial the participants were presented with an unprimed single word (or pseudoword) as the target (e.g., De Groot, Delmaar, & Lupker, 2000, Experiments 2 and 3; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998). The critical targets were either interlexical homographs or non-homographic control words and the response times and error rates in these two conditions were compared. A large number of non-homographic filler targets are typically added to the critical targets. If an interlexical homograph only gives rise to activation in the contextually appropriate language subsystem, homographs and non-homographic controls should be processed equally fast (and produce equally as many errors). On the other hand, if a homograph gives rise to activation in both language subsystems, a difference in response times (and possibly also in error rates) between homographs and non-homographic controls should show up. In other words, the occurrence of a "homograph effect" (i.e., a difference in response times and/or error rates between homographs and control words) would suggest that bilingual word recognition is language nonselective whereas the non-occurrence of such an effect would suggest that it can also be language selective.

In some of these unprimed lexical-decision experiments, the participants were instructed to give a "yes" response if the presented letter string was a word, irrespective of the language to which the word belonged, and to give a "no" response if the letter string was not a word in either of their two languages. This task version is known as "language-neutral" (or "generalized") lexical decision. In other experiments the participants were instructed to give a "yes" response if the presented stimulus was a word in one of their languages (specified beforehand) and to give a "no" response if not. This version of the task is known as "language-specific" lexical decision. In some of the latter type of experiments, language-specific performance was forced upon the subjects by the inclusion of a relatively small number of non-homographic words from the nontarget language that had to be treated as nonwords (i.e., they required a "no" response). Without the inclusion of such "nonwords," the participants may be tempted to reconfigure the task as if it concerned its language-neutral version instead, which would impact on the way interlexical homographs are processed: In language-neutral lexical decision the correct response to homographs ("yes") may be based on the homograph making contact with either one of its lexical representations, ignoring language membership, while in language-specific lexical decision the response must be based on the homograph making contact with its lexical representation in the target language. The inclusion of non-homographic words that belong to the nontarget language probably prevents the use of the language-neutral processing strategy because this strategy would lead to errors on these words (a "yes" response where a "no" response is required). But, of course, an unfortunate consequence of the inclusion of some words from the nontarget language as nonwords is that the experiment is not completely unilingual after all.

In the majority of the lexical-decision studies in which the homographs were presented in isolation a homograph effect was obtained. The task version that was used determined the *direction* of this effect, with language-neutral lexical decision typically resulting in faster response times to homographs than to controls and language-specific lexical decision resulting in slower processing of the homographs. The *size* of the effect depended upon the relative frequency of the homograph in the two languages in combination with the task version used: The effect was especially large when the participants performed language-specific lexical decision and the homograph was more frequent in the nontarget language than in the target language. Figure 4.1 illustrates this pattern of results with data from De Groot *et al.* (2000). These data were obtained in an experiment in which one group of Dutch-English bilinguals (with native Dutch slightly stronger than L2 English) performed language-specific lexical decision with Dutch as the target language and a second group performed this task with English as the target language. The inclusion of a small number of "nonwords" that were in fact words from the nontarget language forced the participants to use the requested language-specific processing strategy. As shown, in both language conditions the (inhibitory) homograph effect was substantially larger when the homograph's less frequent meaning was targeted (Condition LF) than when its more frequent meaning was targeted (Condition HF).

These homograph effects are thought to indicate that bilingual word recognition is language nonselective. In a few of these studies, however, no homograph effect

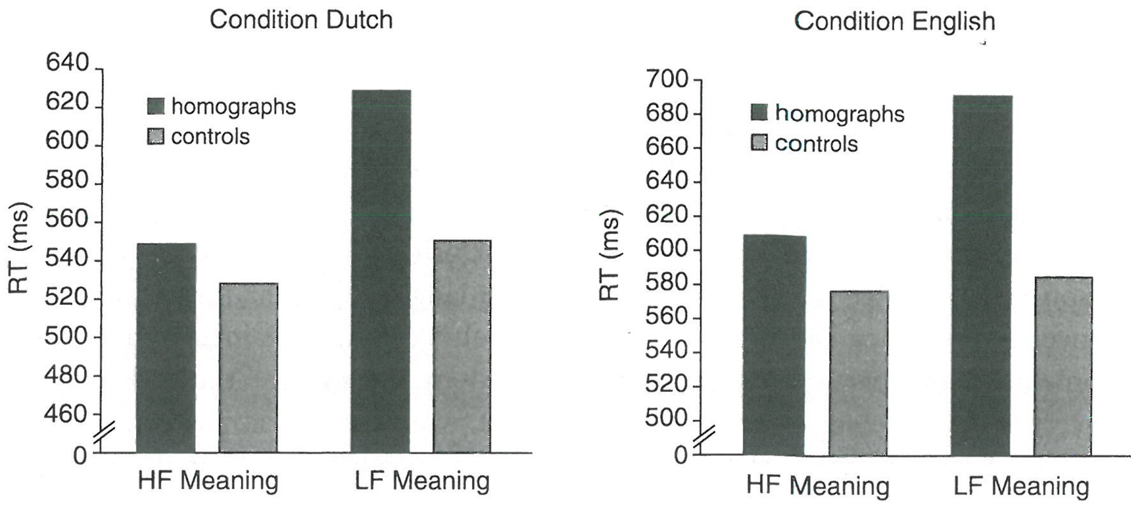

Figure 4.1: Mean lexical decision response time (RT) as a function of language (Dutch, English), stimulus type (homograph, control), and the frequency (high, low) of homographs in the participants' two languages. Based on De Groot, Delmaar, and Lupker, 2000.

was obtained, especially when the participants performed language-specific lexical decision and none of the nonwords was a word in the other language (e.g., De Groot *et al.*, 2000, Experiment 2; Dijkstra *et al.*, 1998, Experiment 1). Instead of concluding that bilingual word recognition can be language selective under at least specific sets of circumstances, the authors of these publications preferred various explanations of this null-effect in terms of language nonselective word recognition. One of these was that, contrary to the instructions to perform language-specific lexical decision, on a subset of trials the participants may have adopted a language-neutral processing mode. As a consequence, an inhibitory homograph effect resulting from language-specific task performance and a facilitation effect resulting from language-neutral task performance (both resulting from language-nonselective processing) cancelled one another out. In conclusion, the results of the lexical-decision experiments in which homographs were presented in isolation may all be compatible with the view that bilingual word recognition is language nonselective.

Still, further interlexical-homograph studies have revealed a number of factors that moderate the influence of the nontarget language in bilingual visual word recognition. A study in which the word-naming task was used provided evidence to suggest that the occurrence of a homograph effect depends on (1) whether or not the activation level of the nontarget language is boosted prior to naming the critical words and (2) whether the target language is the stronger or weaker of the participants' two languages. In the study in question (Jared & Szucs, 2002), English-French bilinguals named blocks of English words in two conditions: A block of English words was preceded by a block of French words, to be named in French, or it was not preceded by a French naming block. A subgroup of participants for whom English, the target language, was weaker than nontarget French named the interlexical homographs more slowly than the non-homographic control words, irrespective of whether or not a block of French trials preceded the English block. In other words, for both conditions a response pattern suggesting language-nonselective word recognition was observed. In contrast, a subgroup of participants for whom target English was the stronger language, a homograph effect only materialized when the block of English target words was preceded by a French naming block. These findings suggest that in unbalanced bilinguals the stronger language can be immune to an influence of the weaker language, unless the activation level of the weaker language is boosted somehow, here, by a prior session of naming words in this language.

A final study to be presented here goes one step further by suggesting that under specific circumstances the weaker language of unbalanced bilinguals can also be immune to an influence of the other language. It concerns a semantic-priming study by Elston-Güttler *et al.*, (2005). On each trial, German-English bilinguals read an English sentence – English being their second and weaker language – and performed a lexical decision to an English target word (or pseudoword) that was shown after the sentence. In a related condition, the last word of the sentence was a German-English homograph and the target word was the English translation of this homograph's German meaning. An example is the sentence "The woman gave her friend a pretty GIFT" followed by the target word POISON (the German word for poison is "Gift"). In an unrelated condition, the same sentences and target words were used except that now the last word of the sentence was a non-homographic control and its meaning was completely unrelated to the target's meaning (e.g, "The woman gave her friend a pretty SHELL" followed by the target word POISON).

Prior to this (data-collection) part of the experiment, the researchers presented the participants with what they called a "global language context": The participants watched an originally silent movie, supplied with either a German narrative spoken by a native speaker of German or an English narrative spoken by an English native speaker. This manipulation was intended to boost the level of activation in either target English or nontarget German prior to data collection.

In this study, in addition to behavioral measures (response times and errors), "event-related potentials" (ERPs) were measured (see Chapter 10 for a description of this methodology). The ERP component that Elston-Güttler *et al.* (2005) were specifically interested in was the N400, which reflects semantic integration. Previous studies have shown that the N400 component is typically less negative to targets preceded by related primes than to targets preceded by unrelated primes. The likely cause of this effect is that semantic integration is relatively easy in the former case. The critical question addressed by the authors was whether the N400 to a target (POISON) following a homographic prime (e.g., GIFT) is less negative than the N400 following a non-homographic control word (SHELL). If so, it could be concluded that the homograph's meaning in nontarget German was also activated during target processing, a finding that would indicate that bilingual word recognition is language nonselective even when the word's surroundings promote the use of one language only. The researchers measured the N400s separately for the first and second halves of the data-collection session, on the assumption that a prior bias to German evoked by an earlier film fragment with German voices might disappear over the course of the, all English, data-collection session. It turned out that, with one exception, similar N400s were obtained in the related and unrelated conditions, thereby suggesting language-selective processing. The exception concerned the first half of the data-collection session following the German film fragment. In other words, only when the activation in the German language subsystem had been boosted prior to data collection, nontarget German influenced the processing of target English, and this only temporarily. The behavioral measures converged with this data pattern. In conclusion, then, in the condition that most resembled natural language processing, the all-English condition, word recognition was not influenced by the nontarget language (despite the fact that English was the participants' weaker language).

To summarize, the joint studies discussed in this section produce a mixed pattern of results, showing that the occurrence of a homograph effect depends on the exact composition of the stimulus set, the experimental task, the relative strength of the target language and nontarget language, prior activation of the nontarget language, and linguistic context. Therefore, the interlexical-homograph data do not clearly rule out either one of the two theoretical positions regarding bilingual word recognition.

4.2.2 Interlexical neighbor studies

A visually presented word not only activates "its own" lexical representation in memory but also those of orthographically similar words. This insight emerged from monolingual studies in which the effect of a word's "intralexical neighborhood" on visual word recognition was examined (e.g, Andrews, 1989). A word's intralexical neighborhood is the set of words that all share a substantial part of their form (say three letters out of four) with the target word, target and neighbors all belonging to the same language. Monolingual neighborhood studies have shown that the time it takes to recognize a word (e.g., "sand") depends on the number and frequency of its "neighbors," words orthographically similar to the target word (e.g., "hand," "land," "sane").

This finding provided bilingual researchers with a further way to study the degree to which bilingual word recognition may be language nonselective, namely, by examining whether a word's neighbors in the nontarget language influence this word's processing. If so, the likely explanation is that elements of the nontarget language are also activated while the target word is being processed, thus suggesting that bilingual word recognition can be language nonselective.

The first study to suggest that neighbors in the nontarget language indeed influence word recognition was performed by Grainger and Dijkstra (1992). These researchers instructed French-English bilinguals to make lexical decisions on three types of English target words (and nonwords) presented visually. Words of the

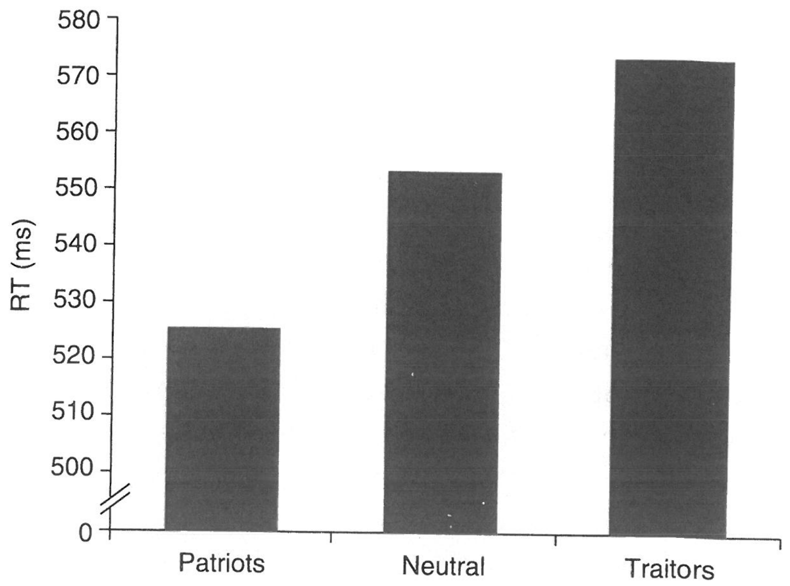

Figure 4.2: Mean lexical decision response time (RT) to English words as a function of their neighbors in English and French. Based on Grainger and Dijkstra, 1992.

first type, called "patriots," had more neighbors in target English than in nontarget French. Words of the second type, called "traitors," had more neighbors in nontarget French than in target English. Finally, words of the third type, called "neutral," had an equal number of neighbors in both languages. The results of this experiment are shown in Figure 4.2. They clearly indicate an influence of neighbors in the nontarget language on performance: Lexical-decision times were longer for traitors than for neutral words, and longer for the latter than for patriots. (The beginning of an explanation is given in Section 4.3.)

This specific type of evidence that bilingual word recognition can involve the activation of word representations in both of a bilingual's language subsystems has since also been obtained in studies that exploited other tasks and paradigms. In one of these, again testing French-English bilinguals, the word-priming methodology was used but with the primes presented so briefly that they could not be identified by the participants (Bijeljac-Babic, Biardeau, & Grainger, 1997). Primes that were orthographic neighbors of the targets slowed down the responses to the targets as compared with orthographically dissimilar primes. This was found both when primes and targets belonged to the same language (e.g., French "soin" as prime followed by French "soif" as target) as when they were from different languages (English "soil" followed by French "soif"). This study thus demonstrated that, even when a word cannot be consciously perceived, it triggers the word-recognition system into activity and that the set of word representations in a bilingual's mental lexicon triggered this way includes word representations of both languages. The fact that the primes do not have to be perceived consciously for these effects to occur in turn suggests that the activation arising in the word-recognition system upon the presentation of a word comes about automatically.

4.2.3 Cognate studies

As must be clear by now, the process that is assumed to underlie the interlexical-homograph and interlexical-neighbor effects is that a visually presented word automatically activates the representations of a set of similar words in memory and that it may do so in a language-independent way. It will therefore not come as a surprise that, as shown in many studies, bilinguals' responses to cognates differ from those to noncognates. After all, in addition to sharing meaning, cognates but not noncognates share (part of their) form with their translations in the other language. So if bilingual word recognition would be language nonselective, the moment a cognate is presented, the representation of its translation in the other language should also become automatically activated. In the vast majority of pertinent studies, in which different tasks were used, cognates were processed faster than noncognate controls. However, in a study that employed word naming (Schwartz, Kroll, & Diaz, 2007), cognates were responded to more slowly than noncognates. This difference in the direction of the cognate effect can presumably once again be accounted for in terms of differences in the processing requirements posed by different tasks (cf. the interpretation in 4.2.1 of the different directions of the interlexical-homograph effects across two versions of the lexical-decision task; see Dijkstra and Van Heuven, 2002, for details).

In most of the "cognate studies," the cognates and noncognates were presented as isolated words, but in a few of them (Duyck, Van Assche, Drieghe & Hartsuiker, 2007; Schwartz & Kroll, 2006; Van Assche, Duyck, Hartsuiker & Diependaele, 2009; Van Hell & De Groot, 2008) they were presented in a sentence context. As we have seen, the homograph effect disappears when the homographs are presented in a same-language sentence context (Elston-Güttler *et al.*, 2005). In contrast, in some of the cognate studies the cognate effect also showed up when the cognates were embedded in a same-language sentence context. This was especially the case in a "low-constraint" condition, where the cognate or the noncognate control stimulus could not be predicted on the basis of the prior sentence context. In a condition where it could be, the cognate effect disappeared. Figure 4.3 presents the cognate effects obtained in one of the pertinent experiments (Duyck *et al.*, 2007). In this experiment Dutch-English bilinguals performed lexical decisions to L2 English target words, cognates or noncognate controls (or to pseudowords) that appeared as the final words of low-constraint English sentences (e.g., "Lucia went to the market and returned with a beautiful cat [cognate]/ bag [control]." A subset of the cognates had identical forms in Dutch and English (e.g., "plan"; left part of Figure 4.3), whereas for the remaining cognates the Dutch and English forms did not overlap completely (e.g., "cat – kat"; right part of Figure 4.3). The cognate effect was significantly larger for identical cognates than for non-identical cognates, but also for the latter the effect was significant. On the assumption that especially the low-constraint condition resembles natural language processing, these findings suggest that bilingual word recognition is

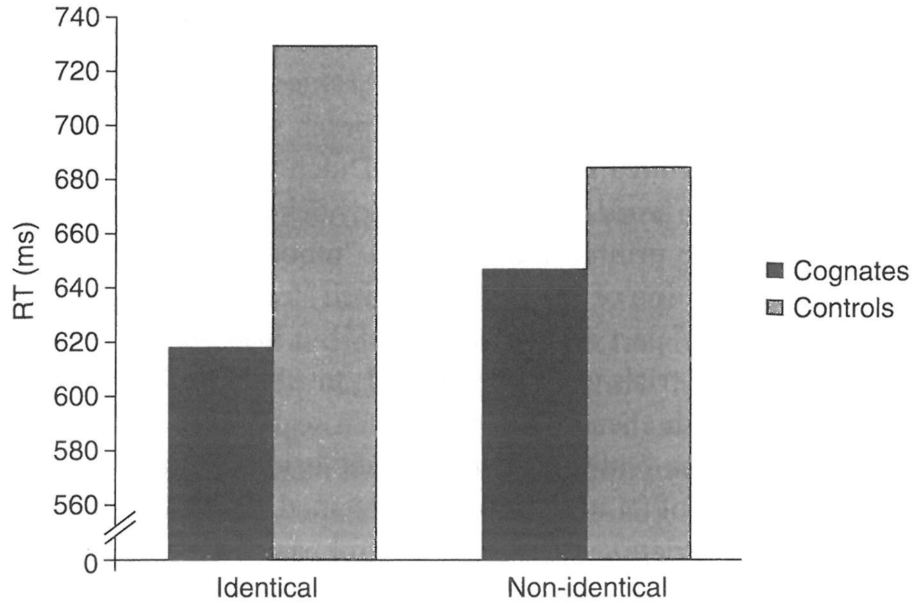

Figure 4.3: Mean lexical decision response time (RT) to English-Dutch cognates and non-cognate controls presented in low-constraint sentences in two conditions: identical and non-identical. Based on Duyck *et al.*, 2007.

language nonselective. But when drawing this conclusion, it remains to be explained why the cognate effect is more resistant to sentence context than the homograph effect.

4.2.4 Language-nonselective phonological activation in bilingual visual word recognition

Monolingual studies have shown that during visual word recognition the printed word's phonology is automatically activated. This not only holds for sound-based scripts (alphabets and syllabic scripts), where the basic units of print map onto units of speech (albeit not consistently so), but even for logographic scripts such as Chinese, where the written characters are not directly mapped to phonemic units. Apparently, phonological activation plays a central role in the processing of written language in general (Frost, 1998). This raises the question of whether in bilinguals a visually presented word automatically leads to phonological activation in *both* language subsystems.

Van Leerdam, Bosman, and De Groot (2009) used a new task, the "bimodal matching task," to examine this question. Dutch-English bilinguals, with English being the participants' L2, were shown monosyllabic printed English words (e.g., "mood"), one word per trial, while at the same time a speech segment was presented. This speech segment was either the correct pronunciation of the printed word's "body" – the vowel and final consonant(s); e.g., the spoken "-ood" part of "mood" – or it sounded differently (e.g., the spoken "-oad" part of "road"). The participants' task was to indicate whether or not the speech segment was the correct pronunciation of the printed word's body, pressing a "yes" button when it was and a "no" button otherwise. The critical comparison was between two types of "no" trials. In one type of "no" trials (the "catch" trials) the speech segment was derived from a Dutch "enemy" of the printed English word: a Dutch word with the same printed word body as the English word but with this body being pronounced differently in Dutch. For example, the printed English word "mood" was accompanied by the correct Dutch pronunciation of "-ood" (as in Dutch "lood" and "rood"), which does not sound like the "-ood" part of English "mood" but like "-oad" in English "road." The second type of "no" trials were control trials in which the speech segment was not derived from a Dutch enemy (e.g., the speech segment accompanying printed "mood" sounded like the "-ide" part in English "bride"). On the catch trials an extremely large number of false positives was obtained ("yes" responses where "no" would have been appropriate), whereas the control trials led to very few errors. The likely explanation of this high error rate on catch trials is that the printed English words gave rise to parallel phonological activation in both language subsystems (e.g., printed "mood" activated both English and Dutch words containing "ood" and, subsequently, the corresponding pronunciations). The match between the Dutch words activated this way and the speech fragment on the catch trials subsequently led to an error. In other words, phonological activation in bilingual visual word recognition appears to be language nonselective.

English and Dutch, the languages tested by Van Leerdam *et al.* (2009), both exploit the Roman alphabet. Evidence of phonological activation in the contextually inappropriate language subsystem has also been obtained in forms of bilingualism involving two languages that use different alphabets. In one of these studies, Gollan, Forster, and Frost (1997) tested Hebrew-English bilinguals, Hebrew and English using completely different alphabets. The researchers used a masked-priming paradigm in which on each trial a clearly visible target was preceded by a masked prime, which the participants did not perceive consciously. The participants performed lexical decisions to the targets. In a between-language condition all primes were in one language and all targets were in the other language. The primes and word targets in this condition were either translations of one another or they were completely unrelated words. Primes and targets within the translation pairs were either phonologically similar in Hebrew and English or they were phonologically totally dissimilar. When the primes were from the participants' (stronger) L1 and the targets from their (weaker) L2, a "translation-priming" effect occurred: Responses to targets that were translations of the preceding primes were faster than those to unrelated targets. Importantly, this priming effect was larger for translation targets that were phonologically similar to the preceding primes than for phonologically dissimilar translation targets. This finding suggests that the primes, although not consciously perceived, activated the corresponding representations in the nontarget language subsystem, including the memory units storing the primes' phonology. This phonological pre-activation subsequently shortened the response to the phonologically similar translation targets.

In conclusion, evidence from both same-alphabet and different-alphabet bilingualism suggests that visually presented words may give rise to automatic phonological activation in the nontarget language subsystem.

4.3 Models of Bilingual Visual Word Recognition

A number of models have been developed to account for the findings presented in Section 4.2. The earliest one of these is a computational model that was specifically developed to account for the interlexical-homograph and interlexical-neighbor effects, especially those obtained when the critical words were presented in isolation. This model, called the Bilingual Interactive Activation model (BIA; Dijkstra & Van Heuven, 1998; Van Heuven, Dijkstra, & Grainger, 1998), implements the idea that word recognition in bilinguals is initially language nonselective. The model, illustrated in Figure 4.4, concerns an extended version of the Interactive Activation

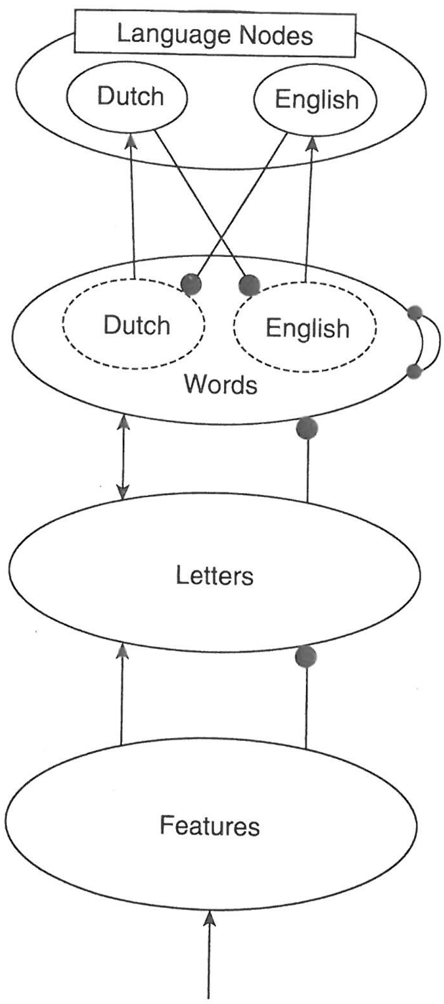

Figure 4.4: The Bilingual Interactive Activation (BIA) model of bilingual visual word recognition. Based on Dijkstra and Van Heuven, 1998.

model of monolingual visual word recognition pioneered by McClelland and Rumelhart (1981).

BIA contains four levels of representation units (or "nodes"), which represent visual features, letters, the orthographic forms of complete words, and language information, respectively. The levels of feature and letter nodes are shared between a bilingual's two languages and the level of word nodes consists of two integrated lexicons. The level of language nodes contains two nodes only, one for each language. The model is called "interactive" because representations at one particular level can activate and inhibit representations at adjacent higher and lower levels. Activation and inhibition between levels come about via spreading activation along excitatory and inhibitory connections (visualized by means of arrowheads and bullet heads, respectively). In addition, the existence of inhibitory connections between all word nodes is assumed, both between the word nodes of one and the same language as well as between those of different languages. (Because of this feature of the model its lexicon is said to be "integrated.") As a consequence of these inhibitory connections, the word nodes mutually suppress each other's activation. This process is called "lateral inhibition."

When a reader sees a printed word, this word first activates the feature nodes that correspond to the input. The activation in these feature nodes is then transmitted upward, exciting the nodes for letters that contain these features and inhibiting those for letters not containing them. Similarly, activated letter nodes transmit activation to word nodes containing these letters and inhibit word nodes that do not contain them. For instance, when English "sand" is seen, it will activate, via the feature level, the letter nodes for "s," "a," "n," and "d," which in turn will activate the word node that represents the target word "sand." The word nodes of the orthographic neighbors of "sand" (e.g., the word nodes for "hand," "sank," and "sane") will also be activated upon the presentation of "sand," via the activation of the features and letters they share with "sand." Importantly, the model assumes that activated letter nodes transmit their activation to word nodes in both language subsets. So, given a Dutch-English bilingual, the word nodes of the Dutch neighbors of English "sand" (for instance, "zand," "mand," and "tand") will also be activated to some extent by the input "sand."

In their turn, activated word nodes send their activation upward to the language node of the corresponding language along excitatory connections. Via inhibitory links between this language node to all the word nodes of the other language, the activation in the word nodes of the other language is suppressed. All activated word nodes compete with one another during the recognition process, inhibiting one another through lateral inhibition. These processes continue until the activation in one of the word nodes exceeds the recognition threshold (see Section 4.1) and the stimulus word is recognized. This moment is generally reached earlier for frequently used words than for infrequent ones. This follows from a further assumption implemented in the model, namely, that word nodes which represent frequent words have a higher baseline level of activation (they are more strongly pre-activated) than those representing infrequent words. Consequently, when the word recognition system is fed with a frequent word, the recognition threshold will be reached relatively rapidly. Similarly, because (unbalanced) bilinguals typically do not use their two languages equally often, the word nodes from the language used most often (the stronger language) have, on average, a higher baseline level of activation in the model than the word nodes from the language used less often (the weaker language).

In terms of BIA, the fact that interlexical neighbors affect bilingual word recognition directly follows from the language-nonselective, bottom-up activation process assumed by the model: Interlexical neighbors lead to more competition in the bilingual word-recognition system than control words that are orthographically similar to words in the target language only. To account for the interlexical-homograph effects, Dijkstra and Van Heuven (1998) assumed that interlexical homographs are represented in two word nodes in the bilingual language system, one node for each language. Due to the perfect match of a stimulus with both word nodes, the presentation of a homograph to the system will lead to a high level of activation in both these nodes and, consequently, a strong competition between the two. In the authors' words: ". . . the two readings . . . 'strangle' each other via mutual inhibition" (Dijkstra & Van Heuven, 1998, p. 209).

As mentioned in Section 4.2.1, interlexical-homograph effects are especially large when the homograph is more frequent in the nontarget language than in the target language (see Figure 4.1). This effect is explained in terms of the relation between word frequency and baseline levels of activation of word nodes mentioned above: Because of its higher baseline level of activation, the word node associated with the homograph's higher-frequency reading has a head start in the recognition process and will therefore start suppressing the node representing its lower-frequency reading earlier than vice versa. Similarly, the different levels of activation of the word nodes representing words of the stronger and weaker language in unbalanced bilinguals can account for the finding reported above that the stronger language (with a higher average baseline level of activation of the word nodes) can be immune to an influence of the weaker language.

A final point to mention regarding BIA – and plausibly the most important one in the present context – is that it has not only successfully simulated the interlexical homograph and neighbor effects as obtained in a number of the studies that presented the critical stimuli in isolation (which suggest that bilingual word recognition can be language nonselective), but also the apparent null effects that have emerged with specific combinations of task demands and stimulus sets (which, at face value, suggest that bilingual word recognition can also be language selective). In other words, this specific computational model of bilingual visual word recognition, which assumes that under *all* circumstances bilingual word recognition is initially language nonselective, not only accounts for obvious evidence of language-nonselective bilingual word recognition but also for apparent counterevidence.

As we have seen in Section 4.2.4, activated nodes that represent orthographic knowledge in their turn activate the corresponding phonological nodes. BIA cannot account for this phonological activation because it only includes orthographic representations. Furthermore, it may have struck the reader that BIA is able to account for interlexical-homograph effects despite the fact that it does not represent semantic information. After all, the most salient distinction between an interlexical homograph and a non-homographic control word is the fact that the former but not the latter is semantically ambiguous between a bilingual's two languages. Plausibly, the way this semantic ambiguity is resolved contributes to the homograph effect as well. Irrespective of whether or not this is the case, any model of word recognition will ultimately have to take meaning into account, because the ultimate goal of word recognition is to retrieve the word's meaning. For these reasons, the lack of phonological and semantic representations clearly indicates two lacunae in BIA.

In two successors of BIA, SOPHIA (short for the Semantic, Orthographic, and PHonological Interactive Activation model) and BIA+, these lacunae were remedied: They contain phonological and semantic representations in addition to orthographic representations. SOPHIA (Van Heuven & Dijkstra, 2001; see also Thomas & Van Heuven, 2005) is illustrated in Figure 4.5.

As can be seen, SOPHIA represents orthography at a more detailed level than does BIA: Two additional layers of nodes are installed in between the original levels of letter and word nodes (the latter now called "O-words"). These intermediate levels represent letter clusters and syllables. Phonology is represented in four analo-

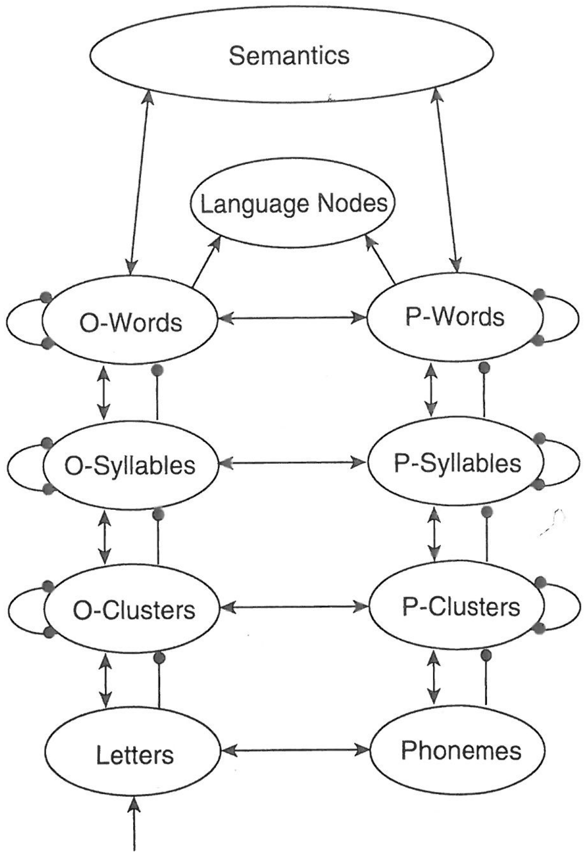

Figure 4.5: The Semantic, Orthographic, and PHonological Interactive Activation (SOPHIA) model of word recognition. Based on Van Heuven and Dijkstra, 2001.

gous levels of nodes that represent phonological units of different sizes. Orthographic units activate the corresponding phonological units and vice versa. Activated orthographic and phonological word nodes activate the corresponding meanings (in the subpart of the system called "semantics"). A further difference between BIA and SOPHIA is that the inhibitory connections from a language node to the word nodes of the other language as included in the original model have been removed. The consequence is that language nodes no longer inhibit words from the other language.

SOPHIA has successfully simulated a number of phonological effects obtained in studies of monolingual visual word recognition (Van Heuven & Dijkstra, 2001) but the model still has to be applied to bilingual word recognition data.

Dijkstra and Van Heuven (2002) developed a further, theoretical, model called BIA+, in which a word-recognition system containing orthographic, phonological, and semantic representations is augmented with a language-external control system. In terms of this model, linguistic-context effects (such as Elston-Güttler *et al.*'s 2005, finding that a linguistic context can nullify the interlexical-homograph effects; see Section 4.2.1) arise from activation processes within the word-recognition system, whereas effects of non-linguistic context (such as the specific requirements of the experimental task) emerge from the workings of the language-external control system. The fact that the direction of the homograph effects varies with the task to be performed by the participants and the exact composition of the stimulus set can also be attributed to the workings of this control system.

In their current forms, neither BIA, nor SOPHIA, nor BIA+ have much to say about the origin of the cognate effects, except that "The available studies suggest that cognates have a special representation" (Dijkstra & Van Heuven, 2002; p. 185). Various suggestions have been advanced regarding the exact nature of this special representation for cognates, for instance, that cognate translations share a morphological representation between a bilingual's two languages (Sánchez-Casas & García-Albea, 2005) or that their semantic representations are more integrated between the two languages than the semantic representations of noncognate translations (Van Hell & De Groot, 1998). Future implementation of the various possibilities in the models and simulations of these extended computational models should reveal which one best accounts for the behavioral data.

4.4 Sentence Processing in Bilinguals

In addition to examining the way bilinguals recognize visually presented words and what the underlying representation system looks like, researchers have investigated how bilinguals process sentences. Within this research area, two types of studies can be distinguished. One of these tries to discover how bilinguals parse syntactically ambiguous sentences for which the preferred solution differs between their two languages. Do they parse these structures the same way in both languages, perhaps applying the solution favored by one of their languages to the other one as well, or perhaps using each of the strategies in both languages some of the time? Alternatively, do they use the strategy that is most appropriate for the language they are currently processing, thus processing syntactically ambiguous structures the way monolingual language users do? The second type of studies examines how bilinguals process syntactically and/or semantically anomalous sentences, the main question addressed being whether or not bilinguals are equally sensitive to these anomalies as monolinguals. This section reviews some of the pertinent studies.

4.4.1 The resolution of syntactically ambiguous sentences

Several researchers have exploited one specific relative clause ambiguity in examining the question of how bilinguals process syntactically ambiguous sentences (e.g., Dussias & Sagarra, 2007; Frenck-Mestre, 2002). The sentences in question contain a complex noun phrase and either the head of this complex phrase or a second noun in this phrase can temporarily be assigned the subject of a subsequent relative clause. An example is the sentence "An eloquent student addressed the colleague of the secretary who stood in the hallway," in which "the colleague of the secretary" is the critical complex noun phrase. In this sentence either "the colleague" or "the secretary" can be the subject of the relative clause (the sentence part starting with "who"). Different languages are known to prefer different solutions of this ambiguity. For instance, Spanish and French favor "N1 attachment," assigning the first noun in the complex noun phrase ("the colleague") the role of subject of the relative clause. In contrast, English favors "N2 attachment," assigning this role to the second noun ("the secretary"). The question now is how people who master two languages that differ from one another in this respect process sentences of this type.

Dussias and Sagarra (2007) examined this question, specifically looking at the effect of amount of current exposure to the L2 on processing this type of sentences in L1. The participants in this study were Spanish monolinguals, Spanish-English bilinguals living and tested in the United States, and Spanish-English bilinguals living and tested in Spain. Both groups of bilinguals were highly proficient in L2 English but their L1 Spanish was still slightly stronger. The degree of L2 proficiency did not differ significantly between the two bilingual groups.

The participants in all three groups had to read L1 Spanish sentences of the above type. The sentences were presented one by one on a computer screen and the participants were instructed to read each sentence at their own pace. Meanwhile, the duration of their eye fixations to the separate words in the sentences was measured by means of eye-tracking equipment. In studies that use this methodology, the length of time a word is fixated on is thought to reflect the reading time for that word.

Unlike in English, in Spanish there is gender agreement between nouns and their modifiers. Therefore, sentences can be created in which the exact form of the words in the relative clause disambiguates the ambiguity toward either the preferred L1 solution or the preferred L2 solution. Consider, for instance, the following sentences from Dussias and Sagarra's study:

1. "El policía arrestó a la hermana del criado que estaba enferma desde hacía tiempo" ("The police arrested the sister of the servant who had been ill for a while")
2. "El policía arrestó al hermano de la niñera que estaba enferma desde hacía tiempo" ("The police arrested the brother of the babysitter who had been ill for a while")

In Sentence 1 the modifier "enferma" in the relative clause agrees in gender with "hermana," the first noun in the complex noun phrase, but not with "criado," the second noun in this phrase (the "a" signals femininity, the "o" masculinity). In contrast, in Sentence 2 the modifier "enferma" agrees in gender with the second noun of the complex phrase ("niñera") but not with the first ("hermano"). In other words, the proper solution of the ambiguity in Sentence 1 is the favored N1-attachment solution in Spanish whereas the proper analysis of Sentence 2 requires the non-preferred N2-attachment solution. In Spanish monolinguals, this difference should be reflected in a reading time difference between these two conditions for "enferma," the disambiguating word. Specifically, the authors predicted a longer reading time for this word in the N2-attachment condition (Sentence 2) than in the N1-attachment condition (Sentence 1). If such a difference were to materialize, it would subsequently be of interest to see what the response pattern would look like for the bilinguals, of whom L1 Spanish and L2 English favor different solutions, and whether current exposure to L2 English biases the ambiguity resolution process toward the N2-attachment strategy favored in English.

The results were clear-cut: Both the monolinguals and the bilinguals living in an L1 Spanish environment spent more time looking at "enferma" when it agreed in form with the second noun of the complex noun phrase (in other words, when N2 attachment was required) than when it agreed in form with the first noun of the complex noun phrase. The pattern reversed for bilinguals living in an L2 English environment: They spent more time looking at "enferma" when its form agreed with the first noun in the complex noun phrase (and, thus, N1 attachment was required). The authors concluded that, while parsing L1 sentences, "sources of information guiding L2 parsing decisions seep into the L1 comprehension system" (Dussias & Sagarra, 2007, p. 114).

In addition to current exposure to the L2, level of proficiency in this language has been shown to play a role in how bilinguals resolve the above type of syntactically ambiguous sentences. This was shown by Frenck-Mestre (2002), who reported the results of two experiments in which the performance of a group of English-French bilinguals on such sentences was compared with that of a monolingual French control group. As in Spanish, N1 attachment is preferred in French. In one of these experiments the bilinguals were relatively nonproficient in French;

in the other they were highly proficient in it. The bilinguals were tested on L2 French sentences and in an L2 French environment. In other words, any performance difference between the two bilingual groups to emerge could not be attributed to a difference in current L2 French language exposure. In both experiments the French monolinguals showed a clear preference for N1 attachment. Interestingly, an equally strong N1-attachment preference was observed for the proficient bilinguals, whereas the nonproficient bilinguals showed a clear preference for N2 attachment, that is, for the attachment strategy preferred in their L1 English. This pattern of results suggests that, with increasing L2 proficiency, L2 parsing strategies change from those consistent with the bilinguals' L1 to those consistent with their L2. In other words, with increasing L2 proficiency L2 speakers' parsing procedures may come to resemble those of native speakers.

4.4.2 The processing of syntactic and semantic anomalies

A persistent question in the study of bilingualism is whether the age at which bilinguals first started to acquire the L2 influences the way this language is ultimately processed, such that bilinguals who acquired it in early childhood ("early bilinguals") process it in a quantitatively and/or qualitatively different way from those who acquired it after childhood ("late bilinguals"). An important reason for posing this question is the idea that during a limited number of years in childhood humans are especially sensitive to linguistic input, perhaps because neural tissue dedicated to language learning is only temporarily available (Pinker, 1994). Language learning during this "critical period" is thought to be relatively effortless and automatic (see Chapter 7 for a discussion of the critical period hypothesis). Once this period of heightened sensitivity to language input is passed, language learning becomes a cumbersome enterprise which requires the exploitation of conscious learning strategies and the end state of these efforts is thought never to equal the level of proficiency reached by early learners.

A couple of ERP studies have examined the question of whether early and late bilinguals differ from one another, and from native speakers, in the way they process visually presented sentences that are syntactically and/or semantically anomalous (e.g., Ardal, Donald, Meuter, Muldrew, & Luce, 1990; Weber-Fox & Neville, 1996). The authors of a further study (Ojima, Nakata, & Kakigi, 2005) wondered whether the processing of such sentences might be affected by L2 proficiency. Accordingly, instead of manipulating L2 acquisition age, Ojima *et al.* manipulated L2 proficiency. Whereas Ardal and collaborators only manipulated semantic anomaly, Ojima *et al.*, and Weber-Fox and Neville, manipulated both semantic and syntactic anomaly. The type of materials used in the three studies is exemplified in Sentences 3 through 6, taken from the (Japanese-English) study of Ojima and colleagues:

3. "The house has ten rooms in total"
4. "The house has ten cities in total"

5. "Turtles move slowly"
6. "Turtles moves slowly"

ERPs were measured from the critical words ("rooms," "cities," "move," "moves"). In Section 4.2.1 it was mentioned that a particular ERP, the N400, reflects the ease with which a word can be semantically integrated with its context. Accordingly, the authors of the present studies predicted the N400 to differ between sentence types 3 and 4 in monolingual native speakers. If so, the next question is what the N400 to the critical words looks like in early and late bilinguals.

Syntactic processing is known to be indexed by two other ERPs, an early negative one that is thought to emerge from neural activity in anterior regions of the left hemisphere and that is sometimes called ELAN (for early left anterior negativity) and the P600, a positive one that is maximally strong 600 ms after presentation of the critical word (Hahne & Friederici, 1999). (See Chapter 10 for further discussion of ERP components for language processing.) The critical words in sentence types 5 and 6 – Type 6 but not Type 5 containing a syntactic anomaly – were therefore expected to show different ELAN and P600 responses in monolingual speakers and the question of special interest was whether this would also be the case for bilinguals.

The results of the studies by Ardal and colleagues (English-French) and Weber-Fox and Neville (Chinese-English) suggested that semantic processing is *qualitatively* the same in monolinguals, early bilinguals, and late bilinguals, because all these participant groups showed an N400 to the critical words and a difference between the amplitude of the N400 to semantically correct critical words ("rooms") and to semantically anomalous critical words ("cities"). The only group difference to emerge in Ardal *et al.*'s study concerned the time course of the N400 to anomalous words: The N400 was delayed in bilinguals as compared with monolinguals, and it was delayed in the bilinguals' L2 as compared with their L1. In other words, semantic integration appears to come about faster in monolinguals than in bilinguals, and faster in bilinguals' L1 than in their L2. L2 acquisition age did not modulate these effects. However, in the study by Weber-Fox and Neville, only the late bilinguals showed a delayed N400 in L2 English as compared with English monolinguals (they did not test the bilinguals in their L1).

Weber-Fox and Neville (1996) showed that, in contrast to semantic processing, syntactic processing *does* qualitatively differ between native monolingual and L2 speakers: Whereas in native speakers syntactic violations modulated the ELAN and the P600 as compared with correct sentences, these effects were not evident in L2 speakers. These results have been taken to mean that first-pass parsing and second-pass re-analysis may differ between native and L2 speakers of a language. The important contribution of Ojima *et al.* (2005) is that they showed that these differences between native and L2 speakers in syntactic processing do not occur when the L2 speakers in question are highly proficient L2 users.

In conclusion, L2 proficiency appears to be a more important determinant of L2 sentence processing than age of acquisition. This conclusion is in agreement with Frenck-Mestre's (2002) results that completed Section 4.4.1. Those findings and the present ones of Ojima *et al.* (2005) converge on the conclusion that with increasing L2 proficiency syntactic processing of the L2 comes to resemble the syntactic processing of native speakers of that language.

Research Questions

1. Consider how interlexical homographs are processed and explain why the direction of the homograph effect in lexical decision varies with the exact version of the lexical-decision task used.
2. Try to think of reasons why the cognate effect is more resistant to sentence context than the homograph effect.
3. Design and draw a theoretical model of visual word recognition for bilinguals with languages that use different alphabets. Include phonological representations in the models.
4. If one of a bilingual's languages favors N1 attachment whereas the other favors N2 attachment, both amount of current exposure to L2 and level of proficiency in L2 will influence the way the syntactic ambiguity illustrated in Sentences 1 and 2 is processed (see Section 4.4.1). This has been shown in studies that manipulated either the one or the other of these two variables. Design an eye-tracking experiment with four groups of bilinguals that together vary on *both* these variables and predict the pattern of looking times to the critical region for each of the four groups.

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