FIRST AND SECOND LANGUAGE VISUAL WORD RECOGNITION:

NEIGHBOURHOOD EFFECTS IN SPANISH AND ENGLISH

Carmen Santos Maldonado

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DECLARATION

I declare that this thesis has been composed by myself, and that the research reported therein is entirely my own work.

To Inés, who constantly delighted me
with her little words.

To Ian, who gave me the time
and space I needed.

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A number of people have contributed to this PhD thesis. I would like to express my gratitude to all of them.

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ABSTRACT

Current models of visual word recognition assume that the recognition of a stimulus word is affected by orthographically similar words (**orthographic neighbourhood**). In this thesis I explore the effects of neighbourhood on monolingual and bilingual word recognition. In particular I study the influence of Word Frequency, **Neighbourhood Size** (**N**) and **Neighbourhood Frequency** (**NF**) in English and Spanish lexical processing. **N** refers to the number of real words that can be created from a given word by changing one letter at a time while preserving letter position. **NF** refers to the frequency of the neighbours in relation to the frequency of the target word. There is a great deal of controversy as to whether orthographic neighbours facilitate or inhibit lexical processing and whether neighbourhood effects are consistent across languages. These questions are examined in four experiments carried out within the lexical decision paradigm.

Experiment 1 investigates the effects of Word Frequency, N and NF with English stimuli and twenty-four English native speakers. Latency differences are not statistically reliable, but they show a tendency for both N and NF to be facilitative of lexical processing. **Experiment 2** examines the same variables with Spanish stimuli and sixty-three Spanish native speakers. Data reveals null effects of N and reliable inhibitory effects of NF, with an interaction of NF with Word Frequency. In Spanish having higher frequency neighbours seems to delay lexical decision times, and this effect appears to be stronger for low frequency words. **Experiment 3** explores neighbourhood effects in eighty bilingual speakers of English and Spanish with bilingual stimuli presented in two language blocks. General results show null effects of N and significant inhibitory effects of NF. Results by target language show reliable facilitative effects of N in English and highly robust inhibitory effects of NF in Spanish. **Experiment 4** further investigates effects of NF in a cross-language lexical decision task with semantic (translation) priming done with sixty-four bilingual speakers of English and Spanish. The purpose of the experiment is to examine the strength of cross-language priming effects under four NF conditions (NF Leaders and Nonleaders, for targets and primes). Data shows reliable priming effects in both language directions, L1 to L2 and L2 to L1. Data also exhibits significant interaction between language and the priming influence of NF Leader primes and NF Nonleaders primes.

The results of these experiments are discussed in the light of current experimental research and in terms of contemporary models of monolingual and bilingual lexical representation. Further questions for future research are outlined.

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Words and the meaning of words are not matters merely
for the academic amusement of linguists and logisticians
or for the aesthetic delight of poets;
they are matters of the profoundest ethical significance
to every human being.
(Aldous Huxley, 1940)

Chapter 1

Introduction

1.1. OPENING REMARKS

Most of us take normal conversation, reading and writing for granted. However, if we think for example about the number of words contained in an everyday conversation lasting just a couple of minutes, it soon becomes apparent that the amount of lexical knowledge accessed in such a short period of time is staggering. For every word, we need to have access to many different kinds of information, not only lexical but morphological, phonological, orthographic, grammatical, syntactic, pragmatic, and so on. All this information is encompassed in our mental lexicon[1]. Without a lexicon, communication

[1] Libben and Jarema (2002) stress three characteristics of the mental lexicon: it retrieves knowledge at a millisecond rate, it continually reorganises itself on the basis of new input, and it keeps information integrity throughout life.

would not be possible. The issue of how words are accessed in the lexicon, that is, the issue of lexical retrieval, is therefore central to linguistic communication[2]. Understanding how linguistic information is retrieved is also important in cognitive psychology because it helps us understand other mental processes, based on retrieving information, like perception, memory, reasoning, learning, and so forth.

Speakers of a language are not only able to recognise words in that language extremely quickly, they are also able to recognise very rapidly if a letter string is not a word in their language. It is clear that understanding how this rapid access to the internal lexicon takes place is relevant to the appreciation of many communication processes, like sentence comprehension and sentence production, because the overall meaning of a sentence could hardly be retrieved until the meaning of individual words has been accessed.

The last three decades have witnessed an enormous growth in cognitive studies related to language and, in particular, to language processing. Within language processing, attention to visual word recognition[3] has also grown tremendously. Visual word recognition has possibly been one of the most widely studied phenomenon in the field of psycholinguistics. There are several reasons for this interest (Perea & Rosa, 1999). First, visual word recognition is

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[2] The relevance of the mental lexicon in current psycholinguistic research is shown in the spring 2002 Special Issue on The Mental Lexicon of *Brain and Language*.

[3] There are different terms used to refer to processes of word identification: lexical access, lexical processing or word recognition. Bradley and Forster (1987) make a difference between 'lexical access' and 'word recognition'. According to these authors, lexical access happens when the physical properties of a word become available, whereas word recognition happens when subjects are actually aware of those properties, and therefore recognition takes place after lexical access. This was the view adopted in some models of word recognition (Forster, 1976; Marslen-Wilson & Tyler, 1980). However, in other models (Morton, 1969; Seidenberg & McClelland, 1989) these two processes are very difficult to separate. In this thesis the terms lexical access, lexical processing and word recognition will be used interchangeably.

a core process in the understanding of reading, so clarification of what goes on at lower levels of processing will no doubt contribute to the understanding of higher level linguistic processes (like reading texts). Crucially, understanding visual word recognition may contribute to the comprehension of processes at the root of reading disorders. There is a second, perhaps more practical, reason for the great development of visual word recognition as an ever growing area of research, and that is the tractability of the 'word' as a research unit (Balota, 1994), and the relative simplicity of the associated experimental techniques[4]. The advantages of 'words' as units of analysis lie in the fact that they can be analysed at different levels (graphemes, phonemes, sublexical units, the word unit itself in isolation, at the level of associative relationships with other words, in the context of other words, in the context of sentences...), and can tap different levels of processing relevant to lexical representation and the organisation of the mental lexicon. For the psycholinguist, words are minimal units that display considerable advantages for research.

This thesis is about visual word recognition and, in particular, about the effects of word frequency and word neighbourhoods in lexical processing, with specific reference to the contrast between English and Spanish.

1.2. RELEVANCE OF NEIGHBOURHOOD EFFECTS

For most people, reading is an automatic and effortless activity. However, if we watch an adult trying to learn to read, we soon realise that the task involves a great deal of complexity. The fascinating aspect of reading is that once we have become skilled readers, the process is so automatic that we

[4] There is no doubt that working with longer research units, like sentences, or even texts, or working with on-line speech, requires more sophisticated techniques.

cannot 'not read', we cannot switch the ability off, and when presented with visual words, in the same way as when presented with spoken words, processing is 'inevitable'. Current models of word recognition suggest that when processing isolated words, the context of other words in the mental lexicon that look similar to the target, is also inevitable. The enormous relevance of the principle of 'lateral inhibition' in models of word recognition has brought the notion of 'lexical similarity' and its implications to a very prominent position in research. The assumption of an internal context, which plays a role in lexical processing, poses two questions whose answers are central for the organisation of lexical knowledge and its theoretical characterisation (Perea & Rosa, 2000):

- What are the determinants of lexical similarity? In other words, which candidates in particular will form the set of candidates activated on the presentation of the stimulus?

- Is the influence of these candidates facilitative or inhibitory of lexical access? In other words, are they 'friends' or 'enemies' of the target word?

The most common operational definition of lexical similarity is that of Coltheart, Davelaar, Jonasson and Besner (1977), in the form of 'neighbourhood'. A neighbour is any real word that can be obtained from a target word by changing one letter at a time while preserving letter position. A word's neighbourhood is the complete set of neighbours of that word. Two parameters of neighbourhoods are relevant to word recognition: neighbourhood size (N), or number of neighbours, and neighbourhood frequency (NF), or frequency of the neighbours relative to the target word. There is little controversy in the relevant literature that neighbourhoods do influence lexical processing. However, there is a great deal of controversy about the exact nature of this influence.

Neighbourhood effects are widely investigated because they provide useful information about access to the mental lexicon. Interest in the research of neighbourhood effects has been fuelled by conflicting results as regards the nature of these effects. Andrews (1989, 1992) has argued that N is the main factor contributing to lexical processing, and that its influence is facilitatory. In contrast, Grainger and his colleagues (Carreiras, Perea & Grainger, 1997; Grainger, 1990; Grainger, O'Regan, Jacobs & Segui, 1989; Grainger, O'Regan, Jacobs & Segui, 1992) have argued that NF is a much more important factor of lexical processing, and that its influence is inhibitory.

Whether neighbourhood effects are facilitatory or inhibitory has implications for models of visual word recognition. Facilitatory effects would give greater prominence to theories of word recognition based on summation of overall lexical activation. Inhibitory effects would support the principle of lexical competition, or lateral inhibition, posed by models like the Interactive Activation Model (McClelland & Rumelhart, 1981) and the Multiple Read-Out Model (Grainger & Jacobs, 1996).

Following Andrews' (1997) suggestion that the nature of neighbourhood effects may in fact be language specific, Ziegler and Perry (1998) have started a very promising line of research. In particular, these authors have suggested that effects of N may be determinant in English, a language where spelling-to-sound correspondences are highly inconsistent (deep orthography), but not in other languages where correspondences between orthography and phonology are much more consistent (shallow orthography). While a considerable amount of work has been done in English, comparatively little work has been conducted in other languages, and even less in a particularly shallow language like Spanish. Experiments 1 and 2 of this thesis were carried out to explore this new hypothesis about the language specificity of neighbourhood effects. Experiment 1 analysed the effects of N and NF in English (deep orthography) in the context of high and low frequency words, while Experiment 2 explored the same variables in Spanish (shallow orthography). Results of these two experiments confirmed that effects of N and NF are, at least to a certain degree, language specific.

1.3. RELEVANCE OF BILINGUAL RESEARCH

Although effects of neighbourhoods on monolingual lexical processing (mainly in English) have been greatly investigated, the field of neighbourhood effects in bilingual[5] lexical processing remains largely unexplored. Van Heuven, Dijkstra and Grainger (1998) have even described this research area as 'unchartered territory'. To the best of my knowledge, only three studies have been published so far that have specifically investigated neighbourhood effects in bilingual processing. Two of these studies (Grainger & Dijkstra, 1992; Grainger & O'Regan, 1992) examined effects of N with English-French bilinguals, in lexical decision tasks using only English targets. The third study (Van Heuven *et al.*, 1998) examined effects of N with Dutch-English bilinguals, using English and Dutch targets. The three studies explored how the recognition of words, belonging to one language only, is affected by the number of orthographic neighbours that those words have in the two languages of the bilingual subject. The results in all three studies were that words with more neighbours in the non-target language than in the target language gave slower reaction times.

[5] The discussion of 'bilingual processing' is by no means restricted to the case of balanced bilinguals (who are really the exception and not the norm). In this thesis, 'bilingual' is used in the broad sense, adopted by Kroll and De Groot (1997), of somebody who actively uses two languages, but not necessarily with a proficient L2 level.

No similar studies have been carried out involving Spanish in any way, using Spanish as one of the two experimental languages. Also, I am not aware of any experiments that have attempted to study the influence of neighbourhood frequency in bilingual processing in any language. Experiments 3 and 4 of this thesis will thus be early contributions in this direction, involving bilingual speakers of English and Spanish.

It has been argued (Ziegler & Perry, 1998; Ziegler, Perry, Jacobs & Braun, 2001) that a large N plays facilitatory effects in English visual word recognition because, in a language which is highly inconsistent in orthography, neighbours (particularly body neighbours) have a special role in helping to establish print-to-sound mapping. In addition, results from other studies suggest (Carreiras, Álvarez & Vega, 1993; Domínguez, De Vega & Cuetos, 1997; Perea & Carreiras, 1998) that Spanish readers are much more influenced by the structure of the syllable in their language. In this light, the aim of Experiment 3 was to examine to what extent effects of neighbourhood, observed separately with native speakers of English and native speakers of Spanish, were also observed in second language speakers of those languages.

Experiment 4 is a bilingual experiment in the context of a lexical decision with semantic (translation) priming. The study explores inter-language NF effects, with primes and targets selected on the basis of this variable and presented in cross-linguistic pairs. Based on predictions derived from the Bilingual Interactive Activation Model (Grainger & Dijkstra, 1992; Van Heuven *et al.*, 1998) and the Revised Hierarchical Model (Kroll & Stewart, 1994; Kroll & De Groot, 1997), the experiment was designed to test two basic hypotheses. These were whether inhibitory effects of NF leaders operate on targets of both languages, and whether NF nonleader primes are less effective primes than NF leader primes.

Both Experiment 3 and Experiment 4 were novel in three respects:

- The group of bilingual subjects included both native speakers of English and native speakers of Spanish.
- Targets of all the experimental conditions were presented in English and Spanish, not just in one language.
- All subjects responded to all the stimuli.

The general results of the experiments will be given in the summary of Chapter 8 and Chapter 9 in the next section.

1.4. OUTLINE OF THE THESIS

The thesis is arranged in ten chapters. The first five chapters are the theoretical background relevant to the experimental work presented in the second five chapters.

The following chapter, Chapter 2, presents a critical selection of models of visual word recognition, which are representative of two fundamental strands: activation models and search models. The models have been selected either because they are the most representative of their kind, or because they have served as the basis for other models. The selection is as follows: the **Logogen Model** (Morton, 1969, 1979a, 1979b, 1982), the **Interactive Activation (IA) Model** (McClelland & Rumelhart, 1981), the **Parallel Distributed Processing Model** (Seidenberg & McClelland, 1989), the **Search Model** (Forster, 1976; Forster & Davis, 1984; Forster, Davis, Schoknecht & Carter, 1987) and the **Activation-Verification (AV) Model** (Paap, Newsome, McDonald & Schvaneveldt, 1982; Paap, Chun & Vonnahme, 1999). For each model, a description of the assumptions underlying the architecture leads to an explanation of how lexical access takes place. Out of all the models presented, the IA Model is the one that best accommodates the results of the experiments described later in the thesis. The principle of lateral inhibition (lexical competition) advocated by the IA Model is crucial to explain some of these results.

Chapter 3 briefly introduces the range of experimental tasks most commonly used in the study of visual lexical processing, with particular reference to the lexical decision task (LDT), which is the experimental paradigm used in the current experiments. The chapter is mainly concerned with how **word frequency** affects lexical processing. The discussion of the word frequency effect not only includes print word frequency, central to the experiments of the thesis, but also the effect of syllable frequency, particularly relevant to lexical processing in Spanish. The role of word frequency counts in lexical research is also examined, as they are an essential tool in stimulus selection. Closely linked to the concept of word frequency is the notion of word familiarity, or experiential frequency, which is fundamental in bilingual processing. The chapter concludes with a reference to how the models presented in the earlier chapter explain the word frequency effect.

Chapter 4 is concerned with the notion of **lexical similarity**, crucial to the focus of this thesis. The chapter discusses the **N metric of lexical similarity**, which has been adopted by virtually all studies on neighbourhood effects, including the studies presented here. Also the most relevant evidence, in connection with the controversy about the facilitatory or inhibitory nature of neighbourhood effects, is presented and discussed. This is a controversy which is still largely unsettled. The chapter finishes with an evaluation of how word recognition models accommodate the experimental data on neighbourhood effects.

Chapter 5 presents three models of bilingual word recognition: the **Bilingual Interactive Activation (BIA) Model** (Grainger & Dijkstra, 1992; Van Heuven *et al.*, 1998), the **Bilingual Activation Verification (BAV) Model** (Grainger, 1993; Grainger & Dijkstra, 1992) and the Revised Hierarchical Model (Kroll & Stewart, 1994, Kroll & De Groot, 1997). The first two models are extensions of the Interactive Activation and Activation Verification models, into bilingual lexical processing, which are mostly concerned with aspects of lexical similarity in a bilingual context. The third model is more concerned with semantic aspects of bilingual processing. The chapter ends with a discussion of the work, albeit very little, carried out on neighbourhood effects with bilingual subjects. This work is discussed with reference to the BIA Model and the BAV Model.

The remaining chapters of the thesis, chapters 6 to 10, present original experimental work on neighbourhood effects in monolingual and bilingual processing, with a general discussion of the results. All the experiments were done within the lexical decision paradigm. Chapter 6 describes Experiment 1, an English monolingual study carried out with 24 subjects. The main objective of this study was to investigate whether neighbourhood effects were facilitatory (as suggested by Andrews, 1989, 1992) or inhibitory (as suggested by Grainger and his colleagues in Grainger *et al.*, 1989, 1992). Results of the experiment generally showed null effects of N and NF in high frequency words. For low frequency words, NF was facilitatory: having higher frequency neighbours improved lexical processing. Also, for low frequency words, NF interacted with N, such that large N was facilitatory only in the NF nonleader condition. Thus the results of the English study only timidly supported Andrews' (1989, 1992) findings. The following chapter, Chapter 7, reports on Experiment 2, a study of neighbourhood effects on monolingual Spanish processing conducted with sixty-three subjects. In nearly all respects, this experiment paralleled Experiment 1, but the results were very different. NF had clearly inhibitory effects for

Spanish: having higher frequency neighbours was detrimental for word recognition, both in speed and accuracy. The results for N were inconclusive. These findings replicate those obtained by Grainger and his colleagues (Carreiras *et al.*, 1997; Grainger, 1990; Grainger *et al.*, 1989, 1992) and suggest that neighbourhood effects could be language specific.

Chapter 8 and Chapter 9 report on two bilingual studies of neighbourhood effects. Experiment 3 was designed to investigate if the effects observed in monolingual processing of English and Spanish were also observed with bilingual speakers of those languages. The study manipulated five variables: Native Language, Target Language, Word Frequency, N and NF. Participants were eighty bilingual speakers of English and Spanish (forty native speakers of English and forty native speakers of Spanish). General results showed a significantly inhibitory effect of NF. For Target Language, N was facilitatory for English items and NF was inhibitory with Spanish items. Experiment 4 involved a bilingual lexical decision task with semantic (translation) priming. It was designed to study the effects of NF in targets and primes and the magnitude of L1→L2 and L2→L1 priming effects. Sixty-four bilingual speakers (thirty-two native speakers of English and thirty-two native speakers of Spanish) responded to targets in both languages in a language-block presentation. As hypothesised, highly significant priming results were obtained in both language directions, which were considerably larger in L1→L2 direction. NF of targets had facilitatory effects, and NF of primes had no significant effects (both these results ran contrary to the experimental hypotheses).

Chapter 10 summarises the results of the experimental work and relates them to findings in previous studies. Results are also discussed in the light of current models of visual word recognition. In particular they are examined in connection with the IA Model (McClelland & Rumelhart, 1981), the BIA

Model (Grainger & Dijkstra, 1992; Van Heuven *et al.*, 1998) and the Revised Hierarchical Model (Kroll & Stewart, 1994; Kroll & De Groot, 1997). Finally, suggestions are made for further investigation.

Chapter 2

Models of Monolingual Visual Word Recognition

2.1. OPENING REMARKS

One of the purposes of psycholinguistic research on visual word recognition is to increase understanding of how lexical information is stored in the mind, and how this information is retrieved so rapidly in the course of communication. In the last thirty years a number of models that attempt to accommodate the growing body of experimental data have been put forward. This interest in language modelling is due, not least, to the fact that advances in technology have put at the disposal of researches an array of techniques which make it feasible for them to suggest new models, or to modify or fine tune previous ones. While this is a positive sign of the good health that psycholinguistic research on word recognition enjoys, it sometimes makes it difficult to establish real differences between some of the models (Taft, 1991). Modifications of previous models are sometimes treated as new ones and given a new category, when in fact the variation may be minimal or not big enough to justify talking about a new model (Álvarez, Alameda & Domínguez, 1999). The purpose of this chapter is to offer an overview of the most influential models of monolingual visual word recognition, some of which have been adapted for bilingual lexical processing. This overview will necessarily be selective and geared towards the main focus of this thesis, namely, how lexical similarity affects visual word recognition.

There are many models of visual word recognition[1]. Theories and models can be grouped according to different criteria, and different authors have proposed different classifications. Massaro (1994) suggests five characteristics on the basis of which the various models can be analysed and compared. Each characteristic is defined as a binary opposition. They are as follows:

1. **Mediation**, which refers to whether word recognition is mediated or non-mediated by units smaller than the word.
2. **Availability of information** about the word, which states whether the information available in the recognition process flows continually or categorically.

[1] See Jacobs and Grainger (1994) for an overview of models of visual word recognition.

3. **Timing of information**, which relates to whether the information about the continuously shaped input is made use of on-line or whether there is any form of delay in initiating lexical access.

4. **Access to memory representations**, which refers to whether the access is serial or parallel.

5. **Context-dependency**, which refers to whether word recognition operates independently of context or whether it is influenced by it.

A further taxonomy of criteria is put forward by Jacobs and Grainger (1994), who propose five broad features specific to the analysis and contrast of models of visual word recognition: format, task, dependent variable, simplicity and word effects. These criteria are briefly examined below.

1. **Format**. This feature refers to the way the model is expressed. There are three basic formats: verbal, mathematical and algorithmic. Verbal models do not resort to any kind of formulae or calculations, and are more likely described by use of figures representing the various processing units and processing stages advocated. In contrast, mathematical models are usually presented by way of closed-form formulae, and algorithmic models are used with computer simulation programmes[2].

2. **Task**. There are three major methodological paradigms that researchers of visual word recognition have traditionally worked with,

[2] Every format has its advantages and disadvantages. For example, verbal models are less precise, and therefore more difficult to falsify than the other two formats, but at the same time they allow greater chance for more creative principles and rules. Conversely, mathematical and algorithmic models are more precise and explicit. However, there may be the risk of getting lost in the calculations, as it is sometimes difficult to see what relationship these calculations bear with language processing.

namely, perceptual identification, lexical decision and naming. There are numerous variants on these three paradigms.

3. **Dependent variable**. There are mainly three different kinds of dependent variable: means of reaction times (RT) to correct responses, distributions of RT, and percentages of incorrect responses.

4. **Simplicity**. To explain simplicity, Jacobs and Grainger (1994) mention eight binary subfeatures that make the different models more or less 'simple' to describe[3].

5. **Effects.** This feature refers to whether a particular model sets out to explain one or more of four effects long established in the literature of visual word recognition, namely, the word frequency effect, the word superiority effect, the orthographic neighbourhood effect, and the regularity/consistency effect.

The most basic assumption in word recognition is that for lexical retrieval to happen there must be some form of 'decodification' from a sequence of sensory input, spoken or written, into a recognised word already stored in our lexical memory. This is the issue of word recognition. In addition, to give the right meaning to a word in the context of a sentence, a whole array of other properties (morphological, phonological, orthographic, grammatical, syntactic, pragmatic, and so on) must also be made available. Some of the models discussed below incorporate accounts for word recognition beyond word-level processing. However, since the interest of this thesis lies in the recognition of

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[3] According to Jacobs and Grainger (1994), a model can be deterministic or probabilistic, localist or distributed, modular or interactive, serial or parallel, and static or dynamic. A model can have a macrostructure or a microstructure, can account for performance or learning, and the generated data can be ordinal data or interval data. The first element of each of these binary subfeatures makes a model simpler.

visual words presented in isolation, aspects dealing with the 'context' will not be discussed here.

There are two basic strands in current models of visual word recognition: activation models and search models, depending on whether the main metaphor is one of activation or one of searching. Borowsky and Besner (1993) and Harley (2001) suggest a third strand for hybrid models, i.e. a combination of both activation and searching. Examples of activation and search models are as follows:

<u>**ACTIVATION MODELS**</u>	<u>**SEARCH & HYBRID MODELS**</u>
• **Logogen Model** (Morton, 1969, 1979a, 1982).	• **Search Model** (Forster, 1976; Forster & Davis, 1984; Forster *et al.*, 1987).
• Dual Route Model (Coltheart *et al.*, 1977; Coltheart & Rastle, 1994; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001).	• Verification Model (Becker, 1976, 1980).
• **Interactive Activation Model** (McClelland & Rumelhart, 1981).	• **Activation-Verification Model** (Paap *et al.*, 1982; Paap *et al.*, 1999).
• **Parallel Distributed Processing Model** (Seidenberg & McClelland, 1989).	• Checking Model (Norris, 1986).
• Quantitative Multiple-Levels Model (Norris, 1994).	• Cohort Model (Johnson & Pugh, 1994).
• Dual Read-Out Model (Grainger & Jacobs, 1994) and Multiple Read-Out Model (Grainger & Jacobs, 1996).	
• Split Model (Shillcock, Monagahn & Ellison, 1999).	

The models that appear in bold face are the ones described in this chapter. They were selected for several reasons: they are the most representative in their category, they have served as a basis for more recent models, and they are relevant to the discussion of word frequency and lexical similarity effects. In addition, some of these models have been extended as bilingual models of visual word recognition. For every model, the two following aspects will be briefly discussed:

- The assumptions the proponents of the model make, and the main features of its architecture.
- How the model explains lexical access.

Later chapters will cover the discussion of how every model accounts for the effect of word frequency and, in particular, how suited these models are to accommodate neighbourhood effects.

2.2. ACTIVATION MODELS

2.2.1. THE LOGOGEN MODEL

The **Logogen Model** was first proposed by Morton in 1969 and it has since gone through a number of formulations (Morton, 1979a, 1979b, 1982; Morton & Patterson, 1980; Patterson & Shewell, 1987). It is one of the earliest models of word recognition and was the first one to incorporate the notions of interaction and activation. The name of the model comes from its primary lexical units, **logogens**, which embody words in the lexical memory.

2.2.1.1. ASSUMPTIONS AND ARCHITECTURE

The basic principle of the Logogen Model is the notion of **activation**. Different properties of linguistic input are viewed as discrete cumulative counts towards the activation of relevant lexical entries; these counts may rise above and fall below a certain threshold. The model also assumes that, given the rapid and continuous nature of reading and listening, activation values of lexical representations decline very quickly back to their baseline values.

In Morton's view, words are represented in the internal lexicon by **logogens**. Logogens are information collecting pools, or linguistic property detectors, which are sensitive to visual, auditory, semantic and contextual properties of linguistic stimuli. When enough information has accumulated in a logogen to exceed a threshold value, the logogen 'fires', and the corresponding response becomes available; that is to say, the particular word is recognised. Different logogens have different threshold values, depending on factors like word frequency, semantic and syntactic context, expectations about stimuli, training, etc.

There are three main elements in the architecture of this model: the **input logogen systems** (one system for visual input and one system for auditory input), the **cognitive system** and the **output logogen systems**[4]. These are illustrated in Figure 2.1.

The cognitive system is the locus of semantic and syntactic characteristics of words. Connected to the cognitive system are the output logogen systems, which house the potential written and spoken responses made available by the cognitive system.

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[4] The initial version of the Logogen Model envisaged one input logogen system, which would accept both visual and auditory data. In later versions of the model (Morton, 1979a, 1982), Morton felt compelled to replace this single input logogen system by one with two separate pools of logogens: visual input logogens, which code orthographic information, and auditory input logogens, which code phonological information. This modification was necessary to accommodate empirical evidence on lexical facilitation effects (Morton, 1979a; Warren & Morton, 1982; Winnick & Daniel, 1970), which suggested that facilitation of word recognition was modality-specific. Thus, for example, on a tachistoscopic recognition task, previously naming a word represented in a picture did not produce facilitating effects that were comparable to those produced by the visual presentation of the word itself (Winnick & Daniel, 1970).

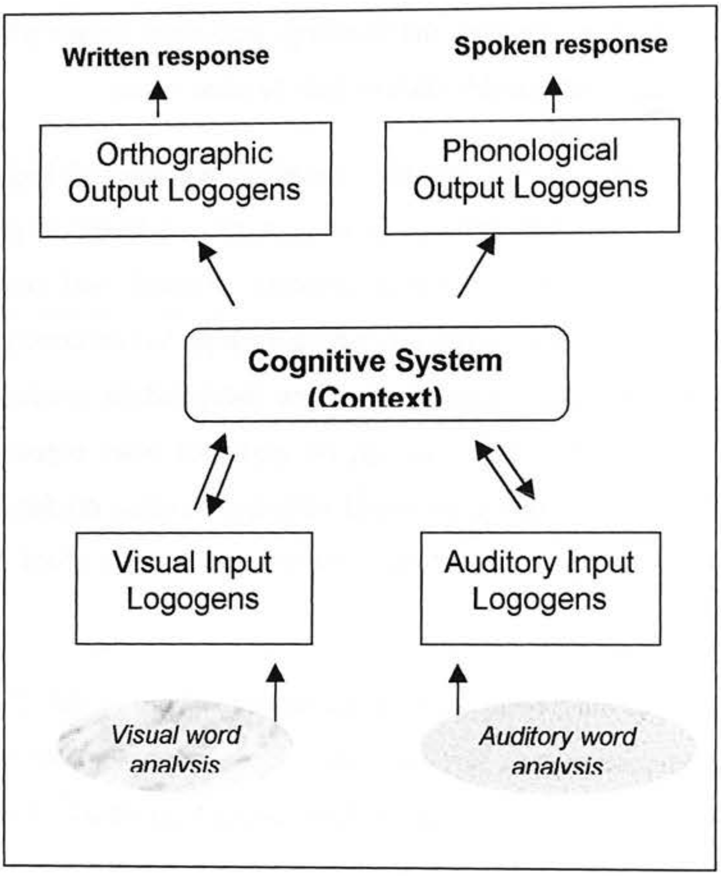

Figure 2.1. Revised version of the Logogen Model *(Adapted from Morton, 1979a). There is continuous exchange of information (interaction) between the input logogen systems and the cognitive system.*

2.2.1.2. LEXICAL ACCESS

Each word is represented by a logogen. On presentation of a stimuli, for example the printed word *packet*, a visual word analysis takes place, and all the logogens representing words sharing one or more sensory characteristics with *packet* will become activated: for instance, logogens of words beginning with *p-*, words with five letters, words ending in *-t*, words with the sequence *-ck-* in them, etc. Thus, the logogens for the words *jacket*, *reckon*, *socket* and *packet*, among many others, will be activated, but *packet* will be 'fired' before the rest because its logogen will have collected the greatest amount of evidence coinciding with the sensory input provided by the stimulus.

It thus follows that, after the analysis of a visual stimulus, many logogens sharing some similarity with the sensory input will be activated to some degree (Patterson & Shewell, 1987), but that only a very small number will receive enough activation to rise above the threshold. If more than one logogen can be 'fired', more than one response can be made available for a single stimulus. The system has to ensure that the right response is likely to be given. This is achieved by assigning response strengths to all possible responses. These response strengths are calculated as the difference between the level of activation of a given logogen and its threshold value. So the probability of any particular response becoming available will depend on the ratio between its response strength and the overall activity in the system at a given time.

As mentioned earlier, the principles of **interaction** and **activation** are central to the Logogen Model. The system is interactive because the information reaching the input logogen systems can come from the sensorial analysis –'bottom-up' flow– as well as from the context provided by the cognitive system –'top-down' flow. In fact, the relationship between the input logogen systems and the cognitive system is such that there is a constant exchange of information between them. Activation operates throughout lexical access, in that the sensory input activates not only the target logogen but also a whole range of other logogens that share some characteristics with the initial stimulus.

Taft (1991) argues that the traditional Logogen Model has serious difficulties explaining how one can decide that a letter string is a nonword. Following the sensorial analysis of a nonword stimulus, two things can happen: either no logogen accumulates enough information to rise above threshold level, in which case no response is made available; or a logogen representing a word that is very similar to the nonword stimulus makes a response available and an incorrect response is given[5]. Clearly, both events go against experimental data, which overwhelmingly show that people can indeed decide extremely quickly and accurately that a letter string is a nonword[6].

The **Dual-Route Model** of word recognition (Coltheart *et al.*, 1997; Coltheart, 1978; Coltheart & Rastle, 1994; Humphreys & Evett, 1985) can be considered an updated version of the Logogen Model. It takes its name from the two routes proposed to access the lexicon: a lexical or direct route, and a phonological or indirect route. These routes are very similar to the visual and auditory input systems of the Logogen Model. In the Dual-Route Model pronunciation of a word can be achieved by summoning phonology from orthography (from regularities in the language) or by directly retrieving the corresponding lexical representation following the orthographic input. A later version of this model, the **Dual Route Cascaded Model** (Coltheart *et al.*, 2001) allows for lexical processing to take place in a cascading way, which gives the model the capacity of parallel processing.

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[5] The response is incorrect because the fired logogen represents a word, and the sensory input corresponds to a nonword.

[6] More recent models of word recognition with a strong base on the Logogen Model, like the Dual-Route Model (Coltheart *et al.*, 1977; Coltheart & Rastle, 1994), have solved this difficulty by proposing a decision deadline: if no logogen has been fired after a certain time, then a decision is made that the stimulus is a nonword. This new parameter would also explain why nonwords take longer to process than words.

2.2.2. THE INTERACTIVE ACTIVATION MODEL

The **Interactive Activation (IA) Model** was developed by McClelland and Rumelhart (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982), and it is one of the most influential models of visual word recognition at present. Most of the assumptions of the experimental work of this thesis are based on the IA Model. This connectionist model draws on the ideas of **interaction** and **activation**, proposed by the Logogen Model (Morton, 1969, 1979a), but takes them further in as much as it introduces and develops the principles of **feedback** between levels, and **inhibition** between units. The IA Model also suggests a parallel route for word processing, with information being processed simultaneously, both within levels and between levels. This notion of simultaneity makes this model stand in absolute contrast with models in which information is processed serially, such as Forster's Search Model (1976) and the Activation-Verification Model (Paap *et al.*, 1982).

2.2.2.1. ASSUMPTIONS AND ARCHITECTURE

The IA Model is based on the metaphor of neuronal connections. Within the general perceptual system, input is dealt with at different levels and degrees of abstraction. As illustrated in Figure 2.2, visual word input is processed at three specific levels: at **feature level**, at **letter level** and at **word level**. These three levels provide 'bottom-up' input (data information). In addition, there are higher levels of processing providing 'top-down' input (conceptual information). Perception is therefore driven by the interaction of two kinds of information flowing simultaneously in the processing system.

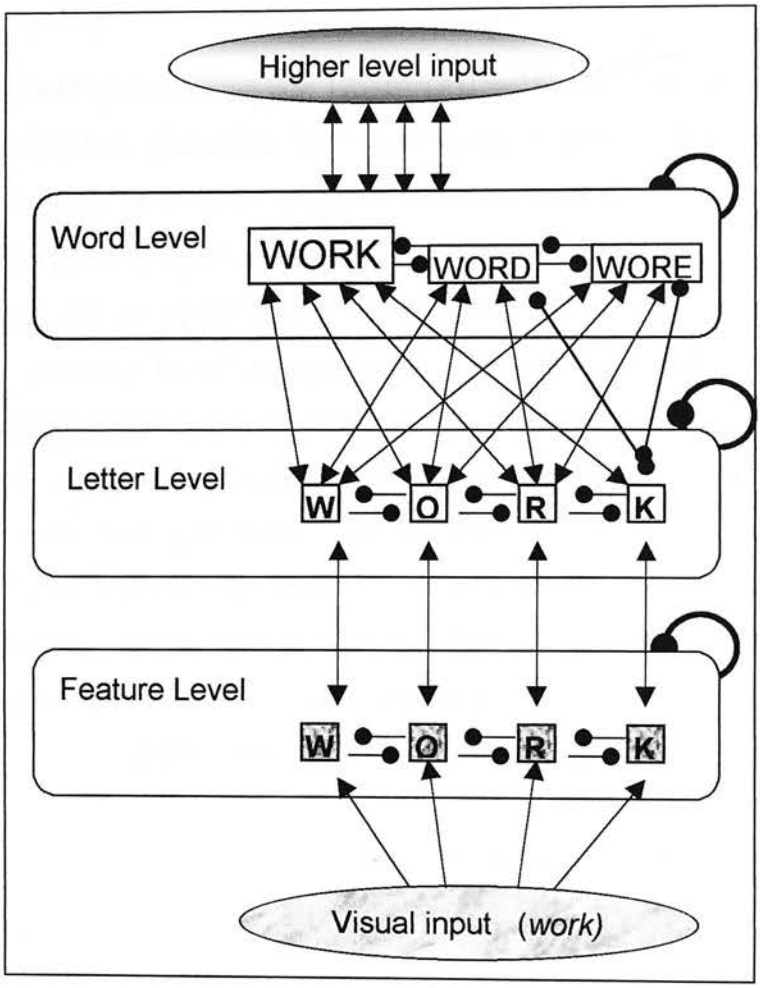

Figure 2.2. Simplified version of the Interactive Activation Model *(Adapted from McClelland & Rumelhart, 1981: 378-380). Illustration of processing the English word 'work'. Excitatory connections are represented by lines ending in an arrow, and inhibitory connections by lines ending in a knob.*

The word level and the letter level are made up of numerous units or **nodes**, representing every word and every letter in a specific letter position within the word. Nodes are connected to other neighbouring nodes by two-way connections, which can be **excitatory** or **inhibitory**. When two nodes imply each other, for example the node for the word *work* and the node for final position *-k*, their connection is excitatory. The set of nodes connected to a particular node with excitatory connections makes up that node's excitatory neighbourhood. When two nodes are incompatible with each other, for example the node for the word *work* and the node for the word *walk*, their connections are inhibitory. The set of nodes connected to a given node through inhibitory connections makes up that node's inhibitory neighbourhood. The concepts of 'excitatory neighbourhood' and 'inhibitory neighbourhood' are central to the present study of neighbourhood effects. Connections between levels can be excitatory or inhibitory, depending on whether or not the nodes involved imply each other. However, connections within the same level are always inhibitory, because two words or two letters cannot reside in exactly the same position at the same time.

Each node has an **activation value** associated with it. When the activation value is positive, the node is active. When the activation value equals zero or is negative, the node is inactive. A node can only influence another node if it is active. In the absence of input from their neighbours, nodes tend to go back to their resting activation levels. The resting values of the different nodes are not all the same, they depend on how frequently the nodes have been activated over time. For example, high frequency words have higher resting levels than do low frequency words, and therefore they need lower amounts of activation to be brought to positive values of activation. The level of activation of a word is, therefore, a function of the degree of positive activation coming from its letter nodes, plus the starting resting level (in other words, the word's frequency) and minus the pressure from lateral inhibition. In turn, the inhibiting capabilities of a word are relative to its degree of activation at a given time.

A further assumption of the IA model is that visual processing occurs in **parallel form**; that is, not only can several letters be processed in the same input load (spatially parallel processing) but also several levels can be involved in processing visual information at the same time (simultaneously parallel processing). Three mechanisms are at the heart of the model:

1. **Spreading activation**: Communication between levels and nodes operates on the basis of spreading activation, a mechanism that allows activation to flow to neighbouring units. As already explained, activation connections can be excitatory or inhibitory, depending on whether they increase or decrease the activation levels of the recipients.

2. **Lateral inhibition**: Within the letter and word levels, the nodes receiving the largest amount of excitatory activation will, in turn, send inhibition messages to the other neighbouring nodes. This intralevel inhibition is a form of lateral inhibition, which defines the terms of competition between incompatible units.

3. **Reverberation** (a kind of echoing of activation; Mathey, 2001): The activated letters positively activate the words that contain those letters and inhibit the words that do not contain the letters. In turn, the activated words send positive feedback to the letters contained in them, and negative feedback to letters not contained in them. This cut and thrust between activation and inhibition determines the speed at which a particular word is recognised in the lexicon.

2.2.2.2. LEXICAL ACCESS

Figure 2.2 (shown earlier) illustrates how the model operates, using the word *work* as an example. When the perceptual system is presented with the visual stimulus, a set of featural inputs is extracted from it and is made available to the system (for example, vertical line, horizontal line, curved line, and so on). The model assumes that these visual features are binary, and that the perceptual system can detect their presence (or absence). Excitatory messages are sent to letter-level nodes that contain those features, whereas inhibitory messages are sent to letter-level nodes that do not contain those features. For example, the feature representing a 'vertical line' will excite letter nodes like R, K or D (all physically containing a vertical line), but will inhibit all the nodes of letters lacking a vertical line, like O, S or A (not represented in the diagram). For each letter position, every letter node will exert lateral inhibition on the other letter nodes. The activated letter nodes then send activation pressures to word-level nodes —excitatory messages for word nodes containing those letters, and inhibitory messages for word nodes not containing those letters. As activated word nodes become 'strong', they inhibit each other laterally, and they send appropriate excitatory or inhibitory feedback to letter nodes. So in the example, *work* sends positive feedback to all letter nodes W, O, R and K, whereas the words *word* and *wore* will send positive feedback to W, O and R, but negative feedback to K[7]. Through a 'rich-get-richer' mechanism, excitatory connections work rapidly to channel the positive feedback towards the appropriate set of letters and the target word.

With reference to nonwords, the IA model explains why letters in the context of nonwords are responded to more slowly than letters in the context of real words: word-embedded letters benefit from the positive feedback generated by activated words, something that cannot happen with nonwords because nonword nodes do not feature in the system. Perceptual facilitation of regular nonwords –pseudowords– is explained by the 'integration of feedback from partial activation of a number of different words' (McClelland & Rumelhart, 1981: 388). The model does not explicitly explain, however, how the perceptual system can conclude that a letter string is in fact a nonword. Jacobs and

[7] One of the effects that the IA model sought to explain was the perceptual advantage of letters embedded in words *vs* letters in isolation, or in unrelated contexts (as first described by Reicher, 1969). The model explains this advantage through the excitatory feedback generated by word nodes consistent with the target letters, whereas isolated letters would not be helped by this reinforcing feedback.

Grainger (1992) simulated negative responses to letter strings in the context of the IA model by taking up the notion of 'temporal integration'[8] of the total lexical activity.

2.2.3. THE PARALLEL DISTRIBUTED PROCESSING MODEL

Seidenberg and McClelland in 1989 offered a 'Distributed, Developmental Model of word recognition and naming' which took McClelland and Rumelhart's (1981) notion of **interactive activation** much further, thus starting a second generation of interactive activation models. The authors also drew on work about **distributed representation of concepts**, carried out by Hinton and his colleagues (Hinton, 1986; Hinton, McClelland & Rumelhart, 1986).

The Parallel Distributed Processing (PDP) Model is a simulation model specifically developed to account for lexical processing tasks, like word pronunciation and lexical decision, and to address the acquisition of knowledge of orthographic redundancy and orthographic-to-phonological correspondences. The model has to be seen in the context of a larger framework of lexical processing, where codes concerning orthographic, phonological, semantic, syntactic, pragmatic and other types of contextual information, should be taken into consideration. However, the authors have only implemented the orthographic and phonological part. Although phonology

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[8] According to Jacobs and Grainger (1992), there is a direct relationship between the summed activation across the nodes and the probability of a certain response. So, the no-decision over a nonword can only be reached when the temporal limit for decision-making expires before a single word node has reached high enough levels of excitatory activation to become accessible to the system. The authors argue that the reason why pseudowords are more difficult to reject than nonwords is because they generate higher levels of overall lexical activity and the decision span is consequently longer. As pseudowords are more similar to real words than nonwords, they activate more neighbour word nodes, the 'temporal integration' is longer and, therefore, an inhibitory effect of pseudowords is predicted.

plays a fundamental role in this model, only the aspects of the model directly concerned with visual word recognition will be examined here.

2.2.3.1. ASSUMPTIONS AND ARCHITECTURE

One of the crucial differences between previous models of word recognition and the PDP Model is that there is no *a priori* architecture in the model to process words. Rather, the architecture gradually emerges from the processing experience itself. The model 'does not contain a lookup mechanism because it does not contain a lexicon in which there are entries corresponding to individual words' (Seidenberg & McClelland, 1989: 525). There are no rules either. Both lexicon and rules are replaced by the single notion of **learning**: through repeated encounters with a limited range of regular words, exception words, and different kinds of nonwords, the processing system learns the spelling-to-sound regularities implicit in the set of stimuli.

Orthographic, phonological and semantic properties of words are assumed to have a distributed representation. This means that information about words is represented as 'patterns of activation distributed over a number of primitive representational units' (Seidenberg & McClelland, 1989: 526). There are four different kinds of simple processing units within this distributed memory network: **orthographic**, **phonological**, **semantic** and **hidden units**[9]. The 'hidden units' act as an interface between the orthographic, phonological

[9] The model assumes that both phonological and orthographic information is encoded as distributed patterns of activation over very crude representational units, each one containing a triplet of appropriate features (for example, 'vowel, liquid, word boundary'). The model makes use of 400 orthographic units, 460 phonological units and between 100 and 200 hidden units. Hidden units do not have any predetermined representational or functional role in the processing system: their role emerges from the training procedure through incoming connection strengths. Hidden units evolve from generating random outgoing connection strengths, to generating meaningful output patterns of activation, which allow the reconstruction of orthography and phonology within the network.

and semantic representational units. In Figure 2.3, the three rectangles represent the part of the model actually developed by the authors, whereas the three ellipses represent parts of the larger framework that was not developed. The double arrows represent the notion of interactivity.

The learning assumption is central to the model. It assumes that the processing system has no *a priori* knowledge of any correspondence between spelling and sound. It is only through experience of, or exposure to, letter strings that the system is able to allocate the right phonological strings to the corresponding orthographic strings. The activation of hidden units projects feedback activation over the orthographic units. At this point, an error index is calculated by comparing the output feedback pattern with the input target pattern. Learning involves modifying strengths in all the connections in the network on the basis of the magnitude of the error, such that the degree of error is reduced over time. In other words, the probability of error is reduced through experience. Weightings in connections are constantly updated with every exposure of the network to a fresh stimulus.

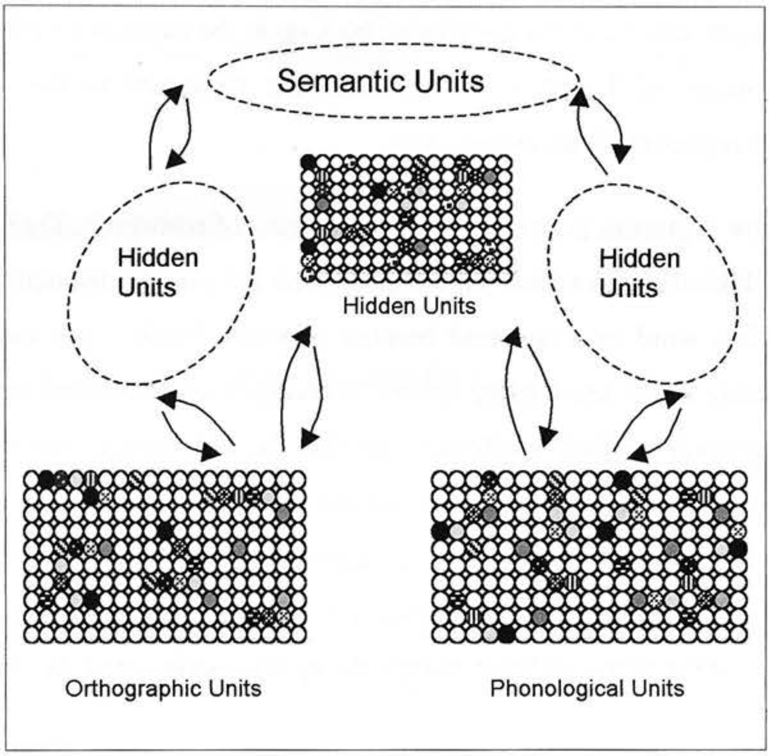

Figure 2.3. Representation of structure and lexical processing in the Parallel Distributed Processing Model *(Adapted from Seidenberg & McClelland, 1989: 526). The different shadings in processing units represent varying weightings of activation, encoding the representations of words.*

2.2.3.2. LEXICAL ACCESS

Another major difference between the PDP Model and previous accounts is that the information necessary to recognise words is not localised in specific lexical units (whether they be logogens, word entries or nodes), and therefore spellings, pronunciations and meanings of words cannot in that sense be 'accessed'. Instead, representations of words are computed in patterns of activation across the network, in units encoding phonological, orthographic and semantic properties of words. These patterns of activation are formed on the basis of the input string and the knowledge built up in the network over time[10]. Thus, the concept of 'lexical access' is somewhat redundant in this model because of its representational assumptions.

The same argument is invoked in the processing of nonwords. Traditional views of the lexical decision task state that subjects are able to distinguish if a letter string is a word or a nonword because they can decide when they can assign a meaning to the letter string or not. To decide that a nonword string is actually a nonword, the PDP Model assumes that the orthographic error score helps in this decision. As representations are 'not lexical', the model responds to a nonword string on the basis of the 'experience' that the network has of that particular string. As the probability of error scores is very high (because there is no experience of the nonword letter string), the system decides that the string is a nonword.

There is no doubt that distributed connectionist models in general represent a new conception of mental processing (Álvarez *et al.*, 1999), as they move from the traditional computer metaphor to a view closer to neural networks, where there are no rules or information nodes, just connections[11]. Herdman (1999) points out that another very valuable contribution of Seidenberg and McClelland's (1989) model is that their approach has encouraged theorists of word recognition to rethink their models and the

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[10] This pattern of activation, in turn, allows activation in the hidden units. A 'net input' is computed for each hidden unit. Computed activations from the hidden units are the basis for feedforward messages over the phonological units and feedback messages over the orthographic units.

[11] See Carreiras (1997), for an in-depth description of the symbolism *vs* connectionism debate, and Harley (2001) for a formal description of the equations used in connectionist modelling.

underlying assumptions, so that the models can be implemented and tested, to see how well they simulate effects observed in human performance[12].

2.3. SEARCH MODELS

2.3.1. THE SERIAL SEARCH MODEL

The **Search Model** has been proposed by Forster and his collaborators (Forster, 1976, 1989, 1992; Forster & Davis, 1984; Forster *et al.*, 1987; O'Connor & Forster, 1981). It stems from the work carried out by Rubenstein, Lewis and Rubenstein (1971a) and Oldfield (1966)[13]. Forster favours the metaphor of the library set-up to explain the organisation of the internal lexicon. His basic concern is how information about words is arranged, so that it can be accessed very quickly via different routes and for different communication purposes.

2.3.1.1. ASSUMPTIONS AND ARCHITECTURE

Forster bases his model on the idea that lexical access inevitably entails some form of searching within a subset of the total lexicon. This means that the precise location of the target word in the group of possible candidates can only be defined through a process of serial search.

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[12] A model that can be implemented has 'more intrinsic validity than the 'box and arrow' approach that has dominated the cognitive literature' (Herdman, 1999: 271).

[13] Paper cited by Forster (1976). Foster discards Oldfield's (1966) notion of the standard dictionary as a plausible description for the organisation of the mental lexicon. He points out that a dictionary-like organisation is uneconomical, and it also runs counter to experimental data about words, nonwords and word frequency effects.

Intuitively, Forster argues, we would need an orthographically arranged lexicon for reading purposes, a phonologically arranged lexicon for listening purposes, and a semantically and syntactically arranged lexicon for speaking purposes. But nothing could be more uneconomical than having three lexicons. Thus, Forster concludes that there is only one lexicon proper, stored in what he calls the **master file**. This master file is connected to three subsidiary files, which he calls the **peripheral access files**: the orthographic access file, the phonological access file, and the semantic and syntactic access file. Figure 2.4 illustrates this architecture.

Word entries in the master file store all the information we have about words, in a modality-free format. Entries in the peripheral files only contain featural information of the kind appropriate to accessing the file. For example, the orthographic access file only contains information relative to visual and orthographic features of words. Entries with similar sensory features in the peripheral access files are grouped together in **bins**. A first step in lexical access is to locate in which bin the target item is likely to be found[14]. Within the bin, entries are arranged according to word frequency, with more frequent words being listed first.

[14] Thus, lexical memory would be 'approximately content-addressable', rather than 'fully content-addressable', as a dictionary is.

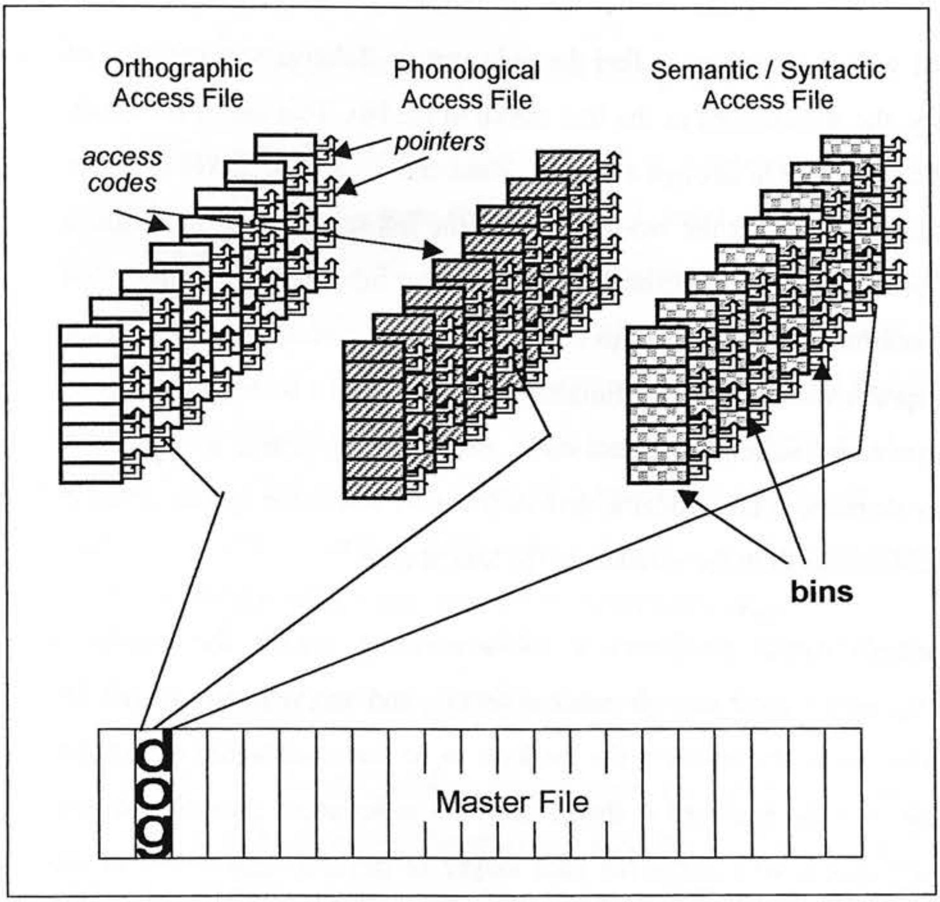

Figure 2.4. The Serial Search Model *(Adapted from Forster, 1976: 268). The master file contains entries for words, and the peripheral access files contain access codes –arranged in bins– and pointers to the corresponding entries in the master file.*

2.3.1.2. LEXICAL ACCESS

To access a word in the master file, users of a language start by accessing the corresponding entry in the appropriate access file –the orthographic access file in the case of visual word recognition. In the first instance, the stimulus is perceptually analysed and an access code is specified. The access code need not be the whole of the word; for example, for longer words, it could just be the first three or four letters or the first syllable. The access code allows a preliminary selection of lexical entries in the same bin, which are then contrasted with the stimulus to find the right match. Relative to a criterion of sufficiency, the search stops at the best match in the bin. This match is directly linked to the master file through a pointer. Thus, the master file makes available all the information about the word, including the full spelling. At this point, a detailed comparison between the sensory incoming information and the word entry is performed. Forster refers to this stage as a 'post-access check'. If there is an acceptable match, then the stimulus is recognised as a word; if there is no match, then a new searching process starts, back in the peripheral access file. A crucial assumption in this model is that information within the system flows in one direction only, from the stimulus to the lexical entry[15].

Forster's model postulates a self-terminating search for words – terminating after a good enough match is found– and an exhaustive search for nonnwords, i.e. all the words in the bin have to be searched before the system can decide that the nonword is absent from the selection of potential targets. This is the reason why nonwords take longer to process than words in the lexical decision task. Every searching attempt will, by definition, yield a mismatch after the detailed comparison of the stimulus with the entry in the master file, which triggers a new search in the corresponding access file.

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[15] As regards priming effects, the model postulates a cross-referencing system which would explain why, for example, it takes less time to access the word *doctor* in the lexicon, when it is preceded by a content-related word like *nurse* than when it is preceded by a content-unrelated word like *book* (Meyer & Schvaneveldt, 1971). This is explained in the model by the possibility of transferring between entries in the same file once the first word has been located. In an updated version of the Serial Search Model (Forster & Davis, 1984; Forster *et al.*, 1987), on presentation of a prime, the entries that are close matches to this prime are 'tagged'. When a target is presented that is orthographically related to that prime, shorter latencies are returned because the entry corresponding to the target has already been partially opened with the 'tagging'. So opening the target entry completely requires less time than if the target had not been partially opened (which is what happens when prime and target are not orthographically related).

2.3.2. THE ACTIVATION-VERIFICATION MODEL

The **Activation-Verification (AV) Model** is a hybrid model, which is based on principles of **activation, interaction** and **serial search**, and, as such, it shares many features with the models described so far. The original formulation of the Verification Model was made by Becker (1976, 1979, 1980), who principally worked on the effect of semantic context on word recognition. The activation-verification variant has been developed by Paap *et al.* (1982, 1999) and Paap, McDonald, Schvaneveldt and Noel (1987). It is called 'activation-verification' because there is an emphasis on the activation that occurs during the encoding stage, prior to the verification stage.

2.3.2.1. ASSUMPTIONS AND ARCHITECTURE

According to the AV model, visual word recognition follows three successive stages: **encoding**, **verification** and **decision**, as illustrated in Figure 2.5. The first stage in word recognition is **encoding**, which involves early activation of two types of units, letters and whole words. Units are stored in the memory in two separate systems, the **alphabetum**, for letters, and the **lexicon**, for words. Each letter in the alphabet is represented by a number of distinctive features. Following the analysis of a visual stimulus, the level of activation of every letter in the alphabetum is relative to the number of features matching those presented by the sensory buffer or perceptual memory. The degree of letter activation is calculated in this model with the aid of a **'matrix of confusion probabilities'**. In turn, activated position-specific letters activate a set of candidate words. The amount of activation in those word units results from the level of activation of each individual constituent letter.

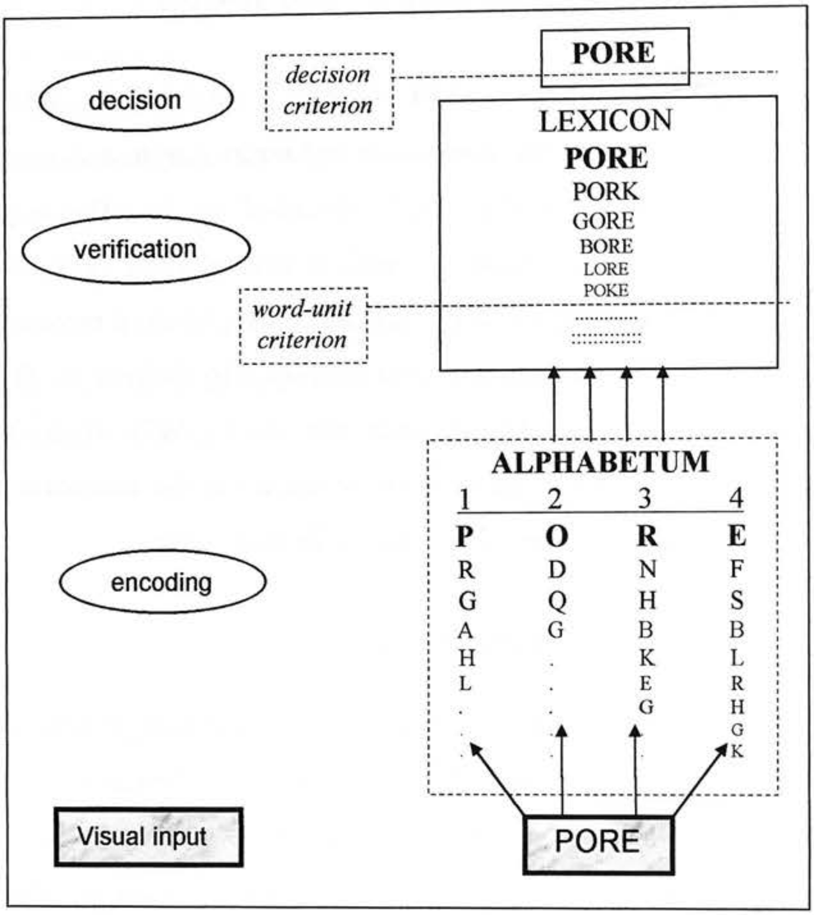

Figure 2.5. The Activation-Verification Model *(Adapted from Paap et al., 1982). Illustration of processing the English word 'pore'. Letters and words in the upper positions have higher levels of activation.*

2.3.2.2. LEXICAL ACCESS

The **verification** stage involves the matching of a particular word with the continuous perceptual analysis of the stimulus, as activation work in the alphabetum is constantly available to the lexicon. This verification is done by comparing the information about the letters of the word with the updated information of the activated letters in the alphabetum. Only the words that exceed a preset **word-unit criterion**[16] will be made available for the next stage, the **decision** stage. The nature of the candidate set is further defined by semantic context and word frequency, which affect the order in which candidates will be verified[17]. If the degree of similarity between the candidate word and the initial visual input exceeds a **decision criterion**[18], then verification will yield a match. If the decision criterion is not reached, verification results in a mismatch, the particular candidate is discarded and the next candidate will be checked. This part of the model, searching serially for the best fit, resembles the searching procedure described in Forster's (1976) Search Model. Also the **Checking Model** developed by Norris (1986) seems to share some features with the AV Model: both models incorporate a post-access mechanism, which takes account of the effect of context to fine-tune the levels of activation of the words selected in the lexicon.

In the example illustrated in Figure 2.5, the words *pore*, *pork*, *gore*, *bore*, *lore* and *poke* were activated in the lexicon because they all exceeded the word-unit criterion. However, *bore*, *pork*, *gore* and *lore* will be verified before the word *pore* because they are more frequent than *pore* (Kuçera & Francis, 1967)[19]. The other candidate also activated in the lexicon, the word *poke*, less

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[16] Words exceeding the preset word-unit criterion enter the subset of candidate words, at this stage ordered according to the geometric means resulting from the confusion probabilities (this is the order illustrated in Figure 2.5).

[17] A revised version of the AV Model (Paap *et al.*, 1999) introduces the possibility of adding noise to the encoding of letters and words. This allows for word frequency to be taken into account under experimental conditions where verification does not take place (for example in the Reicher task with a backward mask following the stimulus).

[18] The authors of the model stress that the word-unit criterion and the decision criterion are different things: the first one makes a particular word available for verification and it is based on alphabetic evidence, whereas the second one enables a decision based on lexical activity.

[19] Word frequency order taken from Mathey (2001).

frequent than *pore*, will not be verified because the process will have terminated after verification of *pore*.

The AV model is well suited to account for the recognition of nonwords, which follow the same recognition process as that of real words. The visual stimulus activates the relevant letters, and these in turn activate the relevant words ready for verification. In the case of nonwords, an exhaustive verification of all the candidates on the list takes place with the final result of mismatch. Only then is the processing system in a position to determine that the visual input provided from the stimulus is in fact a nonword, simply because no match was found in the lexicon.

2.4. CLOSING REMARKS

Jacobs & Grainger (1994) indicate that for a model to be good, it must have generability. They distinguish between horizontal generability and vertical generability. Horizontal generability is the capability that a particular model has to generalise across different kinds of stimuli, or different kinds of tasks, using different dependent variables and explaining as many word recognition effects as possible. Vertical generability is the capability of a model being successfully applied to different degrees of complexity in the recognition process; for example, at intermediate stages of processing as well as final stages, in lexicons with different number of entries, and in lexicons with entries belonging to more than one language.

Despite the relevance of computer modelling in psycholinguistic theory, computational models are not without problems, as Álvarez *et al.* (1999) have argued. First, these models can be 'too versatile', to the extent that they can sometimes account for two opposing effects. Second, they cannot be explained independently of their computerised implementation and can be very difficult to understand and assess in the absence of the simulation itself. Forster (1994) warns that, although computerised models can produce data in accordance with human responses, it is not always clear how they actually produce this outcome. He insists that more detailed accounts of how the network performs the tasks are needed because simulations still require explanations[20]. Jacobs and Grainger (1994) point out that a prevalent problem in many attempts at modelling language processing is that a number of models seem only to account for one particular effect, with a certain type of task and with only one dependent variable.

There is not, as yet, one single model that can accommodate the (sometimes) contradictory array of experimental data originated using different operational definitions, different techniques or different languages. As the next two chapters will point out, most models can explain the word frequency effect, but some have difficulties explaining the effects of neighbourhood. Many researches refer to the IA Model and the AV Model as theoretical backgrounds for their work on neighbourhood effects. However, there is no doubt that the principle of lateral inhibition makes the IA Model more suitable for accommodating lexical competition effects. These two models have also been extended as bilingual models of visual word recognition (Grainger, 1993; Grainger & Dijkstra, 1992) and they will be considered again later in this thesis.

The next chapter takes a brief look at experimental tasks used to explore lexical processing and gives a more detailed description of frequency effects.

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[20] For further arguments on the dangers of network modelling and for an excellent critique on the radical connectionist approach, see Forster's (1994) analysis.

Chapter 3
Effects of Word Frequency on Lexical Processing

3.1. OPENING REMARKS

New possibilities of almost reproducing the way the human brain operates, possibilities of mirroring real time language processing, with on-line techniques, have opened up new avenues of research, distinct from more traditional and less accurate measuring methods. This means that research methods in visual word recognition, as in many other fields of human perception, are becoming more objective, more sophisticated and more in search of the detail. They are developing in the direction of 'a view under the microscope'. This chapter starts with a brief look at the experimental tasks most widely used to study lexical effects. A discussion then follows of one of the best documented effects found in word recognition, the frequency effect.

3.2. EXPERIMENTAL TASKS

Psycholinguistic processes cannot be observed directly, so this makes it necessary for researchers to use indirect methods to provide a key to those processes. Perea and Rosa (1999) have recently reviewed experimental techniques used in visual word recognition of isolated words, and they point out that these tasks fall under one of three broad categories:

1. **Chronometric techniques**. The dependent variable measured with these techniques is the time subjects take between the stimulus presentation and the reaction to that stimulus. This is known as reaction time (RT)[1], and it is usually measured in milliseconds (ms). There are three major kinds of tasks where RT is measured:

    - **Categorisation tasks**. Participants have to decide, as quickly and as accurately as possible, if a stimulus belongs to a certain category. For example, 'is this letter string a word?' or, 'is this word an animal?' The lexical decision task (LDT), the most widely used experimental task in word recognition, is a categorisation task.

    - **Naming tasks**. Subjects have to pronounce as quickly as possible a visual stimulus presented on a screen. Here the measurement is the time taken between the presentation of the stimulus and the utterance of the first sound.

    - **Perceptual identification techniques**. The most common amongst these is the progressive demasking technique, where

[1] Accuracy of response (or error rates) can also be registered with these tasks.

subjects are instructed to react as soon as they are able to identify the stimulus, which is initially presented in a degraded form and then progressively presented more clearly.

2. **Reading measuring techniques**. These techniques register the eye movements and gaze durations that take place during text reading.

3. **Neurophysiological techniques**. This is a new generation of techniques that measure cerebral activity. The one used more frequently is evoked potentials, which are electric changes registered in the brain on the presentation of a stimulus.

The **lexical decision task** (LDT) is still the most commonly used task in visual word recognition. It was first developed by Rubenstein and his team (Rubenstein, Garfield & Millikan, 1970; Rubenstein *et al.*, 1971a, 1971b). In the lexical decision task, subjects are presented with letter strings on a computer screen. Typically, half the letter strings form real words in the subjects' language (e.g. *flag*, *lock* or *hunter*) and the other half form nonwords[2] (e.g. *flug*, *loock* and *thunter*) –they look like real words but they are not. Subjects are instructed to decide as quickly and accurately as possible if the letter string on the screen is a word or a nonword. Words and nonwords are presented at random. Normally, subjects must press the YES-button in a button-box with his or her dominant hand if they think the letter string is a

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[2] I use the general term 'nonword' to mean a string of letters that do not form a real word in a given language, with reference to no particular degree of word-likeness. Most authors use the term 'nonword' in this general sense. However, I am aware that some times it is pertinent to make a distinction between the terms 'pseudoword' and 'nonword' (Alvarez *et al.*, 1999): the former refers to letter strings that are orthographically legal and pronounceable but do not form real words; the latter, then, refers to letter strings that are not orthographically legal.

word, and the NO-button with the other hand if the letter string is not a word. RT in ms and error rates are automatically registered.

Not everybody accepts that the LDT is a suitable task to tap lexical access. Balota and Chumbley (1984) have claimed that the frequency effect may in fact arise at a post-access decision stage, and not in the course of lexical access *per se*. Following Balota and Chumbley's criticisms, other researchers have strongly argued in favour of the LDT (Monsell, Doyle & Haggard, 1989; Paap *et al.*, 1987). The fact remains that a large number of researchers have used this technique because it is thought to provide a good measure of lexical access, and because it is simple to implement. It is reasonable to assume that the only way to know if a letter string is a word or a nonword is to actually search in the mental lexicon (Taft, 1991).

3.3. THE INFLUENCE OF WORD FREQUENCY ON LEXICAL PROCESSING

3.3.1. WORD FREQUENCY EFFECTS

Word frequency is a central issue in visual word recognition. Research has shown that repeated encounters with stimuli make it easier for subjects to process those stimuli, and that the more encounters there are, the shorter subjects take to react to them. Additionally, shorter reaction times are generally accepted as reflecting faster processing. The maxim of body training, 'practice makes perfect', also applies in lexical processing. In visual word recognition 'practice' translates into the **word frequency effect**, confirmed by numerous studies: highly frequently encountered words are reacted to faster and more accurately than less frequent words (Andrews, 1989, 1992; McRae, Jared & Seidenberg, 1990). This translates into shorter responses for different kinds of tasks: shorter eye-movement durations, and shorter latencies in tasks involving lexical decision, word naming, perceptual identification or semantic categorisation. And as already indicated, shorter latencies are taken as a sign of faster lexical access.

Word frequency is perhaps the most robust of lexical effects. One of the earliest reports of this effect was made by Howes and Solomon (1951)[3], and it has consistently been reported ever since, using a wide range of experimental techniques: lexical decision (Burani, Marcolini & Stella, 2002; Forster & Chambers, 1973); naming (Balota & Chumbley, 1984); perceptual identification tasks (Broadbent, 1967); eye movements and eye fixation times (Inhoff & Rayner, 1986; Rayner & Duffy, 1986). Lexical frequency is of great interest to researchers of language processing because its effects are highly reliable, both at the level of comprehension and at the level of production. For example, it has been shown that the difficulty in comprehending a text is closely related to the frequency of the words within the text: the lower the frequency, the more difficult it is to understand the text (De Vega, Carreiras, Gutiérrez-Calvo & Alonso-Quecuty, 1990). Equally, it has been reported (Domínguez & Cuetos, 1992) that one of the main differences between good readers and poor readers among children lies in the difficulties that poor readers have with low frequency words. At the level of production, it is well documented that the tip-of-the-tongue phenomenon occurs mostly with low frequency words (Brown, 1991).

[3] Cited by Domínguez, Cuetos and Seguí (2000).

3.3.2. OTHER FREQUENCY EFFECTS

Some models of word recognition directly address the issue that words are not processed as indivisible units, but as complex structures of sensorial features that integrate into letters, which follow sophisticated rules to form syllables, which in turn make up morphemic units, and which eventually produce the almost 'magical moment of word recognition' (Balota, 1990). The sublexical units contained within the word account for the frequency effect not being a unitary effect. Researchers have focussed on two types of discrete sublexical units to base the effects of frequency on word recognition: the morphological unit and the syllabic unit.

The influence of frequency at the morphemic level has been extensively investigated (Taft, 1979a, 1979b, 1987, 1994; Taft & Forster, 1975, 1976; see also Baayen & Schreuder, 1999; Colé, Beauvillain & Segui, 1989; García-Albea, Sánchez-Casas & Igoa, 1998). The general finding is that the frequency of root morphemes plays a significant role in word recognition. However, the picture is far from simple (Rayner & Pollatsek, 1989). In their recent review on how morphemes and affixes are taken into account as processing units, Domínguez *et al.* (2000) examine results of studies contrasting 'stem frequency' (the cumulative frequency of all the words sharing a root morpheme) and 'surface frequency' (or straightforward word frequency), and conclude that the evidence is in many respects contradictory. For example, Sereno and Jongman (1997), after comparing the processing of English noun stimuli with varying inflectional structures, found that stem frequency contributed very little to response times, and that surface frequency still made a substantial contribution. Baayen, Dijkstra and Schreuder (1997), on the other hand, have made the claim that response times to words in their singular form are determined by stem frequency, and that response times to plural words[4] are determined by surface frequency.

The role of the syllable, and in particular the role of syllable frequency, in visual word recognition has posed 'considerable disagreement' (Balota, 1994). Some authors (Prinzmetal, Treiman & Rho, 1986; Rapp, 1992; Spoehr & Smith, 1973) have argued for a central role of the syllable, whereas other researchers (Jared & Seidenberg, 1990; Seidenberg, 1987) have questioned the relevance of syllable units. Seidenberg (1987) suggests that the orthographic redundancy that accompanies bigrams, specially high frequency bigrams, tends to break words into sublexical units more naturally than syllables[5]. In addition, there is not always total agreement as to where syllabic boundaries lie. This is particularly true in a language like English, where there is a lot of 'ambisyllabicity', that is, a phoneme or a letter can be ascribed to two different syllables (Treiman & Danis, 1988). In Spanish, however, there is virtually no cases of ambisyllabicity, and syllabic boundaries withstand stress-shift[6]. For these reasons, it has been suggested that syllable frequency may be a crucial aspect to access lexical representations in Spanish (Carreiras *et al.*, 1993). The relevance of this line of work is manifest in the considerable amount of research

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[4] In two separate studies about regular and irregular plurals of German nouns, (Clahsen, 1999; Sonnenstuhl & Huth, 2001) the researchers reached the conclusion that decision times for regular plurals did not seem to be affected by word frequency, whereas for irregular plurals there were significant differences between high and low frequency words.

[5] See Rapp (1992) for arguments against this conclusion.

[6] A case in point are the English words *post* and *postal*, where the *–t–* seems to belong in *pos–* in the first word, and in *–al* in the second word. Compare the Spanish translations *<u>po</u>ste* and *pos<u>tal</u>*. There is a stress shift (marked with underlining) from the first syllable in the first word to the second syllable in the second word, but the syllabic division remains at the same place, *pos–te* and *pos–tal*.

published, in the last decade alone, about the role of the syllable as a processing unit in Spanish[7].

3.3.3. THE LOCUS OF THE FREQUENCY EFFECT

An issue that is currently under discussion in connection with word frequency is the question regarding the locus of the frequency effect. Most studies up until fifteen years ago attributed the effects of word frequency to processes operating before or at the moment of word recognition, but more recent data suggests that there may be post-lexical access processes that affect, and perhaps exaggerate, the effect of word frequency (Balota, 1994).

These post-lexical access processes are closely connected to the nature of the experimental tasks. For example, in naming tasks, there may be post-access elements related to the generation and performance of the pronunciation output that are affected by word frequency (Andrews, 1997; Balota & Chumbley, 1985; Connine, Mullennix, Shernoff & Yelens, 1990). In addition, in lexical decision tasks, there may be decision components that enhance the influence of word frequency (Balota & Chumbley, 1984; Besner & McCann, 1987). In their widely cited paper on lexical decision task and frequency effects, Balota and Chumbley (1984) suggested that when subjects are required to differentiate quickly between words and nonwords, the effects of word frequency may be exaggerated as follows. Subjects use two kinds of information to discriminate words from nonwords, namely, familiarity and meaningfulness. Generally, words are more familiar and meaningful than nonwords. However, a very low

[7] Álvarez, Carreiras & De Vega, 1992, 2000; Álvarez, Carreiras & Taft, 2001; Álvarez, De Vega & Carreiras, 1998; Bradley, Sánchez-Casas & García-Albea, 1993; Carreiras & Perea, in press; Domínguez, Cuetos, & De Vega, 1993; Domínguez, *et al.*, 1997; Perea & Carreiras, 1998; Sebastián-Gallés, Dupoux, Seguí & Mehler, 1992.

frequency word like *ortodilian* may look less familiar and meaningful than a very word-like nonword such as *chummingly*[8]. This 'conflict' may put the subject in a position to having to do some extra checking activity –perhaps checking the spelling or the morphology of the word, or its pronunciation– and this checking is time consuming. As subjects are more likely to engage in extra checking for low frequency words, this would accentuate the effects of word frequency in lexical access.

3.3.4. WORD FREQUENCY COUNTS

Despite the seemingly uncontroversial results, the study of word frequency is not without problems. To start with, there is the methodological issue of defining how frequent is 'frequent'. Frequency is a relative concept: a word is more or less frequent than other words within a given corpus. The corpus, in turn, poses the question of 'frequent in what context'. A word can be very frequent in the spoken language, but relatively uncommon in the written language, or vice versa. The words *ta* and *commence* are two cases in point. So far, most frequency counts have been based on written language corpora. However, even if we limit ourselves to the printed word, variation can be enormous: words like *experiment* or *discourse* may be highly frequent in a particular context (e.g. in academic journals), but very uncommon in other contexts (e.g. in the popular press). Furthermore, once the relative frequency of a word has been established, the case is probably true that not all speakers are equally familiar with words of similar frequency.

[8] Examples taken from Balota (1994).

Despite their inadequacies, frequency counts are an indispensable tool for researchers in language processing[9]. There is no doubt that technology has made it easier for researchers to put word frequency counts together, both for the spoken language and for the written language. In English, a frequency count, still of reference, is Kuçera and Francis (1967), based on one and a half million words, although there are now more up-to-date databases (e.g. the CELEX Database, Baayen, Piepenbrock & Gulikers, 1995; and the MRC Psycholinguistic Database, Coltheart, 1981). In Spanish, up until relatively recently, there was only one frequency count, the one compiled by Juilland and Chang Rodríguez (1964). Now there are two more frequency counts[10], which are widely reported (Alameda & Cuetos, 1995; and Sebastián-Gallés, Martí, Cuetos & Carreiras, 1996).

Alameda and Cuetos' (1995) dictionary count was the one used to draw the Spanish items for the experiments reported in this thesis[11]. This dictionary presents enormous advantages over Juilland and Chang-Rodríguez's (1964):

- Alameda and Cuetos' dictionary is based on a corpus of two million words, taken from 606 different texts, including a wide range of genres. All texts were published less than 25 years ago (between 1978 and 1993) and were originally written in Spanish. Juilland and Chang-

[9] There are frequency dictionaries in many languages; for example, in French (Baudot, 1992; Content, Mousty & Radeau, 1990; Imbs, 1971) and Italian (Juilland & Traversa, 1973) to name just two.

[10] There are also word frequency counts for particular areas, like Spanish for medical purposes (Chandler-Burns, 1992).

[11] I am very grateful to the authors of this frequency count for providing me with an on-line version of the dictionary.

Rodríguez's corpus, on the other hand, is considerably smaller, using only half a million words, and it was written between 1920 and 1940[12].

- Crucially, Alameda and Cuetos provide a frequency count of **all** two million words in the corpus, from the base frequency 1 (0.5 occurrences per million –opm). In contrast, Juilland and Chang-Rodríguez's count only included words with a frequency of 5 upwards (10 opm). Clearly, the latter count is manifestly insufficient for the study of low or very low frequency words.

3.3.5. WORD FAMILIARITY

To address the issue that not all speakers of a language are equally familiar with words of similar frequency, the notion of **word familiarity** was introduced in word recognition. Word familiarity, often referred to as **experiential frequency**, is measured by asking subjects to make familiarity judgements using a scale. Familiarity and frequency can be considered two different sides of the same coin, that of encountering a particular word. Familiarity is a subjective measure, provided by the subjects themselves, whereas frequency is an objective measure, based on the likelihood of an encounter.

Connine *et al.* (1990) and Gernsbacher (1984) have used subjectively rated familiarity scales to calculate the frequency with which certain items have been encountered. In particular, Connine *et al.* (1990) have shown that word

[12] The frequency of certain lexical items can vary substantially over time. Because of social, cultural and scientific reasons, relatively frequent words today like *ordenador* or *vídeo* did not exist seventy years ago, and the frequency of words like *autonomía* and *alternativa* has changed considerably (Alameda and Cuetos' examples, 1995).

familiarity can significantly alter the effects of printed word frequency in lexical decision tasks. They also showed that, in a delayed pronunciation task, familiarity ratings were a good predictor of pronunciation performance when the effects of word frequency had faded. Gernsbacher (1984) has provided evidence that when words are matched on familiarity ratings, semantic effects of polysemy and concreteness of meaning vanish. In other words, certain lexical items are more (or less) familiar than frequency indexes may suggest.

The discrepancy between word familiarity and word frequency can significantly affect second language vocabulary processing. A study using Dutch and English bilingual speakers (Bijeljac-Babic, Biardeau & Grainger, 1997) has shown that proficient bilinguals were more susceptible than beginning bilinguals to the inhibitory influence of second language primes orthographically related to first language targets. The authors further found that the majority of their high frequency L2 primes were processed as low frequency L2 primes by their beginning bilinguals (i.e. no interference with L1 target recognition). This is because second language speakers have generally had less experience of L2 words, either through less exposure to the language, or through more restricted language learning contexts, or both. The consequence is that words that have been encountered fairly regularly by the average native speaker (high print frequency), could be very rare for the second language learner (low word familiarity).

In the same way as frequency counts have some limitations, familiarity ratings are not entirely satisfactory. It has been pointed out (Schwanenflugel, Harnishfeger & Stowe, 1988) that it is not entirely clear what sort of information subjects rely on to make their familiarity judgements. It may be possible that subjects bring in aspects like the extent to which they are able to provide a context for the word, or able to articulate a clear meaning for it. Taft (1991) argues that one of the problems with familiarity ratings is that subjects may base those judgements on aspects such as how long they feel it takes to recognise a word. So if words (whether concrete, abstract or polysemous) are matched for the (perceived) accessing times, it is hardly surprising that other semantic effects disappear. Taft (1991) concludes that results from experiments using familiarity rating must be interpreted more cautiously than those using word frequency indexes (for example, genuine effects of concreteness may be masked). Familiarity and frequency are clearly two different aspects but, as they correlate highly with each other, word frequency is perhaps a more reliable measure of how often a speaker has encountered a word.

3.3.6. MODELS OF WORD RECOGNITION AND WORD FREQUENCY

The way particular models of visual word recognition explain the word frequency effect is directly related to their basic metaphor: the activation metaphor or the search metaphor.

Activation models explain word frequency by suggesting that frequent words require less activation to be brought to a processing threshold. In the Logogen Model (Morton, 1969, 1970), a crucial property of logogens is that, when they have been fired, their threshold is lowered for some time relative to their original threshold value. Thus, the reason why high frequency words are faster to be recognised and more intelligible in noisy conditions than low frequency words, is that the former have higher resting activation levels than the latter, as a result of having been fired more often in the past[13]. Similarly, in the Interactive Activation Model (McClelland & Rumelhart, 1981), high

[13] According to Morton (1969, 1970), having lower threshold levels would be equivalent to the presence of contextual information, in that both factors reduce the amount of sensory input needed for a logogen to be activated above the threshold level.

frequency words are recognised faster because they enjoy higher resting levels of activation. The perceptual memory 'keeps track' of connections frequently established over time: the more often a node has been activated in the past, the readier it will be for subsequent activation. This is why, other conditions being equal, high frequency words need a smaller pulse of activation to be brought past their threshold level.

In the Parallel Distributed Processing Model (Seidenberg & McClelland, 1989), word frequency is measured in terms of error scores. Errors will be lower in the recognition of stimuli that have been processed more frequently by the network: there will be a smaller difference between the output activation pattern (across the orthographic units) and the veridical input pattern. This translates into faster reaction times. Lower frequency words, on the other hand, are recognised more slowly and less accurately because of their smaller effect on the network weightings.

Search models explain the frequency effect by assuming that the lexicon is organised as a function of frequency. Forster's (1976, 1979) Serial Search Model explains frequency effects by assuming that words within the bins are listed according to frequency, and that the search between the sensory input and the correct lexical entry proceeds in a serial manner, starting with the closest matching higher frequency entries and working down to the lower frequencies. High frequency words are identified more quickly by virtue of their order in the search set, they are searched before low frequency words[14]. The Activation Verification Model (Paap *et al.*, 1982) accounts for the frequency effects

[14] Word frequency within the peripheral access file is not necessarily the same across the peripheral access codes. For example, a word can be very frequent in the spoken language (and therefore have high frequency in the phonological access file), but very uncommon in the written language (and therefore have low frequency in the orthographic access file).

through the principle of serial verification: within the group of activated words in the lexicon, the first word to be verified is the one with the highest frequency, followed by the second most frequent, and so on. These successive verification cycles terminate when the word being verified matches the visual input.

3.4. CLOSING REMARKS

Any model of word recognition has to account for the fact that, even when a word is encountered in isolation, it is not processed independently of other words in the internal lexicon that look or sound very similar to the target word. This aspect is considered in the next chapter, where the concept of neighbourhood and the effects of orthographic neighbourhoods in visual word recognition are discussed.

Chapter 4
The Influence of Neighbourhood on Lexical Processing

4.1. OPENING REMARKS

Álvarez *et al.* (1999) have pointed out that studying words that look or sound similar (word neighbours) can serve two purposes. On the one hand, research on neighbourhood processing can provide relevant information about the organisation of the mental lexicon. On the other hand, it can help the researcher to put the different word recognition models to a test, as any acceptable model has to explain how the system selects the correct candidate so efficiently amongst a set of highly similar candidates.

This chapter explores different aspects concerning the notion of 'neighbourhood'. It begins with a discussion about the concept of lexical similarity and the methodological issues involved in the definition of 'neighbourhood'. The central part of the chapter examines experimental findings concerning two major neighbourhood effects, namely, neighbourhood size and neighbourhood frequency. The last part looks at how different models of visual word recognition accommodate the neighbourhood effects found in experimental research.

4.2. THE CONCEPT OF LEXICAL SIMILARITY

Current models of word recognition suggest that lexical processing of a word entails the activation of other words in the internal lexicon that are similar to the stimulus word. When we read words in isolation, i.e. away from a sentence or some other semantic context, there is a certain kind of context that is very difficult to avoid, namely the knowledge of other words, their form and meaning. In the specific case of form, the context of words that look or sound very similar to the initial word stimulus, plays an important role in lexical access. The mental representation of a given word appears to readily activate, at least to a certain degree, the mental representation of other words closely linked to the target[1]. This connection between similar words explains why, sometimes, a word is mistaken for another that looks very similar; for example *invert* for *invest*, in English, or *conservación* for *conversación*, in Spanish.

When discussing lexical similarity, the notion of 'neighbourhood' is often invoked to refer to a set of similar words. The first issue concerning the concept of neighbourhood is establishing when two words are neighbours of each other

[1] The first suggestions that similar words actually influence lexical processing were put forward by Havens and Foote (1963) and by Savin (1963) [Cited by Segui and Grainger, 1993]. Their preliminary findings suggested that this influence was of an interfering nature.

and when they are not. The most commonly accepted definition of neighbourhood was developed by Coltheart *et al.* (1977)[2]: a word's **neighbourhood** is the set of real words that can be generated by replacing one letter at a time in every position in that word. This measure is often known as **N**. Neighbourhoods can be phonological and orthographic. A phonological neighbour is any word resulting from replacing one phoneme at a time in every phoneme position of a spoken word. For example, the spoken versions of the words *lake*, *Mike* and *mail*, are phonological neighbours of *MAKE*. Conversely, an orthographic neighbour of a particular word is any real word that can be generated by replacing only one letter at a time while preserving letter positions in the initial word. For example, the words *pane, cane, line, late* and *land* are all orthographic neighbours of the word *LANE*[3], and the words *cable*, *fable* and *sable* make up the entire orthographic neighbourhood of the word *TABLE*. In Spanish, the words *viva, sida, viga, pida, viña, visa* and *veda* make up the complete orthographic neighbourhood for the word *VIDA* [life].

Coltheart *et al.*'s (1977) straightforward definition of 'neighbour' has been adopted by virtually every study on neighbourhood effects, not least because it is relatively easy to manipulate experimentally. This definition, however, makes strong assumptions about the organisation of the mental lexicon, which the researcher must be aware of, as they pose substantial limitations to the concept of lexical similarity. These assumptions have been pointed out by a number of authors (Alameda, 1996; Andrews, 1997; Perea & Gotor, 1994a, 1994b) and can be summarised as follows:

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[2] This neighbourhood measure was first suggested by Landauer and Streeter (1973).

[3] The complete neighbourhood of the word *LANE* is made up of the following words: *bane, cane, dane, fane, LANE, mane, pane, sane, vane, wane, line, lace, lake, lame, late,* and *land.*

- **Specific letter position**. This description of lexical similarity assumes that the lexicon is coded in terms of letter-position slots. This means that (by the N definition) words sharing the same letters as the target, but in a different letter position, like *stop* and *spot*, are not neighbours. This amounts to saying that they are not similar. However, Alameda (1996) has reported that Spanish words like *leal* [loyal] and *lela* [stupid] can actually interfere with each other because of their similarity.

- **Word length**. Only same-length words can be neighbours. This assumption cuts out the potential influence from words that only differ from the stimulus in the presence or absence of one letter; for example the English words *power* and *powder*, and the Spanish words *mundo* [world] and *mudo* [dumb]. Alameda and Cuetos (1997) have reported confusion of Spanish items that present this kind of similarity. Furthermore, using Dutch stimuli, De Moor and Brysbaert (2000) have shown that decision latencies were delayed for targets preceded by an orthographically related prime of different length; for example, when *slijk* [mud] was primed by *lijk* [corpse].

- **Equal weighting of neighbours**. The N metric assumes that all the neighbours have the same capacity to influence lexical processing (whether the influence is facilitative or inhibitory). However, there are studies which show that 'orthographic neighbours are not all equal' (Perea, 1998; Perea & Rosa, 1998)[4]. Perea and Gotor (1994b) showed that, for four-letter words, neighbours differing in the third letter were more difficult to discriminate than neighbours differing in the first letter.

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[4] Perea and Rosa (1998) have shown that targets that differ from the prime in the third letter (like *label* and *lapel*), or the fourth letter (like *frost* and *front*), are recognised more slowly.

More recently, Shillcock and Monaghan (2001) have made similar claims about the special nature of first and last letters, the exterior letters effect[5]. Furthermore, Ziegler and Perry (1998) have demonstrated that only orthographic neighbours that are also body neighbours (they share the same orthographic rime[6]) have a facilitatory effect on lexical processing.

The fact that the number of neighbours across letter positions is not uniform provides grounds for other concepts of lexical similarity. Andrews (1997) offers some revealing statistics about the distribution of 4-letter neighbours in English. In an analysis of 1895 four-letter words, she argues that a greater number of neighbours result from changing the first letter of the target word than from changing letters at each of the other three positions. Specifically, as many as 46% of the neighbours are first-letter neighbours, which shows that many orthographic neighbours are also body neighbours. Andrews (1997) suggests that facilitatory effects of N in English could be the result of the influence of body neighbours. Body-defined neighbours, therefore, are an interesting measure of lexical similarity in English, as they represent a special subset of orthographic neighbours relevant to lexical access. In a study about the role of English rimes in the acquisition of orthography, Treiman, Mullennix, Bijeljac-Babic and Richmond-Welty (1995) had reached a similar conclusion. They showed that orthographic rimes of monosyllabic words were

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[5] Many years ago, Havens and Foote (1963) pointed out that letters in initial and final positions played a more relevant role in word processing than letters in middle positions.

[6] In a monosyllabic word, the rime is the vowel and subsequent consonants that follow the initial consonant o consonant cluster of the word. For example, in the words *sip*, *slip*, and *strip*, *–ip* is the rime (Balota, 1994). Body neighbours are words that share orthographic neighbourhood as well as rime with the target. For example, in relation to the word *MAKE*, the words *lake*, and *take* are body neighbours, and the words *mate* and *male* are only orthographic neighbours.

more efficient in disambiguating vowel pronunciation than other sublexical units, such as morphemes or syllables, and consequently were functional units in word recognition.

Although the N metric strongly relies on the assumption that lexical representation is letter position based, there is no doubt that it provides a very useful operational definition of lexical similarity, as is shown by the fact that most studies on neighbourhood effects do use the N as defined by Coltheart *et al.* (1977).

4.3. DEFINING NEIGHBOURHOOD SIZE AND NEIGHBOURHOOD FREQUENCY

Two attributes of neighbourhoods are particularly relevant to word recognition, namely the number of neighbours and the frequency of the neighbours themselves. The effects that these two factors, size and frequency, have on lexical access are generally known as **neighbourhood effects**. More specifically, these effects are known as the 'neighbourhood size effect' and the 'neighbourhood frequency effect', respectively.

Neighbourhood size (also called neighbourhood density) is the total number of neighbours making up the neighbourhood of a particular word. This variable is relatively simple to manipulate. Depending on how many levels are required for experimental purposes, neighbourhoods can be:

- **Large neighbourhoods**. Typically these are defined as having more than 8 neighbours. Examples are the neighbourhoods of the English word *tall* (17 neighbours) and the Spanish word *puro* [pure] (14 neighbours)[7].

- **Medium-sized neighbourhoods**. These have between 6 and 8 neighbours; for example, the neighbourhood of the English word *play* (8 neighbours) and the Spanish word *alto* [high] (7 neighbours)[8].

- **Small neighbourhoods**. These typically have fewer than 6 neighbours. Illustrations of words with small neighbourhoods are the English word *such* (3 neighbours), and the Spanish word *bien* [well] (3 neighbours)[9].

- There are also '**hermit**' words (Segui & Grainger, 1992), or words with 'no neighbours'; for example the English words *twist* and *clerk*, and the Spanish words *azul* [blue] and *diez* [ten].

One methodological question to bear in mind when manipulating neighbourhood size is what to do with the neighbours that appear to have a frequency of 0 occurrences per million (opm)[10]; whether to accept them as

[7] These are the complete neighbourhoods of the examples, ordered by word frequency. For *TALL: tell, call, wall, talk, hall, fall, ball, TALL, till, tail, tale, toll, gall, pall, mall, talc, tael* and *taal*. For *PURO: pero, pudo, puso, pura, PURO, duro, muro, paro, juro, puño, poro, puri, puto, euro,* and *pufo.*

[8] The complete neighbourhoods are as follows. For *PLAY: plan, PLAY, clay, pray, slay, ploy, plat* and *flay*. For *ALTO: algo, ALTO, alta, acto, auto, apto, almo* and *albo.*

[9] The complete neighbourhood of these words are as follows. For *SUCH: SUCH, much, suck* and *ouch*. For *BIEN: BIEN, buen, cien* and *sien.*

[10] A word with a frequency of 0 opm does not mean that the word is never found in the corpus. For example, three occurrences in a corpus of twenty million words may be returned by the computer with a frequency of 0 opm, when in fact the real frequency is 0.15 opm.

equally valid members of the target word's neighbourhood or not. In a good number of cases, some of these items are really obscure words, unknown to the average speaker[11]. If they are unknown, albeit real words, they can hardly influence lexical processing[12]. Several trimming techniques can be applied to shape neighbourhoods to a more realistic membership[13]. Alternatively, the researcher can decide that no trimming technique should be applied. This is not a trivial question, as applying one trimming method or another can cause certain words to be assigned to a different N category. Of course, the trimming method used, if any, also affects the overall statistics of the experimental stimuli, like average neighbourhood size and average neighbourhood frequency.

For the purpose of the neighbourhoods used in the experiments of this thesis, the following trimming technique was applied, both for the English and the Spanish neighbourhoods. When the computer database (MRC for English, and Alameda, 1996, for Spanish) returned a neighbourhood with more than one word exhibiting an opm of 0, it was decided that the experimental size of the neighbourhood would include all the words that showed an opm of 1 or more, plus only the first of the 0-opm words. So for example, in the case of the word *huge* (54 opm), only the words *hugh* (9 opm), *luge* (0 opm), were counted towards the experimental size of the neighbourhood; the words *hure* (0 opm),

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[11] In this connection, Paap, Johansen, Chun & Vonnahme (2000) have reported that in one of their experiments 'a substantial proportion of words with a frequency of occurrence in the range of 1-5 per million have accessibility problems when presented out of context' (p.1711).

[12] A case in point is the neighbourhood of the word *huge* (54 opm), made up by *hugh* (9 opm), *luge* (0 opm), *hure* (0 opm), *huke* (0 opm), *hugy* (0 opm), *hugs* (0 opm), *euge* (0 opm) and *auge* (0 opm).

[13] For example, the researcher can decide to include in the neighbourhood only words with a word frequency of at least 1 opm, and trim the rest out. He or she can decide to include one or two, or more, words with 0 opm, or he or she can decide to include all the neighbours returned by the computer, i.e. not to apply any trimming method.

huke (0 opm), *hugy* (0 opm), *hugs* (0 opm), *euge* (0 opm) and *auge* (0 opm) were not included.

The second major attribute of neighbourhoods, **Neighbourhood frequency** (or neighbour frequency), refers to the frequency of the neighbours. It is often shortened to **NF**. Manipulating and controlling NF is more complex and poses more problems than manipulating N. The simplest operational definition of neighbourhood frequency uses the division of targets into 'leaders' and 'nonleaders'.

- A **neighbourhood frequency leader** (NF Leader) is a word that has no higher frequency neighbours. A Spanish example of an NF leader is the word *aire*[14] [air].
- A **neighbourhood frequency nonleader** (NF Nonleader) is a word with one or more higher frequency neighbours. A Spanish example of an NF nonleader is the word *alto*[15] [high].

Leader and nonleader will be terms used throughout the description of the experiments of this thesis.

Other ways of manipulating NF are needed to study whether the effect of NF is cumulative; that is, if the effect of having more than one higher frequency neighbour is stronger than having only one (Grainger, 1990; Grainger *et al.*, 1989; Grainger & Jacobs, 1996; Mathey & Zagar, 2000). Thus, in order to know how 'strong' an NF leader is, or how 'weak' an NF nonleader is, we need

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[14] The neighbourhood of the word *aire* is a follows: *AIRE* (a frequency of 288 opm), *abre* (46.5), *mire* (29.5), *tire* (3.5), *acre* (3) and *gire* (0.5).

[15] *Alto*'s neighbourhood is made up by the following neighbours: *algo* (984.5 opm), *ALTO* (202), *alta* (153), *acto* (106.5), *auto* (28.5), *apto* (6.5), *almo* (0.5) and *albo* (0.5).

to know not only the number of higher and lower frequency neighbours but also their frequencies relative to that of the neighbourhood. This can be measured in different ways.

- **By *n* times the mean frequency of the neighbourhood**. This measure refers to the number of times that a NF leader exceeds the average frequency of the neighbourhood[16]. A disadvantage of this method is that in large neighbourhoods, there can be a trail of very low frequency neighbours (sometimes very obscure words) that bring the mean frequency down considerably, and therefore can disproportionally 'inflate' *n*.

- **By proportion of total neighbourhood frequency.** Another way of measuring leadership strength is considering what proportion of the total neighbourhood frequency is occupied by the leader alone[17]. This method may yield a more accurate picture of leadership strength, as it is less sensitive to the number of 'dummy' words in the neighbourhood.

- **By number of higher or lower frequency neighbours**[18]. This method is easier to articulate than the two previous ones, and it is the one most commonly used by researchers.

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[16] For example, the Spanish word *tres* [three] is a high frequency word (553 opm) that is also the most common word in its neighbourhood (5 neighbours). The total frequency of the neighbourhood is 1,098, and the mean is 183. The frequency of the word *tres* is exactly 6 times that of the mean NF.

[17] Using the proportional method with the example *tres* would give the word a 0.505 proportion of the total frequency.

[18] For example, the Spanish word *tres* has 0 higher frequency neighbours and 5 lower frequency neighbours.

It is thus clear that a systematic manipulation of NF can pose some methodological problems (Pollatsek, Perea & Binder, 1999).

A third parameter of neighbourhoods has recently been introduced and tested by Johnson and Pugh (1994), and Pugh, Rexer, Peter and Katz (1994). This parameter is 'neighbourhood distribution' (P), which is the number of letter positions that can yield orthographic neighbours (1 to 4 in a four-letter word)[19]. Pugh and his colleagues concluded that the degree of interference posed by other neighbours directly depended on the number of letter positions at which there is at least one neighbour. N correlates directly with P: the higher the number of neighbours, the higher the number of different letter positions at which the neighbours differ. However, the notion of P is by no means redundant. P refines the concept of N and provides an operational definition to test the 'neighbours are not all equal' hypothesis. A recent study examining the effects of neighbourhood distribution and neighbourhood frequency (Mathey & Zagar, 2000) showed that the inhibitory nature of higher frequency neighbours does not depend on their number, but on whether those neighbours share the same neighbourhood distribution or not. More precisely, Mathey and Zagar (2000) found that words with two higher frequency neighbours were more difficult to recognise when those neighbours were neighbours of each other (twin neighbours) than when they were not (single neighbours)[20].

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[19] The neighbourhood of the Spanish word *fiel* [loyal] allows neighbours in two letter positions (e.g. *piel* and *fuel*). The neighbourhood of the word *misa* [mass] allows neighbours in three positions (e.g. *risa, masa* and *mina*). The neighbourhood of the word *suma* [sum] allows neighbours in all four positions (e.g. *fuma, sima, suya* and *sumo*).

[20] French examples of 'single' and 'twin' neighbours (taken from Mathey & Zagar, 2000), are as follows. *Franc* and *blanc* are 'single' higher frequency neighbours of *flanc* because they do not share a neighbourhood relationship (they are not neighbours of each other). *Ferme* and *forme* are 'twin' higher frequency neighbours of *firme* because they share a neighbourhood relationship (they are neighbours of each other as well as neighbours of *firme*).

In the last few years a number of databases, elaborated on the basis of neighbourhood parameters have been put together for major European languages. For Spanish, in particular, there are at least three such databases (Alameda, 1996; Alameda & Cuetos, 1995; Perea, 1993), which shows how much interest the issue of neighbourhood effects has generated amongst Spanish psycholinguists.

4.4. NEIGHBOURHOOD SIZE AND NEIGHBOURHOOD FREQUENCY: CONFLICT OF INTERESTS?

As already stated, there is little controversy about the fact that orthographic neighbours do influence visual word recognition. The controversial question is whether the influence of those neighbours improves recognition of the target, or makes it more difficult. In 1989 two papers were published which offered apparently conflicting evidence on neighbourhood effects (Andrews, 1989; and Grainger *et al.*, 1989). Using lexical decision and naming tasks, Andrews (1989) found a significant facilitatory effect of neighbourhood size. In the LDT, words with large N exhibited shorter reaction times. This effect of N interacted with word frequency in that the facilitation was significant only for low frequency words and disappeared with high frequency words. In the naming task, the effect was present in both high and low frequency words, although it was also stronger for words of low frequency. Grainger *et al.* (1989), on the other hand, reported that the aspect that was determinant in lexical performance was not neighbourhood size but neighbour frequency. In particular, they found a clear inhibitory effect in the recognition of words with at least one higher frequency neighbour. The authors concluded that

Andrews' (1989) facilitatory effects could be due not to N as such but to a concomitant factor of N, namely bigram frequency[21].

To address the issue of bigram frequency, Andrews (1992) carried out fresh experiments in which she manipulated neighbourhood size and bigram frequency independently. Her results were very similar to those of her earlier work. When bigram frequency was kept constant for large and small N, large N was facilitatory of lexical access. Conversely, manipulating bigram frequency had no effects on word recognition, when N was kept constant. She thus concluded that the facilitatory effect of N was due to lexical similarity and not to orthographic redundancy (or bigram frequency). Meanwhile, Grainger and colleagues obtained further inhibitory results of neighbourhood frequency (Grainger, 1990; Grainger & Segui, 1990; Grainger *et al.*, 1992), using not only lexical decision tasks, but also eye movements and latencies in perceptual identification tasks.

The conflicting aspect of these findings lay not only in the fact that Grainger and his team of researchers had consistently failed to replicate Andrews' facilitatory effects of N but, crucially, in the opposing nature of the two effects: facilitatory for neighbourhood size and inhibitory for neighbourhood frequency. These distinctive effects entail a contradiction, in as much as words belonging to large neighbourhoods (facilitatory effect) are more likely to have higher frequency neighbours (inhibitory effect). That is to say, the total number of neighbours is generally a function of the number of higher

[21] A bigram is any two-letter sequence in a word. For example, in the word *seat*, the bigrams are *se*, *ea* and *at*. Grainger *et al.*'s (1989) argument about bigram frequency was that Andrews' (1989) facilitatory effects of N might not be due to similarity at lexical level, but to similarity at orthographic level. This means that words that are part of a large neighbourhood exhibit higher degrees of orthographic redundancy than words that belong to a small neighbourhood. Bigram frequency is one way to measure this orthographic redundancy.

frequency neighbours. Several studies support this view. Frauenfelder, Baayen, Hellwig and Schereuder (1993) found a positive correlation between the number of neighbours and the average frequency of those neighbours. More recently, Andrews (1997) offered an analysis of frequency and neighbourhood structure of four, five and six letter words in English. Her 'data confirmed the expected relationship between neighbourhood size and neighbourhood frequency: words with more neighbours are more likely to have high-frequency neighbours' (Andrews, 1997: 443). This evidence poses a 'conflict of interests' between N and NF: how can a word be processed faster because of a large neighbourhood and, at the same time, more slowly because of higher frequency neighbours?

Furthermore, Andrews (1997) and Mathey (2001), in their review articles, have pointed out that orthographic neighbourhood effects depend not only on neighbourhood indexes, but also on the nature of the particular experimental tasks and, very importantly, on the language used in the experiments. Andrews (1997) concludes that 'the conflict in the existing evidence is more apparent than real' (Andrews, 1997: 439). She argues that the contradictory results are due to differences in the methodology of the experiments and not so much to aspects inherent to neighbourhood effects.

Many other researchers have investigated neighbourhood effects; their results will be dealt with in the next section. The general picture in not a simple one. Evidence is in some respects contradictory and therefore the paradox about the effects of N and NF remains largely unresolved.

4.5. NEIGHBOURHOOD EFFECTS: MORE EXPERIMENTAL DATA

Coltheart *et al.* (1977) were among the first authors to analyse the influence of neighbourhood size on processing English words. Using a lexical decision task, they found no significant effect of N for words and an inhibitory effect for nonwords. A lot of research on neighbourhood effects has been done since.

After the publication of the two papers by Andrews (1989) and Grainger *et al.* (1989), more than thirty pieces of research have focussed on neighbourhood effects. These include two major review articles (Andrews, 1997; Mathey, 2001), two other less ambitious reviews (Perea & Rosa, 2000; Segui & Grainger, 1993) and several doctoral theses (Alameda, 1996; Mathey, 1997; Perea, 1993; Voice, 1995). Generally, results of these publications suggest that neighbourhood effects play a significant role in lexical processing, and that the key issue is the nature of that role. One problem in comparing results from studies where different experimental techniques were used, is that it is sometimes difficult to assess what effects are task specific and what effects are truly due to the influence of the variables under study. The lexical decision task is the technique that has been used most widely in the study of neighbourhood effects, but it is, at the same time, the task that has conveyed the most contradictory evidence (Grainger & Jacobs, 1996).

In their comprehensive review articles, Andrews (1997) and Mathey (2001) show that the general finding concerning neighbourhood size is that the effect is facilitative, at least for the English language. As explained earlier, Andrews' (1989, 1992) LDT experiments showed that words from large N were responded to more quickly than words from small N. She also found that this effect was sensitive to word frequency: the facilitatory effects were only observed for low frequency words. She suggested that Coltheart *et al.*'s (1977) null effects of N could be explained because the authors had combined high and low frequency words. Facilitatory effects of N, in LDT and other tasks, have been found by many other researchers (Bozon & Carbonnel, 1996; Carreiras *et al.*, 1997, Experiment 3; Forster & Shen, 1996; Huntsman & Lima, 2002; Johnson & Pugh, 1994; Pollatsek, *et al.*, 1999; Sears, Hino & Lupker, 1995; Sears, Hino & Lupker, 1999a; Sears, Lupker & Hino, 1999b). As noted before, Grainger *et al.* (1989) failed to replicate Andrews' (1989) facilitatory effects of N[22]. Similar null effects of N in LDT have also been reported by other researchers (Carreiras *et al.*, 1997, Experiment 2; Coltheart *et al.*, 1977; Grainger & Jacobs, 1996; Mathey & Zagar, 1996; Paap & Johansen, 1994; and Ziegler & Perry, 1998). To add complexity to the picture of neighbourhood size effects, two recent studies carried out by Lavidor and Ellis (2001a, 2001b) have tested and confirmed the hypothesis that the nature of N effects depends on which side of the brain the stimulus word is processed[23].

Sears *et al.*, (1995) carried out a comprehensive study to assess the claims made by Andrews (1989, 1992) and by Grainger and his colleagues (Grainger *et al.*, 1989; Grainger, 1990; Grainger & Segui, 1990; Grainger *et al.*, 1992). Sears *et al.* (1995) set up six experiments in which word frequency, neighbourhood size and neighbourhood frequency were systematically and

[22] However, Grainger, Carreiras & Perea (2000) have recently found facilitatory effects of N for low frequency words using a new paradigm, the luminance increment paradigm.

[23] Using the LDT, Lavidor and Ellis (2001a, 2001b) have investigated the effects of N on the hemispheres. The studies showed facilitation effects of large N (both when the target had many neighbours and when the target and the prime shared many neighbours). These effects, however, were only found when items were presented in the left visual field (i.e. right hemisphere), but not in the right visual filed (left hemisphere). The authors' explanation of these findings is that, in the right hemisphere, semantic coding is coarser than in the left hemisphere. As a result, more detailed orthographic processing takes place in the right hemisphere than in the left hemisphere, where words progress more rapidly from orthography to semantics.

meticulously varied. Their results clearly backed up those of Andrews' (1989, 1992), indicating that neighbourhood size had a facilitatory effect on lexical processing of low frequency words. Words with many neighbours were processed faster than words with few neighbours. On the other hand, Sears *et al.* (1995) were unable to replicate Grainger *et al.*'s (1989) results that neighbourhood frequency was a determinant factor in delaying lexical processing. In addition, using a semantic categorisation task, Sears *et al.* (1999b) found further evidence that words with large N were reacted to faster than words with small N. Sears and colleagues, though, found no effect of neighbourhood frequency.

Experimental results of neighbourhood frequency are, for the most part inhibitory (Carreiras *et al.*, 1997; Grainger, 1990; Grainger *et al.*, 1989; Grainger *et al.*, 1992; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Huntsman & Lima, 1996; Paap & Johansen, 1994; Perea & Pollatsek, 1998; and Zagar & Mathey, 2000). However, there are some reports of null effects, or even facilitatory effects (Huntsman & Lima, 2002; Sears *et al.*, 1995, 1999a, 1999b).

Some researchers have pointed out that neighbourhood size and neighbourhood frequency are different but related effects operating simultaneously. Perea and Algarabel (1992)[24] showed the simultaneous operation of both effects (a facilitatory effect of N and an inhibitory effect of NF) and concluded that the factors allowing for the predominance of one effect over the other are not straightforward. This has led to a number of experiments that have explored the relationship between N and NF. Studies in which the number of higher frequency neighbours was kept constant, found facilitatory

[24] Paper cited by Mathey, 2001.

effects of N (Carreiras *et al.*, 1997; Forster & Shen, 1996; Perea, 1993; Sears *et al.*, 1995). This finding implies that it is the number of lower frequency neighbours, not the overall N, that is facilitative (Paap & Johansen, 1994; Pollatsek *et al.*, 1999). This was exactly Pollatsek *et al.*'s (1999) suggestion about Andrews' (1989, 1992) facilitatory effects of N: the effects might have been caused by a larger number of lower frequency neighbours. This finding of a cumulative (facilitatory) effect of lower frequency neighbours stands in contrast with the non-cumulative (inhibitory) effect of higher frequency neighbours found by Grainger *et al.* (1989), who showed that increasing the number of higher frequency neighbours did not significantly increase lexical decision latencies.

Forster and Shen (1996) explored the relationship between N and NF in a semantic categorisation task. Using English stimuli from a LDT, that had yielded facilitatory effects of N, they reported that the facilitatory effects disappeared in favour of an interaction between N and NF, such that having only one higher frequency neighbour was significantly inhibitory when there was only one neighbour. This inhibitory effect disappeared in the presence of 2 neighbours, and the effect turned facilitatory in the context of 3 or 4 neighbours. With Spanish stimuli, Carreiras *et al.* (1997) also found a significant interaction effect between N and NF in semantic categorisation, but in the opposite direction to that of Forster and Shen (1996). Carreiras *et al.* (1997) found that having a higher frequency neighbour was inhibitory in the context of large neighbourhoods. These results show that, if there is an interaction between N and NF, the nature of this interaction is not a simple one. In any case, as regards the effects of neighbourhood effects in semantic categorisation tasks, Andrews (1997) suggests that results in these tasks may reflect processes specific to the task more than processes specifically related to lexical access.

Perceptual identification tasks have been also widely used to explore neighbourhood effects. In fact, a number of studies have been reported where the same stimuli were used in a series of different tasks, including perceptual identification. Thus, for example, Grainger and Segui (1990) found inhibitory effects of N and NF in French, effects that have been replicated in Spanish and English (Grainger & Jacobs, 1996; Carreiras *et al.* 1997; Snodgrass & Mintzer, 1993; Ziegler, Rey & Jacobs, 1998). Snodgrass and Mintzer (1993) used the same low frequency words that had yielded facilitatory effects of N in Andrews' (1989) LDT and naming experiments. The facilitatory effect of N appeared when subjects were given more than one chance to guess the right words. However, when subjects were given only one chance to respond, the effects of N became inhibitory. Snodgrass and Mintzer (1993), along with Grainger *et al.* (1989), concluded that the effect of higher frequency neighbours is essentially inhibitory, but that the exact nature of the effect depends on whether the subjects are given the chance to discard their initial lexical hypotheses, based on high frequency neighbours.

In perceptual identification tasks where subjects could only give one response, there seems to be unitary inhibitory effects of N. Bozon and Carbonnel (1996), very much like Snodgrass and Mintzer (1993), observed inhibitory effects for N in the perceptual identification task with stimuli that had yielded facilitatory N effects in lexical decision. These finding stress how specific the influence of the experimental task can be on the results.

Grainger and Segui (1990) suggested that the perceptual identification task is particularly sensitive to neighbourhood effects because of the guessing element involved. Forster and Shen (1996), for their part, considered this guessing element (or hypothesis generation) as a weakness of the task, because it makes higher frequency neighbours exert an exaggerated influence: they suggest that in a degraded perceptive context the higher frequency neighbour imposes itself over the potential candidates. However, it could be argued that it is precisely the element of uncertainty in perceptual identification tasks that makes them particularly appropriate for the study of neighbourhood effects, as the absence of a distinct target gives more room for the potential candidates to 'come forward'[25].

The evidence obtained with speed identification tasks where subjects can make several attempts at the target, is so far inconclusive. On the one hand, N was to found to be inhibitory in perceptual identification tasks with progressive demasking (Alameda & Cuetos, 1997; Van Heuven *et al.*, 1998; Van Heuven, Dijkstra, Grainger & Schriefers, 2001). Using a LDT with masked primes, Van Heuven *et al.* (2001) examined how a prime, which shared some neighbours with the target, influenced the recognition of that target. They found smaller priming effects from primes that shared at least one neighbour with the target than from primes that did not share any neighbours. In contrast to this, some recent results indicate that N could be facilitative in other speeded identification tasks (Grainger *et al.*, 2000; and Sears *et al.*, 1999b).

Findings in naming tasks are more unitary than those obtained with other tasks. Generally, effects of N and NF are facilitatory across languages (English, French, Spanish and Dutch). Facilitatory effects of N have been reported by Andrews (1989, 1992), Carreiras *et al.* (1997), Grainger (1990), Peereman and Content (1995), and Sears *et al.* (1995), and facilitatory effects of NF have been obtained by Grainger (1990) and Sears *et al.* (1995). Facilitatory effects

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[25] Hinton, Liversedge and Underwood (1998) conducted two experiments to test Forster and Shen's (1996) hypothesis generation, using ambiguous and unambiguous trigrams (any three-letter sequence in a word). They found a robust ambiguity effect (longer latencies to ambiguous trigrams) with targets that were NF leaders. Since the target was already the most frequent candidate, this effect could not be attributed to the participant generating incorrect hypotheses about the target (Forster and Shen's explanation).

have also been observed for nonwords (Laxon, Masterson, Pool & Keating, 1992; McCann & Besner, 1987; Peereman & Content, 1995). Andrews (1997) suggests that the facilitatory effects obtained with naming tasks could be the result of phonological processes, and not just the result of lexical access processes.

All the evidence discussed so far refers to stimulus words presented in isolation, which is a task far removed from the ordinary task of reading. It is therefore of great interest to examine the results yielded by studies that manipulated neighbourhood variables in the context of the much more natural task of reading. Two recent studies have analysed effects of N and NF using eye movements, gaze durations and back checking procedures in reading (Perea & Pollatsek, 1998; and Pollatsek *et al.*, 1999). Pollatsek and his colleagues found facilitatory effects of N in a LDT, but these effects turned inhibitory when the items used in the LDT were embedded in sentences for silent reading[26]. Their results suggested that the number of higher frequency neighbours was inhibitory in silent reading. The results of this task, a more 'ecological'[27] (natural) task than the LDT, lend support to the claim that the inhibitory effects of NF are robust and more reliable than the facilitatory effects of N.

In conclusion, there seem to be two lines of argument as regards neighbourhood effects. One viewpoint, mainly represented by Andrews (1989, 1992, 1997), supports the claim that the effects of N are facilitatory, and that the effects of NF can be facilitatory or inhibitory, depending of the task. The

[26] The finding that normal reading tasks yield results opposite to LDT, could possibly undermine the validity of LDT for the study of word recognition.

[27] This is the term used by the authors themselves (Pollatsek *et al.*, 1999).

other position, mostly represented by Grainger and his colleagues (Carreiras *et al.*,1997; Grainger, 1990; Grainger *et al.*, 1989; Grainger *et al.*, 1992; Grainger *et al.*, 2000; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Segui & Grainger, 1993) maintain that the determinant factor in visual word recognition is NF, which is inhibitory in nature, and that the influence of N is not entirely convincing. The two positions seem difficult to reconcile. For the most recent comprehensive account of the controversy see Mathey (2001).

4.6. NEIGHBOURHOOD EFFECTS ON NONWORDS

In clear contrast with findings for words, virtually all studies report inhibitory effects of N for nonwords, not only in English but also in other languages (Andrews, 1989, 1992; Bozon & Carbonnel, 1996; Carreiras *et al.*, 1997; Coltheart *et al.* 1977; Grainger & Jacobs, 1996; Johnson & Pugh, 1994; Mathey & Zagar, 2000; Paap & Johansen, 1994; and Ziegler & Perry, 1998). This is hardly surprising: a nonword that has many neighbours shows a high level of lexicality, so rejecting a nonword that looks very much like a real word, requires a checking procedure that takes time and delays decisions.

One factor influencing the nature of N effects on words in the LDT is the context created by the nonwords, in particular by their degree of word-likeness (Johnson & Pugh, 1994). On the one hand, a context of nonwords with many neighbours has an inhibitory effect in the recognition of words because of the time needed to discard the potential competitors. On the other hand, a context of nonwords with few neighbours has facilitatory effects in the discrimination of words: a large N is indicative of lexicality (the item is more likely to be a real word), and therefore the lexical decision is made on the strength of the size of N. There is no need to search the potential competitors thoroughly, and the lexical decision is speeded up. This view is also supported by other researchers

(Mathey & Zagar, 1996). However, Grainger and Jacobs (1996) have suggested that the sensitivity of N and NF to the context created by nonwords is less clear in French than in English.

Forster and Shen (1996) and Sears *et al.* (1995) found facilitatory effects of N for real words in lexical decisions experiments where the nonwords had large N. These results run contrary to the view that neighbourhood effects on words are essentially of an inhibitory nature, and that facilitatory effects of N for words are due to nonword contexts. Very recently, Siakaluk, Sears and Lupker (2002) have similarly found facilitatory effects of N and NF with nonwords. They conclude that the influence of inhibition in English orthographic processing is overemphasised by models like the Multiple Read-Out Model (Grainger & Jacobs, 1996).

4.7. NEIGHBOURHOOD EFFECTS IN OTHER LANGUAGES

Andrews (1997) has pointed out that facilitatory effects of N have generally been reported in studies using English stimuli, and that studies reporting inhibitory or null effects of N have almost all been conducted in languages other than English, most notably French and Spanish. For this reason, she has suggested that the experimental language may be at the root of the conflicting evidence for N.

Ziegler and his colleagues (Ziegler & Perry, 1998; Ziegler *et al.*, 2001), specifically tested this hypothesis, namely, that the facilitatory effects of Large N may be peculiar to English. In the earlier study, their assumption was that N effects were facilitatory in English because, in this language, many orthographic neighbours are also 'body neighbours', that is, they share the same orthographic rime. For example *take, lake, sake, wake, cake, bake, rake, fake* are all body neighbours of *make*. The authors conducted an experiment where they controlled the number of neighbours (N) as well as the number of body neighbours (BN). Their results could not be more revealing: when words were matched for N, the number of BN was significantly facilitative. However, when the number of BN was kept constant, increasing N did not have any beneficial effects on lexical processing (if anything, the effect was detrimental). In the later study, Ziegler *et al.* (2001) tested the hypothesis that larger units (like bodies and rimes) play a significant role in reading languages with inconsistent orthography (e.g. English), and that in languages with more consistent orthography (e.g. German) smaller units (graphemes and phonemes) are preferred by readers. The results of their study confirmed the hypothesis[28]. Ziegler and his colleagues concluded that it was the prominent role of body neighbours in English, and the absence of such a role in languages like German, French or Spanish, that may account for the different effects of N across languages.

Thus the special role of body neighbours in English lexical processing could account for the observed facilitative effects of N. By contrast, experiments done with Spanish and French have yielded null effects of N for the most part. Both these languages have much higher levels of spelling-to-sound correspondences than English, 'so there may be little need for the reader to develop sensitivity to relationships higher than the grapheme-phoneme level to determine the mapping from orthography to phonology' (Andrews, 1997: 458). In English, rime units help readers to establish the not-so-obvious connections

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[28] Ziegler *et al.* (2001) tested native speakers of English and native speakers of German reading identical words in their respective languages; for example, zoo/Zoo, sand/Sand. Their results confirmed that the BN effect was stronger in English than in German. In other words, identical items are processed in a different way by readers of languages with different orthographies. BN had facilitatory effects in English, even when the effects of N had been partialled out.

between the phonological system and a highly idiosyncratic writing system (Treiman *et al.*, 1995).

The pronunciation of nonwords is an interesting case of the strategies that speakers follow to apply the perceived consistencies of the language. Research has shown that, whereas in English the pronunciation of nonwords with many body neighbours (like *tain*) is helped by words having many neighbours (Treiman, Goswami & Bruck, 1990), the pronunciation of French words seems less influenced by body neighbours and more influenced by syllabic parsing strategies (Patterson & Morton, 1985; Taft & Radeau, 1995). Similarly, there are reports showing that rime units are not as relevant in French as they are in English, because they do not help to disambiguate the pronunciation of unknown words or nonwords in the same way as body units do in English (Peereman & Content, 1997).

Spelling-to-sound correspondences are highly predictable in Spanish, even more than in French, and particularly in English (Goswami, Gombert & Fraca de Barrera, 1998). In Spanish, the relevance of syllables is similar to the relevance of body neighbours in English, and their salient role in Spanish processing has already been highlighted in this thesis. A significant number of recent publications have stressed that syllables play a far more important role in lexical processing than do body neighbours, and that the influence of syllable neighbours[29] tends to be inhibitory rather than facilitative (Álvarez *et al.*, 2000; Álvarez *et al.*, 2001; Domínguez *et al.*, 1997; Perea & Carreiras, 1998). Facilitative effects of N in English serve to the development of orthography-to-phonology mapping. In Spanish, syllabic neighbours do not have to conspire in

[29] Examples of syllable neighbours of the Spanish word *casa* [house] are the words *pesa*, *losa* and *risa*.

this way. On the contrary, they compete with each other. Working with Spanish stimuli, Perea and Carreiras (1998) have shown inhibitory effects of syllabic neighbours when the number of orthographic neighbours was controlled.

In conclusion, if facilitatory effects of N in languages like English are triggered by the presence of body neighbours, then it is hardly surprising that, in languages where body neighbours do not play such a salient role, these effects are not found.

4.8. MODELS OF WORD RECOGNITION AND NEIGHBOURHOOD EFFECTS

Neighbourhood effects are central to the evaluation of current models of visual word recognition. In this section we move from empirical grounds to theoretical grounds to examine how the different models of monolingual recognition, described in Chapter 2, accommodate experimental data on the effects of neighbourhoods.

Models based on the activation metaphor, like the Logogen Model (Morton, 1979a; Morton & Patterson, 1980) and the Interactive Activation Model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; see also Grainger & Jacobs, 1996), have problems explaining facilitatory effects of neighbourhood size, since they predict exactly the opposite effect. In the Logogen Model, a word with a larger N simultaneously activates a large number of logogens. This, in turn, increases the sum of activity over the system and proportionally lowers the activation ratio of the target logogen. A lower ratio means lower probability of a correct response. This leads to the conclusion that a large N will have a detrimental effect on visual word recognition. The Interactive Activation (IA) Model also predicts an inhibitory effect of neighbourhood size as a result of lateral inhibition operating between nodes of the same level. This translates into more inhibitory messages when a word has a large N. The messages that a word can receive from other words can only be inhibitory messages: 'connections between the word level are mutually inhibitory, since only one word can occur at any place at any one time' (McClelland & Rumelhart, 1981: 379). However, Andrews (1989, 1992) suggests that the IA Model can explain facilitatory effects of neighbourhood size through the mechanism of reverberation. She argues that a set of letters making up a word with many neighbour words will, in the first instance, activate those word nodes as well as the target. These word nodes, in turn, will generate a great deal of positive feedback towards the letters that are consistent with the visual input; that is, they generate a great deal of reverberation (or echoing of positive feedback). This way, more excitatory activation will be channelled towards the appropriate letter nodes, and thus enhance rapid recognition.

It can be argued that this mechanism of reverberation could be at play, to explain the facilitatory effects from body neighbours found by Ziegler and Perry (1998) and Ziegler *et al.* (2001). Taft (1991), however, had previously suggested that reverberation would not be enough to explain facilitatory effects of any neighbours, body neighbours or otherwise, because the principle of lateral inhibition between words would still impede any facilitation within the same level of nodes (in this case, word nodes). He thus argued for a level of body representations, in the context of activation models, to accommodate facilitatory results of N.

The IA Model also predicts inhibitory effects of neighbourhood frequency. Not only is the target more inhibited by a larger number of higher frequency neighbours but, crucially, by how frequent those neighbours are relative to the target. As explained earlier, words inhibit each other through the principle of lateral inhibition, and the inhibiting power of a node is a direct reflection of its level of activation. It has also been shown that high frequency words are more easily activated because of higher resting activation levels. It therefore follows that if a word node has neighbours of higher frequency, these neighbours will send stronger inhibiting messages to the word –because of their higher activation– than if they are of a frequency lower than that of the target word. This leads to two further predictions about NF. The first is that inhibitory effects of higher frequency neighbours are cumulative: the larger the number of higher frequency neighbours, the larger the strength of inhibitory messages received by the target. The second prediction refers to no effects of NF from lower frequency neighbours, because the inhibition messages are not strong enough to affect the target significantly. As we have seen, these predictions are not substantiated by experimental data. It is true, however, that interactive models are in a better position to explain facilitatory effects of lower frequency neighbours (Paap & Johansen, 1994; and Pollatsek *et al.*, 1999) than are verification models. The interactive models can account for those facilitative effects through the mechanism of reverberation.

The authors of the Parallel Distributed Processing (PDP) Model (Seidenberg & McClelland, 1989) reported an exact replication of Andrews' (1989) facilitatory results of neighbourhood size. In computer simulations of this model, the size of a word's neighbourhood interacted with word frequency: as the frequency of a word decreased, the facilitatory effects of N increased. This is presumably due to the similarity of activation patterns of the word's neighbours. However, it is not altogether clear why neighbourhood size should interact with word frequency. Furthermore, PDP models do not incorporate any competition or inhibition mechanism in their assumptions, and every pattern of activation is argued to happen as a result of training over time.

Models based on the searching metaphor, like Forster's Serial Search Model (Forster, 1976, 1989, 1992; Forster & Davis, 1984; Forster *et al.*, 1987;

O'Connor & Forster, 1981) and the Activation Verification (AV) Model (Paap *et al.*, 1982, 1987, 1999) have considerable problems explaining any neighbourhood size effects, as the search through the set of candidates is only done by straight word frequency. In particular, the models cannot account for the facilitatory effects of neighbourhood size reported by Andrews (1989, 1992, 1997) and Sears *et al.* (1995). According to the models, the number of neighbours activated in the lexicon and ready for verification do not, *per se,* influence word recognition. Interference can only be exercised by neighbours which are more frequent.

The AV Model strongly predicts that neighbourhood frequency should have an inhibitory effect on lexical processing: recognition of the target word will be influenced not by all the activated words in the lexicon but, crucially, by those words which are more frequent, as they will be verified before the target. The AV Model also predicts a cumulative effect of NF: a larger number of higher frequency neighbours will inevitably delay lexical decision because more candidates have to be verified before the target. There is, however, some evidence showing that the inhibitory effects of higher frequency neighbours are not cumulative (Grainger *et al.*, 1989) and that lower frequency neighbours can have facilitatory effects (Paap & Johansen, 1994; and Pollatsek *et al.*, 1999). The AV Model cannot account for these latter effects.

Also, the AV Model is not able to account for the facilitatory effects of body neighbours, because there is no provision in these models for any specific weighting of any subset of orthographic neighbours. In these models, all neighbours are equal except for word frequency. For the models to be sensitive to body neighbours, they would have to give up their strong letter-position-based concept of neighbour, or make this concept more flexible.

The proponents of the AV Model argue that semantic context, as well as word frequency, affects levels of word activation and the nature of the candidate set. That is, words from the set that are context-related will be checked before words that are not. It is not very clear, however, how and at what stage the criteria of word frequency and context are combined to determine exactly the resulting order of the candidate verification procedure. This drawback is amplified by the assumption that information only flows upwards, from feature and letter levels to word levels, but not downwards from higher levels to lower levels. As it will be seen in the next chapter, general context, including the context of the language a particular word belongs to, is an important factor in lexical processing.

4.9. CLOSING REMARKS

The evidence shows that both neighbourhood size and neighbourhood frequency play a role in lexical processing. The data indicates that word recognition models that incorporate mechanisms allowing for lexical competition as well as lexical facilitation (like the interactive models), seem to accommodate experimental data more satisfactorily.

The main focus of this thesis is the nature of neighbourhood effects in bilingual processing. Two of the models discussed in monolingual visual word recognition (the IA Model and the AV Model) have also been adapted as models for bilingual research on neighbourhood effects. This is the subject of the next chapter.

Chapter 5

Models of Bilingual Visual Word Recognition

5.1. OPENING REMARKS

Any model of lexical processing must account for the fact that when we read words, our processing system must retrieve different kinds of information, very quickly and very efficiently, from the vastness of the mental lexicon. When the reader has not one but two languages, the lexical selection process seems to work just as efficiently, and practically as quickly. Subjects are largely unaware of how lexical decision happens, but this does not diminish the complexity of the process.

Recent work on bilingual lexical representation has gone beyond the traditional controversy about whether there is one or two lexical memory systems, and is more concerned with the nature of the connections between the lexical representations of words in the two languages and with the factors that enhance or restrict those connections. Contemporary models of bilingual memory implement two levels of representation: a level for the form of the word, or lexical representation; and a level for the meaning of the word, which relates to higher processing levels, like conceptual representation and general knowledge of the world (Potter, So, Von Eckardt & Feldman, 1984; Kroll & Sholl, 1992; Kroll, 1993). The key issues are now reformulated as 'lexical' *vs* 'semantic' representations.

This chapter analyses how three models of bilingual word recognition, the Revised Hierarchical Model, the Bilingual Activation Verification (BAV) Model and the Bilingual Interactive Activation (BIA) Model, hypothesise the representation of lexical knowledge in the bilingual's two languages.

5.2. THE REVISED HIERARCHICAL MODEL

The **Revised Hierarchical Model** of bilingual representation (Kroll, 1993; Kroll & Sholl, 1992; Kroll & Stewart, 1994) is based on the hierarchical hypotheses of word association and concept mediation, first put forward and tested by Potter *et al.* (1984). The model is hierarchical because it distinguishes two different levels of representation: the level of the words and the level of the concepts.

The **word association** hypothesis assumes that words in the second language access concepts in the semantic memory via the words (translation) in the native language. The **concept mediation** hypothesis assumes that words in the second language (L2) are directly connected to the conceptual representation, very much like words in the first language (L1). Potter *et al.* (1984) conducted extensive research with bilingual speakers of different degrees of proficiency, using different experimental tasks (word translation and picture naming), and found evidence in support of both hypotheses. Later research has shown that it is the less fluent bilinguals who are more likely to perform translation tasks according to the word association hypothesis (Chen & Leung, 1989; Kroll & Curley, 1988), and that the performance of more fluent bilinguals seems to operate according to the concept mediation hypothesis. These findings indicated that there is a shift in how meaning is accessed from the second language: learners initially access the meaning of the L2 words by association with L1 words; it is at a later stage, when learners become more fluent, that they access meaning directly from the L2 word.

5.2.1. ARCHITECTURE AND BILINGUAL LEXICAL ACCESS

One of the consequences of the initial dependence on the first language, to access meaning for second language words, is an asymmetry in the strength of lexical-to-conceptual connections between the two languages (Kroll & De Groot, 1997). Experimental evidence showing this asymmetry in bilingual processing (Kroll, 1993; Kroll & Sholl, 1992) led Kroll and Stewart (1994) to propose a Revised Hierarchical Model, whose principal peculiarity is an asymmetry in the connections between L1 and L2 (see Figure 5.1). On the one hand, conceptual links are stronger for L1 words and relatively weak for L2 words, because, by the time the second language learner starts acquiring the L2 words, there is already a firmly established relationship between L1 words and concepts. So L1 is initially the natural path to access meaning, and later retains that privileged access. On the other hand, lexical links are stronger from L2 to L1 because L2 initially relies quite heavily on L1 for access to meaning. The proponents of the model assume that both kinds of connections, lexical and conceptual (and their asymmetries), remain at very high levels of L2 competence, even when the learner is proficient enough to be able to access concepts directly.

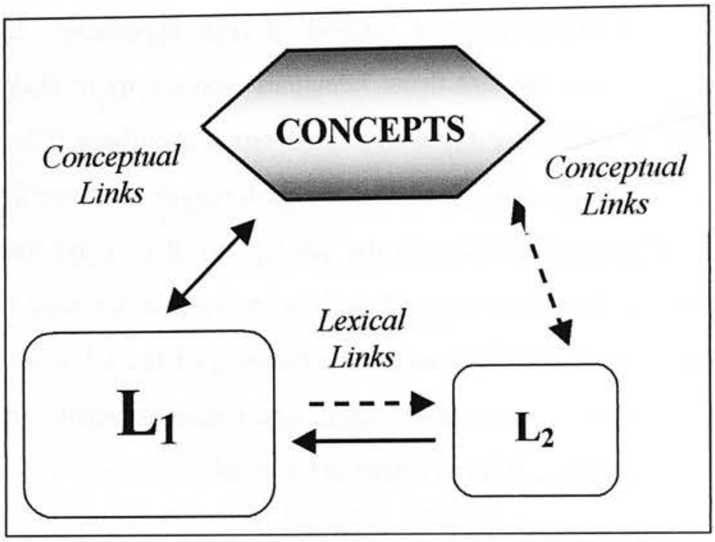

Figure 5.1. The Revised Hierarchical Model *(Adapted from Kroll & Stewart, 1994). Words in each language are connected to concepts (conceptual links) and to words in the other language (lexical links). Solid lines represent stronger connections, and broken lines represent weaker connections.*

The difference sizes in the lexicons represented in Figure 5.1 indicate that the lexicon of L1 contains more words than the lexicon of L2 and more information about those words.

5.2.2. EXPERIMENTAL DATA

The Revised Hierarchical Model makes predictions about translation and about semantic priming, which are central to the experimental hypotheses of this thesis. As regards translation, the model predicts asymmetrical translation from, and to, the native language. In particular, the prediction states that translation from L1 to L2 (L1→L2) takes longer and is less accurate than translation from L2 to L1 (L2→L1). As L1 words are biased towards concepts, L1→L2 translation is more likely to engage conceptual processing (a more circuitous route to L2 words) than L2→L1 translation. L2→L1 translation is faster because L2 words are biased towards L1 words through stronger lexical links. In addition, lexical links are less sensitive to semantic factors. Evidence from earlier studies gave support to these claims about the asymmetrical translation, with results showing that L1→L2 translation was indeed slower and more influenced by semantic context (De Groot, Dannenburg & Van Hell, 1994; Keatly & De Gelder, 1992; Keatly, Spinks & De Gelder, 1994; Sánchez-Casas, Davis & García-Albea, 1992).

The proponents of the model (Kroll & Stewart, 1994) tested the predicted translation asymmetry with Dutch and English bilinguals, using words that could be in random lists or in lists semantically categorised[1]. Not only did they find that L2→L1 translation was faster and more accurate, they also found that L2→L1 translation was not affect by semantic context in the same the way as L1→L2. Furthermore, Sholl, Sankaranarayanan and Kroll (1995) tested the hypothesis that L1→L2 translation, and not L2→L1, would give results similar to picture naming, a task that requires conceptual mediation. Their results showed that L1→L2 translation was sensitive to a previous picture-naming task, something that did not happen in L2→L1 translation[2]. Furthermore, the

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[1] Example of a categorised list in English: *dress*, *suit*, *shoes*, *coat*, *jacket*, *boots*, *sweater*, *gloves*. Example of a random list: *orange*, *lion*, *ambulance*, *lemon*, *skates*, *grapes*, *bicycle*, *raft*. Examples are taken from Kroll and Stewart (1994).

[2] However, a study conducted by La Heij, Hooglander, Kerling and Van Der Velden (1996) failed to replicate the translation asymmetry between L1 and L2, predicted by the Revised Hierarchical Model. La Heij *et al.* (1996) tested a group of highly proficient Dutch-English bilinguals (very similar to the bilinguals tested by Kroll and Stewart, 1994) and found that translation in **both** directions was affected by semantic factors. It has been argued (Kroll & Tokowicz, 2001) that La Heij *et al.*'s results are not damaging for the model because the model was specifically developed for out-of-context single word translation, and La Heij *et al.*'s translation task provided some semantic context (in the form of a picture), almost equivalent to the semantic context of normal language use. In any case, La Heij *et al.*'s (1996) results could possibly undermine the model's prediction that L2→L1 translation is solely lexical (Sánchez-Casas, 1999).

predicted translation asymmetry has also been obtained in languages with different scripts, like English and Chinese (Cheung & Chen, 1998).

In relation to priming, the Revised Hierarchical Model similarly predicts asymmetrical effects across first and second language. Because of their bias to concepts, L1 words are more likely to activate their meanings, and therefore they will be more effective primes than L2 words. As a result, stronger priming effects should be observed from L1→L2 than L2→L1. More precisely, effects of semantic priming across languages should parallel those of translation[3]. Experimental data has generally confirmed these predictions by showing that significant priming results are only obtained in the L1→L2 direction[4] or, if they are obtained for both directions, L1→L2 priming effects are greater (Altarriba, 1992; Chen & Ng, 1989; Frenck & Pynte, 1987; Keatly *et al.*, 1994; Schwanenflugel & Rey, 1986; Tzelgov & Eben-Ezra, 1992). These effects have been also found in translation priming experiments with languages of different scripts, for example Hebrew and English (Golland, Forster & Frost, 1997) and Chinese and English (Forster & Jiang, 2001; Jiang & Forster, 2001).

Kroll and De Groot (1997) interpret these asymmetrical cross-linguistic priming results (both semantic and translation) to the effect that more information is made available to the speaker with an L1 prime than with an L2 prime. In addition, an L1 word is recognised more rapidly than an L2 word.

[3] Conversely, it has been argued (Forster & Jiang, 2001) that the Revised Hierarchical Model would anticipate exactly the opposite effects: larger semantic translation priming effects in the L2→L1 direction, because of the stronger lexical links between L2 words with L1 words.

[4] Some of the results supporting the priming predictions of the Revised Hierarchical Model, however, only occurred under certain conditions. For example, Keatly and De Gelder (1992) obtained cross-language priming only for translation equivalents, not for cross-language associative pairs; and De Groot and Nas (1991) obtained semantic priming results only with translation equivalents that were cognates (lexical items that share both form and meaning).

Therefore an L1 prime will be more effective as a prime and less likely to be influenced as a target.

The Revised Hierarchical Model mostly addresses the issue of the routes to the concepts in the bilingual lexical memory, but it does not address the issue of the nature of those lexical representations. This is done by models like the **Conceptual Feature Model** (De Groot, 1992a, 1992b, 1993; De Groot *et al.*, 1994; Kroll & De Groot, 1997), but this model falls outside the scope of this discussion, because its does not relate to the experimental work presented in this thesis. The next section examines two models that explain how lexical access takes place in the bilingual's two languages, at least in early (orthographic) stages of lexical processing. These models are the BAV Model and the BIA Model.

5.3. THE BIA AND THE BAV MODELS

Grainger and Dijkstra (1992) argue that, in bilingual lexical processing, performance in one language is affected by lexical representations of the other language when they share some characteristics with the stimulus word. This influence can be observed even when the task does not involve the other language in any obvious way. This happens, the authors suggest, because the two lexicons always remain active, at least to a certain degree. In connection with this 'non-selective access'[5] to the bilingual lexicon, Grainger (Grainger & Dijkstra, 1992; Grainger, 1993) offers an account of how two current models of monolingual visual word recognition, the Activation Verification Model and the

[5] As Bijeljac-Babic *et al.* (1997) point out, a long-standing controversy in bilingual literature is one about whether the representation of translation equivalents in bilingual memory is interdependent (i.e. language selective) or independent (i.e. language non-selective).

Interactive Activation Model, can be extended to explain 'interlanguage interference' in bilingual processing. These extensions are called the BAV (Bilingual Activation Verification) Model and the BIA (Bilingual Interactive Activation) Model, although, the authors suggest, they are better thought of as theoretical frameworks than as specific models as such[6].

5.3.1 ARCHITECTURE AND BILINGUAL LEXICAL ACCESS

Both the BAV Model and the BIA Model use the activation metaphor to indicate that the sensory input, received by the perceptual system, activates a set of lexical candidates which share letters in the same position as the letters of the target.

The BAV Model (see Figure 5.2) assumes that orthographic information progressing to the encoding stage activates lexical representations, in both languages, that are consistent with the letter positions specified by the stimulus. It is later, at the verification and decision stages, that language context guides the search to the most likely lexicon. Within each lexicon, activated candidates are ordered by word frequency, with higher frequency words being searched before lower frequency words. If an acceptable match is not found in the search of the first lexicon, the search continues within the second lexicon.

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[6] For a detail account of the Interactive Activation Model and the Activation Verification Model see sections 2.2.2 and 2.3.2. of Chapter 2, respectively.

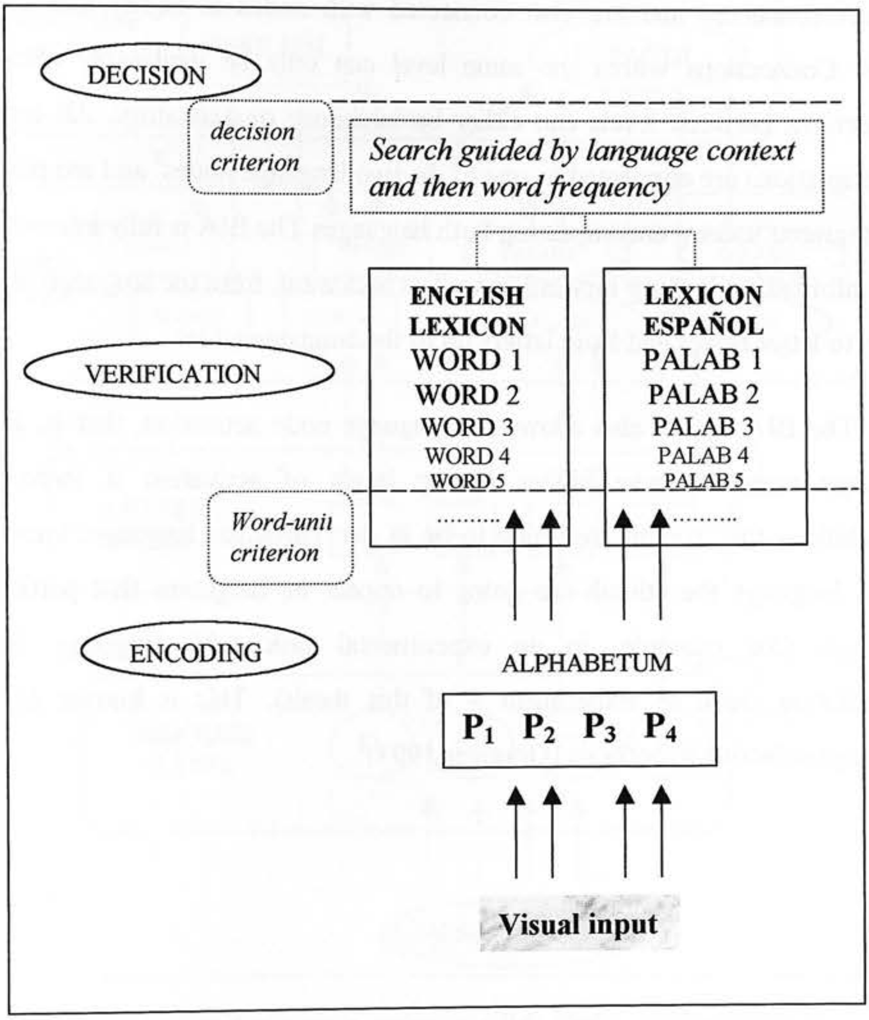

Figure 5.2. The Bilingual Activation Verification (BAV) Model *(Adapted from Grainger, 1993). The final candidate is selected according to language context and then word frequency.*

A verbal account of the BIA Model was first offered by Grainger (Grainger & Dijkstra, 1992; Grainger, 1993). This account has later been implemented by Dijkstra and Van Heuven (1998) as a computer model. Relative to the architecture of the basic model, the BIA Model has an extra level of representation containing two language nodes (see Figure 5.3). Beyond the feature level, the BIA Model has three fundamental levels of representation:

letter nodes, word nodes and language nodes. All the nodes at the same level are interconnected and are also connected with nodes at higher and lower levels. Connections within the same level can only be inhibitory, whereas connections between levels can either be inhibitory or excitatory. All lexical representations are connected to one of the two language nodes[7] and are part of an integrated lexicon encompassing both languages The BIA is fully interactive, with information flowing forward as well as backward, from the language nodes down to letter nodes and from letters up to the language nodes.

The BIA Model also allows for language node activation, that is, for a language node to have higher resting levels of activation if there are expectations that stimuli are going to be in that particular language: knowing which language the stimuli are going to appear in, heightens that particular language (for example, in an experimental task with language block presentation, such as Experiment 4 of this thesis). This is known as the language-selective hypothesis (Grainger 1993)[8].

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[7] Interlingual homographs would be the only word nodes connected to both language nodes.

[8] The language-selective hypothesis (Grainger 1993) is the equivalent of the 'input switch' hypothesis (Macnamara, 1967; Macnamara & Kushnir, 1971). The input switch hypothesis explains that, when subjects know which language the input is going to be in, they 'prepare' themselves and direct the input to the appropriate lexicon.

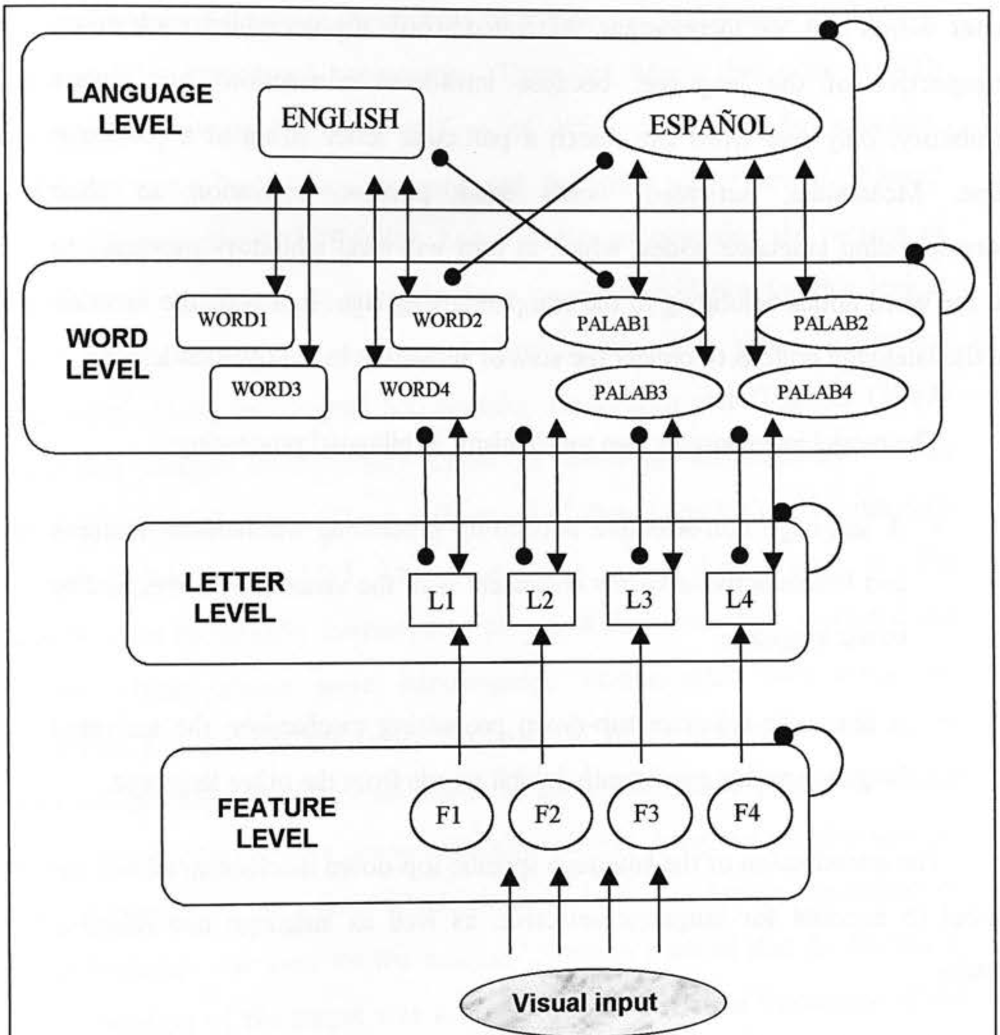

Figure 5.3. The Bilingual Interactive Activation (BIA) Model *(Adapted from Van Heuven et al., 1998). There is an integrated lexicon for both languages, and a representation level for 'language'. Excitatory connections are represented by lines ending in an arrow, and inhibitory connections by lines ending in a knob.*

When the perceptual system is presented with a string of letters (the visual input), the feature nodes representing the features contained in the input, are activated. The activated feature nodes activate the corresponding letter nodes for the relevant letter positions, while they inhibit the letter nodes not relevant to the letter position. Activated letters in turn activate words in both languages, with which the activated letters are consistent, and they inhibit the letter words that are inconsistent. Activated words always inhibit each other, irrespective of the language, because intra-level connections are always inhibitory: only one word can match a particular letter string at a particular time. Meanwhile, activated words send positive activation to their corresponding language nodes, which in turn will send inhibitory messages to all the word nodes belonging to the competing language. In a way, the function of the language node is to collect the sum of activation in the relevant lexicon.

The model incorporates two mechanisms in bilingual processing:

- A language non-selective bottom-up processing mechanism: features and letters activate words consistent with the visual input, irrespective of the language.
- A language selective top-down processing mechanism: the activated language nodes consistently inhibit words from the other language.

The introduction of the language specific top-down mechanism allows the model to account for language selective, as well as language non-selective results.

5.3.2. EXPERIMENTAL DATA

5.3.2.1. INTERFERENCE DATA

There is a large body of work in support of the hypothesis that the initial access to the orthographic representations of words, in the bilingual's two lexicons, is non-selective. This evidence mainly comes from experiments which have used different forms of 'interference between languages' paradigms.

An interesting case in connection with bilingual interference is the one represented by interlingual homographs. These are words that exist in both languages with exactly the same spelling but different meaning. For example, the English words 'red', 'once', 'quince' and 'fin' mean 'net', 'eleven', 'fifteen' and 'end' (respectively) in Spanish. Some studies investigating the pattern of activation of interlingual homographs have provided evidence for this lexical access in a non-selective manner, at least in the early stages of lexical processing[9]. Using interlingual homographs, Beauvillain and Grainger (1987) found that bilingual speakers may access the non-target language, even when they are instructed not to. These authors asked their French-English bilinguals to react to targets in a LDT. The targets were preceded by primes, but the subjects were specifically instructed to disregard the words that preceded the targets. These primes were interlanguage homographs: they could be interpreted as words in the target language (in which case prime and target were semantically related) or as words in the non-target language (in which case, prime and target were not semantically related). A crucial variable was the word frequency of the prime, which could be higher or lower, depending on which language was used for the reading[10]. Results showed that facilitation in the recognition of the target was a function of the relative frequency of the meaning of the prime in each language. In other words, there was less facilitation when the meaning of the prime was of higher frequency in the non-target language (as a result of the non-target reading being activated). One

[9] Studies on monolingual homographs (Simpson & Burguess, 1985) like *bow* or *read*, have yielded similar patterns: there is early activation for both interpretations of the letter string, which is a function of word frequency. The context then fine-tunes the activation in favour of the most likely interpretation.

[10] For example, in the pair *coin-MONEY* (*coin* means 'corner' in French), *coin* is more frequent in French than in English. In the pair *bride-GROOM* (*bride* means 'bridle' in French), *bride* is less frequent in French than in English. Examples taken from Beauvillain and Grainger (1987).

implication of these results is that subjects can involuntarily activate lexical representations in the non-target lexicon, even in the presence of a bias of language context. These results have been interpreted as strong evidence in favour of language non-selective hypothesis.

A study that seemed to contradict Beauvillain and Grainger's (1987) results, was conducted by Gerard and Scarborough (1989). These authors tested Spanish-English bilingual subjects with cross-language homographs (like *red*, *once*, and *quince*) in monolingual LDTs (either English or Spanish). They found that reaction times were a function of the printed frequency of the item in the target language in which the LDT was being performed (with no interference of the non-target language). In other words, homographs were reacted to faster when they were high frequency in the language of the LDT, and more slowly when they were low frequency in the language of the LDT, regardless of printed frequency in the non-target language. The authors took these results as support for a language selective access to the bilingual lexicon. However, Bijeljac-Babic *et al.* (1997) have suggested that these results only indicate that the subjects correctly accessed the meaning of the item in the target language. Nevertheless these results do not exclude the possibility that the meaning in the other language was also accessed (except that this was irrelevant for the particular experimental task).

Two separate studies done with Dutch-English interlingual homographs (De Groot, Delmaar & Lupker, 2000; Dijkstra, Timmermans & Schriefers, 2000), have recently presented compelling evidence that bilingual lexical access is non-selective, i.e. that there is interference from the non-target language. Both studies worked with interlexical homographs of varying relative word frequency. De Groot *et al.* (2000) used a translation recognition task and a lexical decision task. They obtained inhibitory results from the non-target language reading of the homograph, and found that this effect was particularly large when the 'weaker' homograph (less frequent reading) had to be selected. Dijkstra *et al.*'s (2000) interlexical homographs were embedded in identical mixed-language lists. These authors similarly found that the target language homographs were inhibited by the non-target language homographs when these were of a higher relative frequency, thus supporting the view that both languages were active during lexical processing.

Another interesting case of interference is found in studies where subjects are asked to reject nonwords in the target language, which are in fact real words in the non-target language. Thus, Nas (1983) obtained results supporting specifically this kind of interference from the inactive language. Using Dutch-English bilinguals, Nas found that, in the context of an English lexical decision task, bilingual subjects took longer to reject nonwords that were in fact Dutch words or pseudowords. The author hypothesised that the reason for this delay could lie in the orthographic similarity between Dutch and English words, which activated non-target lexical representations. He also argued that this was evidence for a 'cooperation model of lexical access', in other words, the non-selective access hypothesis. Very similar results had been obtained by Altenberg and Cairns (1983) in a English LDT with English–German bilinguals, where subjects took longer to discard nonwords that were illegal in English but legal in German.

Similar studies, but with results supporting the language-selective hypothesis, were carried out by Soares and Grosjean (1984), and Scarborough, Gerard and Cortese (1984). These authors found that, in a LDT where English-Spanish bilingual subjects had to decide if a word belonged to one language only, they did not find any difference between the negative response times to nonwords that were normal nonwords and to nonwords that were real words in the non-target language. Grainger (1993) has suggested that Scarborough and colleagues' subjects could have used orthographic cues present in the Spanish stimuli (for example, final position *–a*, which is quite rare in English) that immediately gave away those items as Spanish, and which could have helped subjects make very quick lexical decisions.

Thus, although there is strong evidence in favour of a language non-selective access, some conflicting results suggest that further research is needed. A relatively new area of research, orthographic neighbourhood effects in bilingual processing, can provide additional data in this direction.

5.3.2.2. NEIGHBOURHOOD EFFECTS ON BILINGUAL PROCESSING

The study of cross-language orthographic neighbourhood effects is still a largely unexplored area of bilingualism, and only a handful of studies have been published. The general finding is that orthographic similarity across languages does influence lexical processing in bilingual speakers.

Two early studies were conducted by Grainger and his colleagues (Grainger & O'Regan, 1992; Grainger & Dijkstra, 1992). The subjects were English-French bilinguals[11], and the task was a monolingual lexical decision. The target stimuli were English words selected on the basis of their neighbourhoods, which included both English and French neighbours. The spelling of the English words was not obviously English (i.e. they did not contain sequences which are illegal in French, like *wh* and *sh*). The stimuli were distributed according to three categories:

- 'Patriots': English words with more English neighbours than French (non-target language) neighbours.

[11] In Grainger and O'Regan's (1992) study, the experimental subjects were the two researchers themselves.

- 'Traitors': English words that had a lot more French neighbours than English neighbours.
- Neutral words: which had more or less the same number of English neighbours as French neighbours.

Results showed that 'patriot' response latencies were significantly shorter than either neutral words or 'traitors'. This evidence indicated that considerable inhibitory effects came from the non-target language neighbours, thus lending support to the idea that early lexical processing in bilinguals is language independent.

In a more recent study, Van Heuven *et al.* (1998) investigated how the word recognition in bilingual speakers is affected by the number of neighbours of the word, both in the target language and in the bilingual's other language. They selected Dutch and English items according to the size of N (large, small) in the target language and in the non-target language[12]. The same items were used in a series of progressive demasking[13] and lexical decision experiments. The results of these experiments showed that the recognition of words in the target language was strongly inhibited by the neighbours in the non-target language. In particular, these Dutch–English bilinguals reacted more slowly to English words that had many Dutch neighbours than to English words that had few Dutch neighbours. This happened even when participants were specifically

[12] For example, the English word *moon* has a large Dutch N and a large English N; the English word *milk* has a small Dutch N and a large English N.

[13] *Progressive demasking* (Grainger & Segui, 1990) is a relatively new experimental task within the perceptual identification paradigm, in which the target gradually becomes visible, and the subjects press a button as soon as they recognise the stimulus. Then they type the word into the computer.

informed that the target words were only English words, again giving support to the view that the non-target language was automatically activated.

Finally, further evidence in favour of the non-selective access hypothesis was provided by a study conducted by Bijeljac-Babic *et al.* (1997) with French-English bilinguals. Monolingual experiments have shown that the inhibitory effects of orthographic neighbours can be enhanced by priming the target word, very briefly, with a neighbour just before the presentation of the target (Segui & Grainger, 1990). On the strength of this, Bijeljac-Babic *et al.* (1997) examined if bilingual words were sensitive to the same inhibition effects, with briefly presented primes that were orthographic neighbours from the non-target language. As they had hypothesised, results showed that their bilingual subjects took longer to recognise low frequency words in one language when these words were preceded by high frequency orthographically related primes in the non-target language.

With respect to the two models of bilingual word access presented earlier in this section, the evidence discussed seems to be accommodated better by the BIA Model than by the BAV Model. The BAV Model has some difficulties explaining the results presented by Grainger and O'Regan (1992) and Grainger and Dijsktra (1992), about French neighbours influencing the recognition of English target words in a monolingual LDT. This model predicts that, when the subjects know that the stimuli they have to respond to are all in English (target language), the lexical search is directed to the English lexicon (see Figure 5.2, shown earlier) and that the lexical decision is made on the basis of English candidates only. This means that the result of the search should not be affected by neighbours of the non-target language, which is exactly contrary to what Grainger and his team found. The model runs into similar problems explaining Van Heuven *et al.*'s (1998) results.

The experimental evidence, however, is fully consistent with the predictions made by the BIA model, which embodies a non-selective hypothesis for bilingual lexical access. The model predicts that, when a 'traitor' word (a word with more neighbours in the non-target language) is presented to the system, more words are activated in the non-target language node than in the target language node. This increased level of activation will induce larger levels of inhibition directed to the target language node via lateral inhibition from the non-target language node. This is how a traitor will initially trigger an inhibitory influence that will result in delayed response latencies

5.4. CLOSING REMARKS

The literature review presented in this chapter is selective. However, it is not coincidental that no studies of bilingual neighbourhood effects involving Spanish have been discussed. To the best of my knowledge, these studies do no exist. There can be several reasons for this. First, this area of research has only started to develop relatively recently. A second reason could be that Spanish shows a considerably smaller degree of orthographic overlap with English (which is the language most widely studied in neighbourhood research) than do languages like Dutch, German or even French[14]. So fresh ways of contrasting the English and Spanish lexicons have to be implemented. The experimental work reported in the remaining chapters of this thesis is a step in this direction.

[14] However, Spanish and French share considerable orthographic overlap, and there are no bilingual studies on neighbourhood effects involving these languages, either.

Chapter 6

Experiment 1: Monolingual Study[1] on Neighbourhood Effects in English

Experiment 1 investigated the effects of Word Frequency, Neighbourhood Size and Neighbourhood Frequency in English lexical processing. Twenty-four English speakers performed a standard lexical decision task (LDT), and reaction times (RT) and number of mistakes were recorded as measures of speed and accuracy of word recognition. Variables were manipulated orthogonally: Word Frequency (High, Low); Neighbourhood Size

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[1] I named Experiments 1 and 2 Monolingual English Study and Monolingual Spanish Study respectively, to differentiate them from the subsequent bilingual studies.

(Large, Small); and Neighbourhood Frequency (NF Leaders, NF Nonleaders). The main results of the experiment can be summarised as follows:

1. There were no significant overall effects of N and NF.
2. There were facilitatory effects of large N and NF nonleaders in the N by NF interaction.
3. There were null effects of N and NF for high frequency words.
4. There were facilitatory effects of NF for low frequency words.
5. There were facilitatory effects of large N and NF nonleaders for low frequency words, in the N by NF interaction.

6.1. INTRODUCTION AND HYPOTHESES

Andrews (1989, 1992) showed that large neighbourhoods improved lexical processing of the target word. At the same time, Grainger *et al.* (1989) reported that having higher frequency neighbours had a detrimental effect on word recognition. Chapter 4 outlined the terms of the paradox posed by the fact that words with large neighbourhoods typically also have higher frequency neighbours. Experiments 1 and 2 were designed to test the claims made by Andrews (1989, 1992) and Grainger *et al.* (1989).

It has recently been pointed out (Andrews, 1997) that one factor, which may be at the root of the conflicting evidence of neighbourhood effects is the experimental language. As most studies showing facilitatory effects of N have been carried out in English, and most studies reporting inhibitory effects of NF have been performed in languages other than English, some researchers (Ziegler & Perry, 1998; Ziegler *et al.*, 2001) have suggested that perhaps effects of N are determinant in English lexical processing but not in languages with a more shallow orthography.

Experiments 1 and 2, done in English and in Spanish respectively, were set up in the light of the 'neighbourhood effect paradox'. In particular, their purpose was to study to what extent neighbourhood effects are language specific. Experiment 1 was a lexical decision task (LDT) in English which manipulated three variables: Word Frequency, Neighbourhood Size, and Neighbourhood Frequency. The experiment was designed to specifically test the two poles of the paradox, neighbourhood size and neighbourhood frequency, and to test their relationship with word frequency. The precise hypotheses that this experiment was set out to investigate were as follows:

1. High frequency words are processed faster and more accurately than low frequency words. This hypothesis tested the **word frequency effect** (Balota, 1994; Balota & Chumbley, 1984; García-Albea *et al.*, 1998).

2. Words belonging to large neighbourhoods are processed faster and more accurately than words from small neighbourhoods. This hypothesis tested the **neighbourhood size effect** (Andrews, 1989; Forster & Shen, 1996; Huntsman & Lima, 2002; Sears *et al.*, 1995, 1999a, 1999b).

3. Words that are neighbourhood frequency leaders are processed faster and more accurately than words which are neighbourhood frequency nonleaders. This hypothesis tested the **neighbourhood frequency effect** (Grainger *et al.*, 1989; Huntsman & Lima, 1996; Carreiras *et al.*, 1997; Perea & Pollatsek, 1998).

6.2. VARIABLES

There were two dependent variables in the LDT: RT to correct responses, measured to the nearest millisecond (ms), and percentages of incorrect responses. Faster RT and lower error percentages were interpreted as improved word recognition. There were three independent variables for the stimuli in the experiment: Word Frequency (WF), Neighbourhood Size (N) and Neighbourhood Frequency (NF). In this experiment estimates of N and NF were taken from the MRC Psycholinguistic Database (described in Coltheart, 1981).

6.2.1. WORD FREQUENCY (WF)

Estimates of word frequency were made on the basis of Kuçera and Francis' (1967) frequency count of the English language, which is expressed in frequency of 'occurrence per million words' (opm). There were two levels in this variable, 'high frequency' and 'low frequency'.

1. **High Frequency Words**: The threshold for high frequency was established at a minimum of 150 opm. Examples of high frequency words are *love* (232 opm) and *back* (967 opm).

2. **Low Frequency Words**: The cut-off point in the category of low word frequency was set at a maximum of 55 opm. Examples of low frequency words are *item* (54 opm) and *vary*, (34 opm).

6.2.2. NEIGHBOURHOOD SIZE (N)

Neighbourhood Size referred to the number of orthographic neighbours which make up the word's neighbourhood (Colheart *et al.*, 1977). There were two levels in this variable: 'large neighbourhoods' and 'small neighbourhoods'.

1. A **large neighbourhood** was a neighbourhood with 7 neighbours or more. Examples of words with large neighbourhoods are *home* (11 neighbours) and *dear* (18 neighbours).

2. A **small neighbourhood** was one with 6 neighbours or less. Examples are *open* (3 neighbours) and *bomb* (4 neighbours).

6.2.3. NEIGHBOURHOOD FREQUENCY (NF)

Neighbourhood Frequency referred to the frequency of the target word relative to the frequencies of the other words in the neighbourhood. There were two levels in this variable: 'frequency leader' and 'frequency nonleader'.

1. **Neighbourhood Frequency Leader**: In this category, the target word was the most frequent word of its neighbourhood. Examples of NF leaders are the words *year* and *body*[2].

2. **Neighbourhood Frequency Nonleader**: In this level, the target word is not the most frequent word in the neighbourhood. Examples of NF nonleaders are the words *book* and *gate*[3].

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[2] In *year*'s neighbourhood, with 13 neighbours, *year* leads with a frequency of 660 opm, and its nearest frequency competitors are the words *near* (198 opm) and *hear* (153 opm). In *body*'s neighbourhood, made up of 3 neighbours, *body* leads with a frequency of 276 opm, and its nearest frequency competitors are the words *bony* (7 opm) and *bogy* (2 opm).

[3] In *book*'s neighbourhood, with 9 neighbours, the word *took* (426 opm) is the NF leader, followed by the word *look* (399 opm) in the second place. The target *book* (193 opm) comes in the third place. In *gate*'s neighbourhood, made up of 13 neighbours, the word *gave* (285 opm) is the frequency leader, followed by the words *rate* (209 opm), *late* (179 opm), *game* (123 opm), *date* (103 opm), *hate* (42 opm) and the target, *gate* (37 opm).

6.3. METHOD

6.3.1. SUBJECTS

Twenty-four native speakers of English took part in this study. They were all unpaid volunteers in their First Year of a Modern Languages Degree at The University of Edinburgh. As part of the testing session, participants answered informal questions about their linguistic background and hand dominance. Subjects had normal or corrected-to-normal vision.

6.3.2. STIMULI AND DESIGN

A total of 86 four-letter English words[4] were chosen to meet the specifications of the variables described above, in an orthogonal 2 x 2 x 2 design: Word Frequency (High, Low) x Neighbourhood Size (Large, Small) x Neighbourhood Frequency (Leader, Nonleader). Except in two of those categories[5], there were 12 items in each experimental category. Most words were monosyllabic words (86%), and the rest were bisyllabic words (14%). The complete set of stimuli is shown in Table 6.1.

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[4] The English words were chosen from the pools of words used by Andrews (1992) and Sears *et al.* (1995).

[5] The two categories with less than 12 items were 'High Frequency & Small N & NF Nonleader' and 'Low Frequency & Large N & NF Leader'. Finding enough appropriate items for these categories proved a little difficult. Other authors have encountered similar problems (Sears *et al.*, 1995). It was decided that it was better to have fewer words in those categories than to compromise the operational specifications of the design. Thus there were a total of 42 high frequency words and 44 low frequency words.

N SIZE →	1. LARGE NEIGHBOURHOOD						2. SMALL NEIGHBOURHOOD					
N FREQ →	1. LEADER			2. NONLEADER			1. LEADER			2. NONLEADER		
WORD FREQUENCY	Item	WF	N	Item	WF	N	Item	WF	N	Item	WF	N
1. HIGH	*back*	967	13	*book*	193	9	*also*	1069	1	*ever*	345	3
	form	370	15	*care*	162	23	*body*	276	3	*kind*	313	6
	full	230	12	*cost*	229	10	*door*	312	5	*much*	937	3
	have	3941	13	*east*	187	11	*each*	877	1	*play*	200	4
	head	424	13	*fine*	161	16	*girl*	220	3	*town*	212	6
	last	676	15	*here*	750	10	*high*	497	4	*what*	1908	4
	love	232	13	*hold*	169	13	*many*	1030	2			
	mean	199	9	*home*	547	11	*next*	394	5			
	more	2216	17	*live*	177	12	*only*	1747	2			
	side	380	10	*move*	171	10	*open*	319	3			
	work	760	9	*read*	173	12	*turn*	233	5			
	year	660	13	*rest*	163	12	*view*	186	1			
2. LOW	*gift*	33	8	*bone*	33	12	*bomb*	36	4	*beef*	32	4
	loan	46	9	*core*	37	24	*copy*	38	4	*calm*	35	4
	milk	49	7	*dear*	54	18	*dirt*	43	3	*easy*	42	2
	path	44	8	*fake*	33	16	*glad*	38	3	*fish*	35	5
	pick	55	12	*fill*	50	16	*huge*	54	2	*foam*	37	4
	skin	47	7	*gate*	37	13	*inch*	40	2	*golf*	34	4
	soil	54	7	*male*	37	21	*iron*	43	1	*knee*	35	3
	suit	48	7	*rope*	40	15	*item*	54	2	*self*	40	2
				seed	41	14	*myth*	35	3	*shut*	46	4
				sell	41	12	*navy*	37	4	*soul*	47	5
				tall	55	15	*plot*	37	5	*stem*	29	5
				wire	42	14	*tiny*	50	4	*vary*	34	5

Table 6.1. English Monolingual Study. *Complete set of experimental items. WF= Word Frequency; N= Number of Neighbours. LEADER= The most frequent word in the neighbourhood. NONLEADER= Not the most frequent word in the neighbourhood.*

A summary of the characteristics of the words for the various categories is presented in Table 6.2. For the category of high frequency words, the frequency ranged from 161 to 3941 opm, and the frequency mean was 600.3 opm. For the category of low frequency words, frequency ranged between 29 and 55 opm, and the frequency mean was 41.5. The number of neighbours in the large neighbourhoods ranged between 7 and 24, with a mean size of 12.6. Small neighbourhoods ranged between 1 and 6 neighbours, with a mean size of 3.4.

N SIZE →	LARGE NEIGHBOURHOOD				SMALL NEIGHBOURHOOD					
N FREQ →	LEADER		NONLEAD		LEADER		NONLEAD		OVERALL	
WORD FREQUENCY ↓	WF	N	WF	N	WF	N	WF	N	Mean WF	Range for WF
HIGH	921.2	12.7	256.8	12.4	596.7	2.9	652.5	4.3	600.3	161-3941
LOW	47	8.1	41.7	15.8	42.1	3.1	37.2	3.9	41.5	29 - 55
MEAN FOR N	12.6				3.4					
RANGE FOR N	7 - 24				1 - 6					

Table 6.2. English Monolingual Study. *Statistics of the experimental words according to Word Frequency (WF) and Neighbourhood Size (N).*

For the purpose of the lexical decision task, a total of 86 four-letter nonwords[6] were added to the set of stimuli. The number of nonwords was the same as the number of real words. They were selected from the set of nonwords used by Allen, McNeal and Kvak (1992), and Allen, Wallace and Weber (1995) in their experiments. Not one of the nonwords were random letter strings. Half the nonwords had been constructed from high frequency words and the other half from low frequency words. They were all formed by changing the last letter of the word. Using this method, most of the resulting nonwords, about 85%, were true pseudowords, i.e. orthographically legal and therefore with a high

[6] In these experiments the term 'nonword' is used as a synonym of 'pseudoword'. See footnote n.2 in Chapter 3.

degree of word-likeness. The remaining 15 % of the nonwords were quasi-pseudowords. Table 6.3 lists the complete set of nonwords[7].

NONWORDS							
Constructed from **HIGH** FREQUENCY WORDS				Constructed from **LOW** FREQUENCY WORDS			
besc	*frej*	*lasc*	*roob*	*bluc*	*fadt*	*luct*	*pult*
bodv	*girb*	*latk*	*sorn*	*brav*	*filp*	*marl*	*ridl*
carv	*givo*	*neek*	*taky*	*brex*	*goln*	*menk*	*rinf*
casb	*gonk*[8]	*nexd*	*tald*	*cano*	*guld*	*mila*	*risc*
cosk	*halg*	*parb*	*telk*	*cark*	*hatn*	*molz*	*salb*
datu	*halm*	*pasc*	*turb*	*chep*	*haup*	*pacq*	*shib*
dayn	*hele*	*plab*	*wesp*	*crig*	*holg*	*paib*	*sict*
donu	*heln*	*plar*	*worw*	*deat*	*huga*	*paty*	*soik*
feeg	*keef*	*ratz*	*yeal*	*dirj*	*hurg*	*perb*	*suik*
fing	*kina*	*reaa*		*dovn*	*laks*	*pinc*	*tace*
foub	*knop*	*resb*		*dran*	*lotz*	*poer*	*teni*

Table 6.3. English Monolingual Study. *Complete set of 'high' and 'low' frequency nonwords.*

6.3.3. PROCEDURE

The experiment was run using PsyScope 1.1 on Performa Apple Macintosh computers placed in quiet rooms. Subjects were tested individually in a single session of about ten minutes. They sat in front of the computer and followed the instructions on the screen. Subjects were informed that they were

[7] The number of 'high frequency' and 'low frequency' nonwords matches the number of high frequency and low frequency experimental items, respectively. Hence there are two fewer high frequency nonwords than low frequency words.

[8] After the data of the experiment had been collected and analysed, my attention was drawn to the fact that *gonk*, a nonsense word, is actually a registered trade mark that means 'a cushion-like soft toy, usually with arms and legs' (Chambers English Dictionary, 1990).

going to see a number of letter strings on the screen, which could be true English words or pseudowords. By pressing one of two buttons on a response box, participants had to decide, as quickly and as accurately as possible, whether the letter string on the screen was a real word or not. If they thought it was a word, they had to press the YES-button with their dominant hand (typically, their right hand). If they thought it was not a real word, they must press the NO-button with the other hand. Changes were made to the buttons to accommodate left-handers. Both correct and incorrect responses were automatically recorded by the computer, and reaction times to the stimuli were measured to the nearest millisecond.

Each trial started with a fixation point at the centre of the monitor. Exactly 500 ms after the onset of the fixation point, the stimulus was presented in the same place, in lowercase (in black bold 18-point courier against a white screen), and it remained on the screen until the subject responded, and it had a time-out of exactly two seconds. The participant's response terminated the stimulus display and the fixation point reappeared after a timed interval of 500 ms. The order of stimulus presentation was controlled by randomising items, automatically, with every re-run of the programme. All the subjects were presented with all the experimental material.

The experiment started with a small practice session comprising 12 trials, to allow for familiarisation with the task. None of the practice stimuli were used in the actual experiment. At the end of the practice, subjects could ask questions. They were reminded that emphasis was both on speed and accuracy of response. The experiment proper then followed.

6.4. RESULTS

The responses to nonwords and all the incorrect responses for words (4.1%) were omitted from the reaction time (RT) analysis. Mean RT to correct responses and error rates for words were calculated[9]. No answers to words were excluded from the latency analysis other than incorrect ones[10]. Table 6.4 shows mean RT for words for the independent variables, Word Frequency, Neighbourhood Size and Neighbourhood Frequency, to give a general idea of first order effects. The table also gives RT differences (*RT DIFFER*) between the two levels of each variable. A 'negative' *RT DIFFER* means that the results went in the direction of the experimental hypotheses, whereas a 'positive' difference means that results conflicted with the hypotheses.

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[9] All the statistical analyses for the experiments reported in this thesis were carried out using SPSS 9.0 for Windows. For the preparation, exploration and analysis of the data with this statistical package, I followed the recommendations made by Kinnear and Gray (1997).

[10] The data was preliminarily inspected for 'outliers' –very short or very long answers. In lexical decision tasks, some authors (Sears *et al.*, 1995) suggest removing from the analysis latency responses shorter than 250 ms or longer than 1500 ms. However, as only 4 observations (0.19%) lay outside the suggested cut-off points, it was decided in this experiment not to trim outliers off.

	NEIGHBOURHOOD SIZE			NEIGHBOURHOOD FREQUENCY			
	LARGE	SMALL		LEAD	NON-LEAD		
WORD FREQUENCY	RT	RT	*RT DIFFER*	RT	RT	*RT DIFFER*	MEAN RT
HIGH	488	493	*–5*	493	488	*+5*	491
LOW	524	525	*–1*	531	518	*+13*	525
RT DIFFER	*–36*	*–32*		*–38*	*–30*		*–34*
MEAN RT	506	509	*–3*	512	503	*+9*	

Table 6.4. English Monolingual Study. *Results for words for the INDEPENDENT VARIABLES, without crossing N and NF. Mean RT in ms to correct responses. RT DIFFER= Difference in mean RT between both levels of each variable.*

Table 6.4 shows mean RT without crossing N and NF. Table 6.5 presents mean RT and percentages of errors for words across all the experimental conditions, crossing all the variables orthogonally.

N SIZE →	**LARGE NEIGHBOURHOOD**					**SMALL NEIGHBOURHOOD**				
N FREQ →	LEADER		NON-LEADER			LEADER		NON-LEADER		
WORD FREQUENCY	RT	ERROR (%)	RT	ERROR (%)	*RT DIFFER*	RT	ERROR (%)	RT	ERROR (%)	*RT DIFFER*
HIGH	494	2.8	483	3.8	*+11*	492	3.8	494	2.8	*–2*
LOW	541	3.1	507	5.6	*+34*	520	4.9	530	5.2	*–10*
RT DIFFER	*–47*		*–24*			*–28*		*–36*		
MEAN RT	517		495		*+22*	506		512		*–6*

Table 6.5. English Monolingual Study. *Results for words for ALL the EXPERIMENTAL CONDITIONS (all variables orthogonally crossed). Mean RT to correct responses in ms and Error Rates in percentages. RT DIFFER= Difference in mean RT between two levels of the same variable.*

For words, mean RTs for correct responses were calculated independently across subjects and items, and separate analyses of variance (ANOVAs) were carried out on each set of data. The variables Word

Frequency, Neighbourhood Size and Neighbourhood Frequency were used as within-subjects factors in a repeated-measures ANOVA for subjects, and as between-items factors in an ANOVA for items. Incorrect responses to words for subjects and items were submitted to the same statistical analyses. The F values of the ANOVAs are given for subjects (F_s) and items (F_i)[11]. The probability, *p*, of being wrong in rejecting the null hypothesis (the level at which results become significant) was set at 0.05.

6.4.1. RESPONSE LATENCIES

ANOVA results for correct responses to words are given in Table 6.6. As expected, the ANOVA on latency data for words returned a significant main effect of Word Frequency, both for subjects and items. High frequency words were identified 34 ms faster than low frequency words. The effect of N was not significant, and neither was the effect of NF.

The interaction between Word Frequency and N was not statistically reliable. The analysis also yielded a non-significant effect of Word Frequency by NF. These results therefore do not replicate those obtained by Andrews (1989), who found facilitatory effects of N in low frequency words. Similarly, the absence of an NF effect does not support Grainger *et al.*'s (1989) results, where the presence of at least one higher frequency neighbour had a strongly inhibitory effect on lexical processing.

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[11] I am aware that, in many studies, F for subjects and F for items are referred to as F_1 and F_2. However, there are some authors (Andrews, 1989, 1992; Sears *et al.*, 1995, 1999b) who use the less conventional, but more meaningful, notation of F_s (for subjects) and F_i (for items). I have adopted the latter option, as I believe it is clearer.

CORRECT RESPONSES			
EFFECTS	F_S (1,23) F_i (1,78)	MSE[12]	*p* <
WORD FREQ. (WF)	F_S = 15.4 F_i = 20.8	3606 1252	*.001* *.001*
NEIGHB. SIZE (N)	F_S < 1 F_i < 1		
NEIGHB. FREQ. (NF)	F_S = 1.9 F_i = 1.0	1905 1252	*.183* *.314*
WF x N	F_S < 1 F_i < 1		
WF x NF	F_S < 1 F_i < 1		
N x NF	F_S = 5.2 F_i = 3.0	1775 1252	*.032* *.086*
WF x N x NF	F_S = 2.7 F_i < 1	1106	*.118*

Table 6.6. English Monolingual Study. *ANOVA results of CORRECT RESPONSES to words, for subject and item data. Significant results are highlighted.*

The N by NF interaction (see Figure 6.1) proved significant in the subject data. The item data was not statistically reliable, but it approached significance. Words from large neighbourhoods were responded to faster (22 ms) when they were NF nonleaders than when they were NF leaders, which clearly suggested a facilitatory, not inhibitory, influence of higher frequency neighbours. For words with few neighbours, however, the presence of more frequent neighbours had a small (5 ms) inhibitory effect. There was no three-way interaction between Word Frequency, N and NF.

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[12] MSE refers to the mean square error.

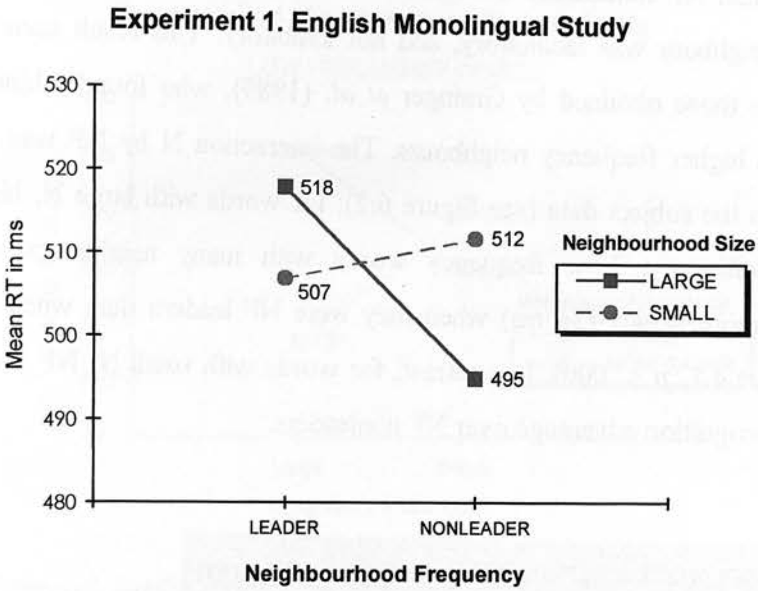

Figure 6.1. English Monolingual Study. *Profile plot of RTs to words according to Neighbourhood Size (Large & Small) and Neighbourhood Frequency (Leader & Nonleader).*

Many studies reporting significant neighbourhood results have only used low frequency stimuli, or effects were obtained only with low frequency words (Andrews, 1989; Carreiras *et al.*, 1997). So *post hoc* analyses were performed on the results of the experiment to explore the influence of Word Frequency. All the data were submitted to separate ANOVAs for high and low frequency words. The analysis on high frequency words yielded no significant results [all the F_s <1 and F_i<1].

The analysis of the low frequency words of the experiment, on the other hand, conveyed a more interesting picture (see Table 6.7). The main effect of N was still not significant for low frequency words, but the main effect of NF was significant in the by-subjects analysis. This effect, however, was in the opposite direction to the one expected. NF leaders were identified more slowly (13 ms), not faster, than NF nonleaders[13]. In other words, having at least one higher frequency neighbour was facilitatory, and not inhibitory. This result seems to conflict with those obtained by Grainger *et al.* (1989), who found inhibitory effects from higher frequency neighbours. The interaction N by NF was also significant in the subject data (see Figure 6.2): for words with large N, higher NF was facilitatory. Low frequency words with many neighbours were recognised more slowly (34 ms) when they were NF leaders than when they were not [t_s= 4.1, $p < .000$]. In contrast, for words with small N, NF leaders were at a recognition advantage over NF nonleaders.

CORRECT RESPONSES (Low Freq words only)			
EFFECTS	F_S (1,23) F_i (1,40)	MSE	*p* <
NEIGHB. SIZE (N)	F_S < 1 F_i < 1		
NEIGHB. FREQ. (NF)	F_S = 5.2 F_i < 1	745	*.032*
N x NF	F_S = 8.2 F_i = 3.0	1369 1607	*.009* *.090*

Table 6.7. English Monolingual Study. *ANOVA results of CORRECT RESPONSES to LOW frequency words, for subject and item data. Significant results are highlighted.*

[13] Consistent with the description of the variable **Neighbourhood frequency** given in this chapter, I would describe the NF effect obtained in Experiment 1 as 'inhibitory'. In other words, being a 'neighbourhood frequency leader' hinders lexical processing. However, if the variable is defined as 'having at least one higher frequency neighbour', then the effect is 'facilitatory': having at least one higher frequency neighbour improves processing. Recent review articles (Andrews, 1997; Mathey, 2001; Perea & Rosa, 2000) have adopted the latter description of NF ('having at least one higher neighbour'), and this is the description that will be followed in the interpretation of the results of the current experiments.

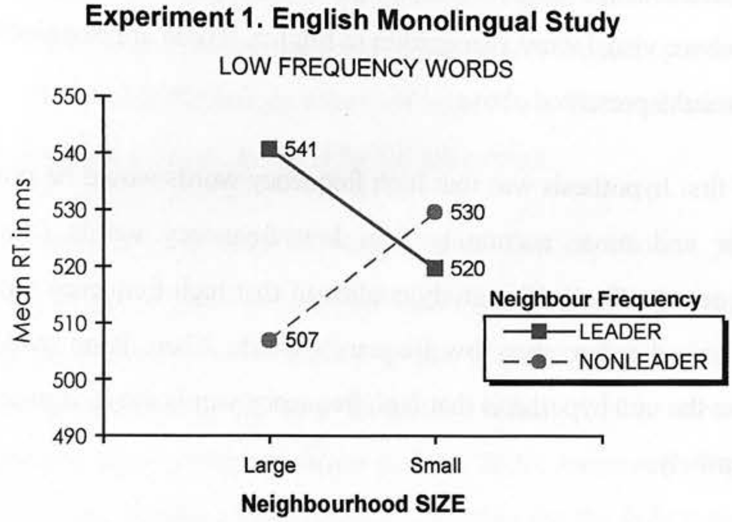

Figure 6.2. English Monolingual Study. *Profile plot of RTs to Low Frequency words. Interaction between Neighbourhood Size (Large, Small) and Neighbourhood Frequency (Leader, Nonleader).*

6.4.2. ERROR RATES

Error numbers for words (see Table 6.5 above for details) were also submitted to a repeated-measures ANOVA for subjects and to a separate ANOVA for items. The overall error rate was 4.1 %. On the whole, subjects made fewer mistakes with high frequency words (3.3%) than with low frequency words (4.7%), and with NF leaders (3.6%) than with NF nonleaders (4.3%), but these differences were not reliable. The effect of Word Frequency was not significant [$F_s(1, 23)= 2.8$, MSE= .475, $p < .11$; $F_i(1, 78)= 1.9$, MSE= 1.18, $p < .17$] and neither was the effect of N or NF [all $F_s < 1$ and $F_i < 1$]. All the interaction effects were also non-significant. It was slightly puzzling to find that high frequency words were not processed more accurately than low frequency words, but this could be due to the fact that low frequency words in this experiment were relatively 'high' in comparison to other studies. I will come back to this point in the discussion.

In conclusion, the English Monolingual Study was set up to test three hypotheses about visual word recognition in English. These are examined in the light of the results presented above:

1. The first hypothesis was that high frequency words would be processed faster and more accurately than low frequency words (the **word frequency effect**). This study confirmed that high frequency words are recognised faster, than low frequency words. There is no evidence to reject the null hypothesis that high frequency words are recognised more accurately.

2. The second hypothesis was that words with large N would be processed faster and more accurately than words from small neighbourhoods (the **neighbourhood size effect**). This hypothesis could not be confirmed.

3. The third hypothesis was that words that are NF leaders in their neighbourhood would be processed faster and more accurately than NF nonleaders (the **neighbourhood frequency effect**). This hypothesis was not substantiated. However, a NF effect was found for low frequency words in the opposite direction from the one expected: NF leaders were processed more slowly, not faster, than NF nonleaders.

6.5. DISCUSSION

The main results of the English Monolingual Study, in terms of neighbourhood effects, were as follows:

1. There were no significant effects of N and NF.
2. There were facilitatory effects of large N and NF nonleaders in the N by NF interaction.

3. There were null effects of N and NF for high frequency words.
4. There were facilitatory effects of NF for low frequency words.
5. There were facilitatory effects of large N and NF nonleaders for low frequency words, in the N by NF interaction.

Like Grainger *et al.*'s (1989) experiments, this experiment yielded no evidence that N *per se* was a determinant factor in speed or accuracy of lexical processing, not even for low frequency words. These results therefore do not support the evidence in favour of a facilitatory effect of N (Andrews, 1989, 1992; Forster & Shen, 1996; Huntsman & lima, 2002; Johnson & Pugh, 1994; Sears *et al.*, 1995, 1999b). One possible explanation for the failure to replicate significant effects of N could lie in the fact that the word frequencies of both my high frequency words and low frequency words were much higher than the complete sets of those of Andrews' (1989) and Sears *et al.*'s (1995) stimuli[14], and therefore the stimuli may not be comparable in this respect. There is some evidence that 'very low' frequency words are more sensitive to the facilitatory effects of N than are 'medium low' frequency words. If this is so, then the much higher mean frequencies of this study could account for the lack of a main neighbourhood size effect.

Along with Sears *et al.* (1995), I did not obtain any significant main effect of NF. However, for low frequency words, this experiment yielded effects of NF; they were facilitatory and not inhibitory, as predicted. In particular, for

[14] Kuçera and Francis' (1967) average frequency for Andrews' (1989) high frequency words was 261 opm. For Sears and colleagues, average frequencies were 159 opm in their Experiments 1 and 2, and 271 opm in Experiments 3a and 3b. The average frequency of my high frequency words was 600.3 opm. Similarly, the average frequency of the low frequency words in the studies mentioned was considerably lower than the average frequency of my experiment. For Andrews' experiments it was 15.75 opm (Carrol, Davies & Richman, 1971), and for Sears and collaborators' experiments it was 8 opm, compared to 41.5 opm in my experiment.

words with many neighbours, having higher frequency neighbours improved, rather than hindered, lexical access (Figure 6.1 already shown). This was exactly what Sears *et al.* (1995) found. In clear conflict with these results, studies by Grainger and his colleagues (Grainger *et al.*, 1989; Grainger, 1990, Grainger & Segui, 1990; Grainger *et al.*, 1992) have consistently revealed inhibitory NF effects. It is somewhat surprising that Sears *et al.*, (1995), when trying to explain why their results seemed to challenge those of Grainger *et al.*'s (1989), made no reference at all to the fact that the languages of the compared experiments were different. Sears and his colleagues, and Andrews, used English stimuli, whereas Grainger and his team worked in French and Dutch. The conflicting evidence, in relation to neighbourhood effects, may be more apparent than real, as some research has shown that the nature of neighbourhood effects might be, to a large extent, language specific. Great differences in the degree of letter-to-phoneme correspondence, commonly referred to as deep and shallow orthography, could explain, at least partially, the conflicting experimental results. Andrews (1997), Ziegler and Perry (1998) and Ziegler *et al.* (2001) have pointed out that the inhibitory effect of a more frequent neighbour has been reported mostly in experiments conducted in French, Dutch and Spanish (but see Huntsman & Lima, 1996, and Perea & Pollatsek, 1997, for reports on inhibitory effects of NF in English).

It can be argued that another source of the divergent results of this experiment, relative to Grainger's work, could reside in the different way the variable NF was manipulated. In my study, NF was dichotomous (leader and nonleader) and no control was made of the strength of the potential cumulative effect of NF. This is what Grainger *et al.* (1989) controlled in their four-level manipulation of the variable (no neighbours, NF leader, NF nonleader by one neighbour, and NF nonleader by more than one neighbour). However, Sears *et al.* (1995) specifically tested the effects of Grainger's manipulation, i.e. they changed their dichotomous NF variable to a four-level one, and they still failed to obtain any cumulative neighbourhood frequency effect, or indeed any significant effect at all.

One other result that the English Monolingual Study produced was an interaction between N and NF, which was most noticeable for low frequency words. As can be seen in Figure 6.2 (shown earlier), having higher frequency neighbours plays a facilitatory effect on words with large neighbourhoods. These results lend support to the claim that NF is facilitatory in English lexical processing and suggest the possibility that the inhibitory nature of NF claimed by Grainger *et al.* (1989) is perhaps specific to languages other than English .

In conclusion, the results of this experiment support the idea that there is some language-specificity to neighbourhood effects, though it is not clear to what extent different languages can account for the differing, even contradictory, results. So, in order to investigate further the influence of experimental language, I conducted another experiment, parallel to this one in design, but with Spanish stimuli and Spanish speakers.

Chapter 7

Experiment 2: Monolingual Study on Neighbourhood Effects in Spanish

Experiment 2 examined neighbourhood effects on Spanish lexical processing with sixty-three Spanish speakers. The task was a lexical decision, where stimuli fitted the following design: Word Frequency (High, Low) x Neighbourhood Size (Large, Small, Zero N) x Neighbourhood Frequency (NF Leaders, NF Nonleaders). Dependent variables were response latencies and error rates, as measures of speed and accuracy of word recognition. The main findings of the experiment can be summarised as follows:

1. NF had a clear inhibitory effect: NF nonleaders were processed both more slowly and less accurately than NF leaders.

2. N and NF interacted with word frequency: low frequency words were more sensitive to the inhibitory effects of N and NF.

3. The word frequency effect was very robust with Spanish stimuli, much more than had been registered in Experiment 1 with English stimuli.

7.1. INTRODUCTION AND HYPOTHESES

While researchers have conducted a considerable amount of experimental work on neighbourhood effects on English lexical processing, not so much work has been done on these aspects of word recognition in Spanish.

Experiment 2, a Spanish Monolingual Study, paralleled Experiment 1 in most aspects of the experimental design, except that the stimuli were Spanish and the participants were Spanish speakers. The aim of Experiment 2 was twofold: first, to further explore the relationship between neighbourhood size and neighbourhood frequency, in the light of the 'neighbourhood effects paradox'; and, second, to examine if standard findings regarding English word recognition were also found in Spanish. Thus, the hypotheses for this experiment were the same as for Experiment 1 and they tested the same effects. Briefly:

1. The **word frequency effect**: High frequency words are processed faster and more accurately than low frequency words.

2. The **neighbourhood size effect**: Words from large neighbourhoods are processed faster and more accurately than words from small neighbourhoods.

3. The **neighbourhood frequency effect**: Words with no higher frequency neighbours will be processed faster and more accurately than words with higher frequency neighbours.

7.2. VARIABLES

The dependent variables were the same as in Experiment 1, reaction times (RT) to correct responses in the lexical decision task, measured to the nearest millisecond, and percentages of incorrect responses. Similarly, the independent variables were Word Frequency, Neighbourhood Size and Neighbourhood Frequency.

7.2.1. WORD FREQUENCY (WF)

Estimates of word frequency were made on the basis of Alameda and Cuetos' (1995) frequency dictionary of the Spanish language[1]. Frequency in this dictionary is measured in 'occurrences per **two** million words'. Since most frequency counts referred to in the literature are given 'per million words' (e.g. Kuçera & Francis, 1967), frequencies offered by Alameda and Cuetos (1995) were recalculated as number of 'occurrences per million words' (opm).

As in the English Monolingual Study, there were two levels of word frequency, 'high frequency' and 'low frequency'. However, the cut-off points of the operational definition of this variable were lowered considerably in the

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[1] I would like to sincerely thank the authors of this frequency dictionary, in particular J. R. Alameda, for kindly allowing me to use the on-line version of their database (Alameda, 1996) at a time when it was not readily available to the public.

Spanish experiment relative to the English one. The reason for this adjustment was the greater sensitivity to neighbourhood effects that lower frequency words have shown in experimental data. This was the operational definition of the variable:

1. **High Frequency Words**: A word was considered of high frequency when it had a frequency of 55 occurrences per million (opm) or more, for example *ropa* [clothes] (88.5 opm) and *mil* [thousand] (152 opm).

2. **Low Frequency Words**: A word was considered of low frequency when it had a frequency no higher than 12 opm, for example *cebo* [bait] (6 opm) and *fosa* [ditch] (4 opm).

7.2.2. NEIGHBOURHOOD SIZE (N)

Coltheart *et al.*'s (1977) definition of orthographic neighbourhood was adopted here. The variable Neighbourhood Size, or N, had three levels in this study: 'large', 'small' and 'no neighbourhood'.

1. A **large neighbourhood** had 9 neighbours or more. Examples of words with large neighbourhoods are *tema* [theme], with 11 neighbours, and *cazo* [small pan], with 14 neighbours.

2. A **small neighbourhood** was one with 2 to 5 neighbours. Examples are the words *cine* [cinema], with 3 neighbours, and *huso* [spindle], with 4 neighbours.

3. **No neighbourhood**. This level only included words with no neighbours, elsewhere called 'hermit' words (Segui & Grainger, 1992), like *azul* [blue] and *bedel* [janitor].

In order to keep the three levels of the variable sufficiently different, words with 1, 6, 7 or 8 neighbours were not included in the study.

7.2.3. NEIGHBOURHOOD FREQUENCY (NF)

The variable Neighbourhood Frequency referred to the frequency of the target word relative to that of its neighbours. There were two levels in this variable: NF 'leader' and NF 'nonleader'[2].

1. **Neighbourhood Frequency Leader**: In this condition, target words had no higher frequency neighbours. An example of NF leader is the word *mano* [hand][3].
2. **Neighbourhood Frequency Nonleader**: Words in this category were not the most frequent in their neighbourhood. An example of a NF nonleader is the word *dos* [two][4].

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[2] There is evidence that the inhibitory effect of NF is not cumulative, i.e. having more than one higher frequency neighbour does not seem more detrimental for word recognition than having only one higher frequency neighbour (Grainger *et al.*, 1989; Pollatsek *et al.*, 1999).

[3] In *mano*'s neighbourhood (15 neighbours), *mano* is the most frequent word (549.5 opm); its nearest frequency competitors are the words *malo* [bad], *mayo* [may], *vano* [vain], *mono* [monkey], whose frequencies are 76.5, 38, 35.5 and 24 opm, respectively.

[4] In the neighbourhood of the word *dos* (1,432.5 opm) there are 12 neighbours. Two of these words are more frequent than *dos*, the words *los* [the] and *nos* [us], which have a frequency of 15,699.5 and 1,524.5 opm, respectively.

7.3. METHOD

7.3.1. SUBJECTS

Sixty-three native speakers of Spanish participated in the study. They were all unpaid volunteers. Most of them normally lived in Spain and had reached university education. They had arrived in Great Britain only days before taking part in the experiment, and had come to Edinburgh to follow a three-week summer course in English language. Prior to the experiment, participants answered informal questions about their linguistic background, studies and work, and hand dominance. The subjects had normal or corrected-to-normal vision.

7.3.2. STIMULI AND DESIGN

The levels of the three independent variables described earlier made up a 2 x 3 x 2 experimental design: Word Frequency (High, Low) x Neighbourhood Size (Large, Small, No-Neighbours) x Neighbourhood Frequency (Leader, Nonleader). This design is outlined in Table 7.1 below.

WORD FREQUENCY →	**1. HIGH FREQUENCY**				
NEIGHBOURHOOD SIZE →	**1. LARGE**		**2. SMALL**		**3. NO NEIGHB.**
NEIGHBOURHOOD FREQUENCY →	1.Leader	2.NonLeader	1.Leader	2.NonLeader	

WORD FREQUENCY →	**2 LOW FREQUENCY**				
NEIGHBOURHOOD SIZE →	**1. LARGE**		**2. SMALL**		**3. NO NEIGHB.**
NEIGHBOURHOOD FREQUENCY →	1.Leader	2.NonLeader	1.Leader	2.NonLeader	

Table 7.1. Spanish Monolingual Study. *Conditions in the experimental design.*

The stimulus set consisted of 150 critical words. Unlike the stimuli for the English Study, the stimulus set for the Spanish Study was specifically put together for this experiment. As can be expected, there were numerous methodological issues involved in the preparation of items from scratch. As well as the operational definitions of the independent variables, the following criteria were considered relevant in the selection of the items:

- no neighbour items
- same word length
- same word class
- no written accents
- neutral meaning

In practice, the nature of the Spanish lexicon is such that not all the criteria specified beforehand could be met, and some compromises had to be made. Here is a description of the above criteria and why they were thought relevant to the study.

1. Words should not be neighbours of each other, so as to avoid confounded priming effects[5]. This decision automatically restricted the potential number of stimulus candidates considerably.

2. Word length should be controlled throughout. Initially, it was decided to use only four-letter words. There were three reasons for this: first, four letters is the most common word length used in neighbourhood experiments; second, it is the length that is most suitable for the manipulation of the neighbourhood variables; and third, all the stimuli in the English Monolingual Study were four-letter words. However, with four-letter words only, not enough experimental items could be drawn together, so word length had to be extended to three and five-letter words[6]. The final stimulus set comprised 77 four-letter words, 54 five-letter words and 19 three-letter words. Average word length was 4.23. As for number of syllables: 86.7% of the words were bisyllabic, 10.7% were monosyllabic and 2.6% were trisyllabic[7].

3. Preferably, words should all belong to the same grammatical category: only nouns, in their unmarked (singular) form were initially chosen. However, it proved impossible to complete the list of items only with nouns, and thus some adjectives were introduced: neutral

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[5] Unfortunately, after all the data had been collected and analysed, three stimuli (*cola*, *pelo* and *gasa*) were found to have one other neighbour in the stimulus set (*cota*, *peto* and *gata*, respectively).

[6] As far as possible, a good balance was kept between the number of four-letter words (77), and the number of the other two lengths (73). The average word-length for each condition can be seen in Table 7.3.

[7] Compare the syllabic structure of the Spanish critical stimuli with the syllabic structure of the English stimuli of Experiment 1: 86% of words were monosyllabic, and 14% were bisyllabic.

adjectives, which do not change for gender, like *doce* [twelve] or *igual* [same]. No other type of word was used.

4. Words should require no written accent. Given the visual nature of the stimuli, it was important to avoid any ambiguity stemming from the presence or absence of written accents[8]. It was decided to use only words that did not need an accent at all. Nonwords were kept the same way.

5. As regards meaning, slang words, taboo words and words with potentially high emotional content were avoided.

Taking all the above criteria into consideration, a total of 944 neighbourhoods were generated from Alameda's (1996) database: 70 neighbourhoods belonged to three-letter words, 450 to four-letter words and 424 to five-letter words. All the neighbourhoods were carefully examined against the operational definitions of the three independent variables of the study.

Fifteen Spanish words were to be selected to fill each category of the experimental design. However, a further methodological problem became apparent. No experimental items could be found in the database to make up the category of 'Low Frequency & Large Neighbourhood & Neighbourhood

[8] In Spanish there are many written words that only differ in the presence or absence of a written accent, for example *médico* [physician], *medico* [I prescribe a medicine] and *medicó* [he prescribed a medicine]. These words also vary in the stressed syllable when spoken, indicated by the underlining. Other words, like *árbol* [tree] and *salón* [lounge], necessarily require a written accent, and many native speakers would quite legitimately class these as 'nonwords' if the written accent was missing. Clearly, the inclusion of words with written accents in a lexical decision task could introduce potential confusion in the word-nonword discrimination.

Frequency **Leader**' with the specifications of word frequency stated earlier[9]. For this reason, this category was an 'empty' cell. In order to compensate for the imbalance posed by the 'empty' cell, its sister category 'Low Frequency & Large Neighbourhood & Neighbourhood Frequency **NonLeader**' contained twice as many items as the rest of the experimental categories, i.e. thirty items. The complete stimulus set for the nine categories, therefore, consisted of 150 items. They are listed in Table 7.2[10].

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[9] The reason for this lack of stimuli for the category 'Low Frequency & Large N & NF **Leader**' was implicitly stated by Andrews (1997) and Sears *et al.* (1995) when discussing how words with large neighbourhoods typically have higher frequency neighbours. This tendency is more marked in the case of low frequency words.

[10] Word Frequency counts are given in 'occurrences per million' words (opm). The decimal points result from recalculating the frequency counts offered by Alameda and Cuetos (1995), originally given in 'occurrences per **two** million' words. For example, the word *alma* [soul], which has a frequency of 329 in Alameda and Cuetos' dictionary, here appears with a frequency of 164.5 opm.

HIGH FREQUENCY WORDS

LARGE NEIGHBOURHOOD						SMALL NEIGHBOURHOOD						NO NEIGHBOURS	
LEADER			NONLEADER			LEADER			NONLEADER				
Item	WF	N	Item	WF	N	Item	WF	N	Item	WF	N	Item	WF
alma	164.5	9	*caja*	60	22	*aire*	288	5	*calor*	122.5	3	*agua*	396.5
boca	200	14	*cola*	63	13	*amor*	379.5	3	*cien*	64	3	*azul*	115
calle	300.5	9	*cura*	63.5	12	*cine*	217.5	3	*coche*	150.5	2	*civil*	76.5
carta	113.5	14	*dama*	65	15	*final*	208.5	2	*doce*	57.5	4	*diez*	133
duda	230	10	*dos*	1432	12	*grupo*	160.5	4	*dolor*	117	2	*edad*	198
lado	374	13	*hijo*	268	12	*hora*	322.5	4	*fin*	511.5	4	*feliz*	99
mano	549.5	15	*mes*	83.5	14	*lugar*	499	5	*fuego*	100	4	*flor*	59
mesa	234.5	12	*moda*	66.5	14	*mundo*	887.5	4	*menor*	130.5	3	*igual*	237.5
mito	73.5	13	*pan*	69	13	*papel*	197.5	2	*mil*	152	3	*isla*	55.5
pena	97	15	*pelo*	152.5	17	*pie*	193	5	*obra*	290	5	*joven*	215
rato	114.5	17	*piso*	83.5	14	*real*	203.5	2	*ojo*	96	3	*luz*	446
ropa	88.5	12	*puro*	66	14	*sitio*	120	5	*padre*	513.5	4	*miedo*	169
suelo	217	11	*tono*	116	9	*tarde*	480	4	*pobre*	132.5	4	*mujer*	667.5
tema	134.5	11	*vaso*	59.5	10	*viaje*	147	4	*resto*	117	5	*reloj*	71
vez	1415	9	*vino*	179.5	9	*zona*	93.5	3	*sur*	71	4	*ritmo*	76.5

LOW FREQUENCY WORDS

LARGE NEIGHBOURHOOD						SMALL NEIGHBOURHOOD						NO NEIGHBOURS	
NONLEADER						LEADER			NONLEADER				
Item	WF	N	Item	WF	N	Item	WF	N	Item	WF	N	Item	WF
asa	3	13	*mago*	6.5	12	*abuso*	10	3	*acta*	3.5	5	*alud*	3
baba	7	16	*maza*	2	17	*ardor*	8.5	2	*apto*	6.5	5	*bedel*	10
cal	10.5	10	*moro*	6	18	*chulo*	8.5	4	*bicho*	8.5	4	*efebo*	1
cala	5.5	27	*nata*	4	14	*copia*	11.5	5	*cable*	8	4	*hedor*	6
cazo	3.5	14	*pavo*	11	10	*faena*	10.5	2	*cerco*	8	5	*lapso*	7.5
cebo	6	12	*peto*	3	16	*freno*	9	3	*faz*	10	5	*matiz*	9.5
cepa	2	10	*reo*	3	12	*joya*	5.5	4	*gel*	2	5	*olmo*	3.5
copo	2	13	*romo*	0.5	12	*ocre*	5	3	*hiel*	3	4	*ozono*	10
cota	5	16	*saga*	3.5	14	*oral*	10	3	*horma*	1	5	*ruin*	3.5
foco	9.5	11	*silo*	0.5	11	*peine*	10	3	*huso*	4.5	4	*sopor*	8
fosa	4	9	*soda*	4.5	14	*rival*	8	2	*litro*	7.5	3	*tenaz*	10.5
gasa	2	13	*tara*	1	12	*saque*	9	4	*nabo*	0.5	5	*tribu*	10
gata	5	16	*timo*	11	9	*senda*	9	4	*olla*	5.5	3	*usual*	9
lis	3	10	*veda*	2	9	*soplo*	8	4	*tul*	2	3	*viril*	10.5
loto	5	16	*viga*	5	11	*urna*	1	2	*uva*	5.5	4	*zoo*	3

Table 7.2. Spanish Monolingual Study. *Complete set of EXPERIMENTAL ITEMS. WF= Word Frequency; N= Number of Neighbours. LEADER= The most frequent word in the neighbourhood. NONLEADER= Not the most frequent word in the neighbourhood.*

A summary of the characteristics of the words for the various categories is presented in Table 7.3. Average frequency was 229 opm for high frequency words and 6.2 opm for low frequency words. The average word length for large neighbourhoods was 3.9 and for small neighbourhoods it was 4.4[11]. The number of neighbours for the category of large neighbourhoods ranged from 9 to 27, with a mean N of 12.9. For small neighbourhoods, the range of N was 2 to 5, with a mean N of 3.7.

N SIZE →	LARGE NEIGHBOURHOOD						SMALL NEIGHBOURHOOD						NO			
N FREQ →	LEADER			NONLEAD			LEADER			NONLEAD			NBS		OVERALL	
WORD FREQUENCY ↓	WF	WL	N	WF	WL	N	WF	WL	N	WF	WL	N	WF	WL	Mean WF	Range for WF
HIGH	287	4.1	12.3	188	3.8	13.3	293	4.5	3.7	175	4.2	3.5	201	4.2	229	55 – 1432
LOW	—	—	—	4.5	3.9	13.2	8	4.8	3.2	5	4	4.3	7	4.6	6	0.5 – 11
MEAN FOR N	12.9						3.7						—			
RANGE FOR N	9 - 27						2 - 5						—			
MEAN FOR WL	3.9						4.4									

Table 7.3. Spanish Monolingual Study. *Statistics of experimental words according to Word Frequency (WF), Word Length (WL) and Neighbourhood Size (N).*

A further 150 orthographically legal and pronounceable Spanish nonwords[12] were constructed by changing, adding or deleting one letter in real Spanish words. This meant that the nonwords were very word-like (De Groot

[11] I am fully aware that word length can affect lexical decision times (Álvarez *et al.*, 1999). However, in interactive activation models (McClelland & Rumelhart, 1981) all the letters of a short word can be processed in a simultaneous way.

[12] See footnote n.2 in Chapter 3, about the distinction between 'nonwords' and 'pseudowords'.

& Nas, 1991). In the lexical task there were the same number of three, four and five letter nonwords as there were in the experimental items. Furthermore, half the nonwords were obtained from high frequency real words (a frequency of at least 55 opm) and the other half from low frequency real words (a frequency no higher than 12 opm). No experimental word was used to construct nonwords. Table 7.4 presents the complete set of nonwords.

NONWORDS									
Constructed from **HIGH** FREQUENCY WORDS					Constructed from **LOW** FREQUENCY WORDS				
alge	*decil*	*gaber*	*nunto*	*siño*	*abigo*	*chel*	*gañol*	*nea*	*reaz*
allu	*desñe*	*ganto*	*nus*	*sonu*	*adoru*	*chuña*	*gruco*	*nesen*	*rege*
anted	*difo*	*gra*	*ocro*	*subre*	*afifa*	*cies*	*gumo*	*niva*	*rid*
aoco	*dil*	*gron*	*ojoa*	*sulo*	*afo*	*cir*	*hofa*	*ñose*	*rite*
apora	*dolde*	*hager*	*ontre*	*tada*	*alpa*	*colba*	*laed*	*oasid*	*roia*
aque	*elco*	*halta*	*paes*	*tadie*	*ancer*	*comio*	*lañar*	*oaya*	*ruena*
azos	*elmos*	*hania*	*paña*	*tado*	*azafe*	*cupa*	*lauta*	*ojeie*	*seyo*
buan	*elos*	*hape*	*pas*	*taner*	*ban*	*dafa*	*led*	*olgo*	*sijen*
capi	*elua*	*ista*	*pevo*	*tiele*	*bapa*	*dana*	*lifas*	*onon*	*sime*
coho	*equel*	*lon*	*pir*	*tisma*	*bas*	*doca*	*liha*	*pieno*	*sizan*
colo	*eraz*	*lueto*	*pos*	*trus*	*bati*	*doen*	*liño*	*pine*	*tiar*
cruo	*esdas*	*metos*	*puez*	*uda*	*bino*	*edas*	*lixa*	*plom*	*ubra*
cuil	*fisto*	*min*	*sañe*	*unol*	*biso*	*fimen*	*lupro*	*poal*	*xena*
dace	*foe*	*moy*	*sero*	*usten*	*blar*	*flabo*	*melo*	*pole*	*yija*
damae	*fuega*	*nunia*	*sias*	*yajo*	*buco*	*gahos*	*mitis*	*prozo*	*zuto*

Table 7.4. Spanish Monolingual Study. *Complete set of 'high' and 'low' frequency nonwords.*

7.3.3. PROCEDURE

Subjects were tested individually in a single session lasting for about twelve minutes. The task was a lexical decision whose procedure was identical to that of Experiment 1. Briefly, participants saw a number of letter strings on a computer screen. They had to decide as quickly and as accurately as possible whether the letter string was a Spanish real word or not, by pressing a YES-button or NO-button in a response box. The computer recorded accuracy of responses and RT to the stimuli in milliseconds.

Each trial was made up of the following sequence: A fixation point (an asterisk) on the screen lasting 500 ms, followed by the stimulus presented in the same position, in lowercase (in black bold 18-point courier against a white screen). The participant's response terminated the stimulus display and the fixation point reappeared after a timed interval of 500 ms. The computer automatically randomised the presentation of the items for every subject. All the subjects were presented with all the experimental materials. The experiment started with a small practice session of 12 trials.

7.4. RESULTS

Mean RT for correct responses to words, and error rates for words, were calculated[13]. For words, latency times shorter than 300 ms and longer than 1500 ms (0.38% of the data) were omitted from the analysis[14].

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[13] All the calculations were done using SPSS 9.0. See footnote n.9 in Chapter 6 (Experiment 1).

[14] Cut-off points for outliers –very short or very long latency times– are commonly applied in the analysis of RT in lexical decision tasks. Perea and Algarabel (1999) point out that outliers are not only observations that lie outside the bulk of data, they could also be observations that do not belong in the distribution of the experimental data. These responses are probably the result of factors unrelated to the experimental design, such as distraction of the subject's attention or a hiccup in the equipment. Perea and Algarabel (1999) suggest that the method of truncated means –the one applied in this experiment– is a very useful method to increase statistical power. For a study of other methods for dealing with RT outliers see, Perea and Algarabel (1999) and Ratcliff (1993).

Table 7.5 presents results of RT for correct responses to words. RT are given globally for the three independent variables: Word Frequency, Neighbourhood Size, and Neighbourhood Frequency, and this conveys a preliminary idea of first order effects. *RT DIFFER* refers to the difference in RT between two levels of the same variable: when the difference is 'negative', results point towards confirmation of the hypotheses of the study, when the difference is 'positive', results run contrary to the hypotheses of the study.

	NEIGHBOURHOOD SIZE				**NEIGHBOURHOOD FREQUENCY**			
	LARGE	SMALL		NO 'N'	LEAD	NON-LEAD		
WORD FREQUENCY	RT	RT	*RT DIFFER*	RT	RT	RT	*RT DIFFER*	MEAN RT
HIGH	550	544	*+6*	541	543	551	*–8*	545
LOW	637	622	*+15*	653	608	637	*–29*	637
RT DIFFER	*–87*	*–78*		*–112*	*–65*	*–86*		*–92*
MEAN RT	593	583	*+10*	597	575	594	*–19*	

Table 7.5. Spanish Monolingual Study. *Results for the INDEPENDENT VARIABLES. Mean RT in ms to correct responses. RT DIFFER= Difference in mean RT between two levels of a variable.*

Table 7.6 presents results for words across all the different conditions of the experimental design for correct answers and error rates.

N SIZE →	LARGE NEIGHBOURHOOD					SMALL NEIGHBOURHOOD					NO NEIGHBOURS	
N FREQ →	LEADER		NON-LEADER			LEADER		NON-LEADER				
WORD FREQUENCY ↓	RT	ERROR (%)	RT	ERROR (%)	*RT DIFFER*	RT	ERROR (%)	RT	ERROR (%)	*RT DIFFER*	RT	ERROR (%)
HIGH	549	1.4	551	2	*−2*	538	1.8	550	2.2	*−12*	541	1.2
LOW	—	—	637	11.7	—	608	4	637	9.8	*−29*	653	11.9
RT DIFFER			*−86*			*−70*		*−87*			*−112*	
MEAN RT			594			573		593		*−20*	597	

Table 7.6. Spanish Monolingual Study. *Results ALL the experimental CONDITIONS. Mean RT to correct responses in ms and Error Rates in percentages. RT DIFFER= Difference in mean RT between two levels of the same variable.*

Mean RT were calculated independently across subjects and items, and separate analyses of variance (ANOVAs) were conducted on each set of data. The variables Word Frequency, N and NF were used as within-subjects factors in repeated-measures ANOVAs for subjects, and as between-subjects factors in ANOVAs for items. Average numbers of incorrect answers to words for subjects and items were analysed in the same way. The resulting F values are given as F_s for subjects, and as F_i for items[15]. The *p* level, at which results were considered significant (level of confidence to reject the null hypothesis), was set at 0.05.

Although the independent variables were the same as for Experiment 1, the experimental design was not as neatly nested. As explained earlier, the experimental category 'Low WF & Large N & NF Leader' did not, in fact, exist because it was an 'empty' category. In addition, the NF variable was irrelevant at the level of 'No Neighbours' of the N variable. For these reasons, the three

[15] See footnote n.11 on the use of F_s and F_i in Chapter 6 (Experiment 1).

independent variables could not be statistically analysed in a fully factorial design and, consequently, partial ANOVAs on different subsets of the data had to be carried out:

- ANOVA on the full data to analyse WF and N (design: 2 x 3)
- ANOVA on data exclusive of 'No neighbours', to analyse WF and NF (design: 2 x 2)
- ANOVA on high frequency data exclusive of 'No neighbours', to analyse N and NF in (design: 2 x 2)
- *t*-tests on low frequency words[16], comparing means of N and means of NF.

7.4.1. RESPONSE LATENCIES

ANOVA results for words are shown in Table 7.7. As in Experiment 1, latency data for words revealed a significant main effect for Word Frequency for both subject and item data. High frequency words were identified significantly faster (92 ms faster) than low frequency words[17]. The effect of N was also significant for subjects, with words with few neighbours being responded to faster than either words with many neighbours or words with no neighbours (see Figure 7.1). *Post hoc* comparisons revealed that mean RTs for small N words were significantly smaller than mean RT for large N words and words with no neighbours (this result is somewhat surprising and we will come back to it in the discussion). Equally, the main effect of NF was reliable both in the subject and item data. This influence was inhibitory: having higher

[16] The absence of the 'Low WF & Large N & NF Leader' category made it impossible to perform an ANOVA on low frequency words.

[17] Mean RT to high frequency words was 545 ms, and to low frequency words, 637 ms.

frequency neighbours was detrimental for item recognition (see Figure 7.1). As hypothesised, words that were NF leaders were responded to 19 ms faster than nonleaders.

CORRECT RESPONSES			
EFFECTS	F_S & F_i	MSE	$p<$
WORD FREQ. (WF)	$F_S(1,62) = 457.6$	1763	*.001*
	$F_i(1,144) = 135.0$	2545	*.001*
NEIGHB. SIZE (N)	$F_S(2,124) = 8.1$	836	*.001*
	$F_i(2,144) = 1.4$	2545	*.237*
NEIGHB. FREQ. (NF)	$F_S(1,62) = 22.7$	878	*.001*
	$F_i(1,116) = 4.8$	2188	*.031*
WF x N	$F_S(2,124) = 12.5$	756	*.001*
	$F_i(2,144) = 1.7$	2545	*.188*
WF x NF	$F_S(1,62) = 9.7$	753	*.003*
	$F_i(1,116) = 2.1$	2188	*.154*

Table 7.7. Spanish Monolingual Study. *ANOVA results of CORRECT RESPONSES to words, for subject and item data. WF= Word Frequency; N= Neighbourhood Size; NF= Neighbourhood Frequency. Significant results are highlighted.*

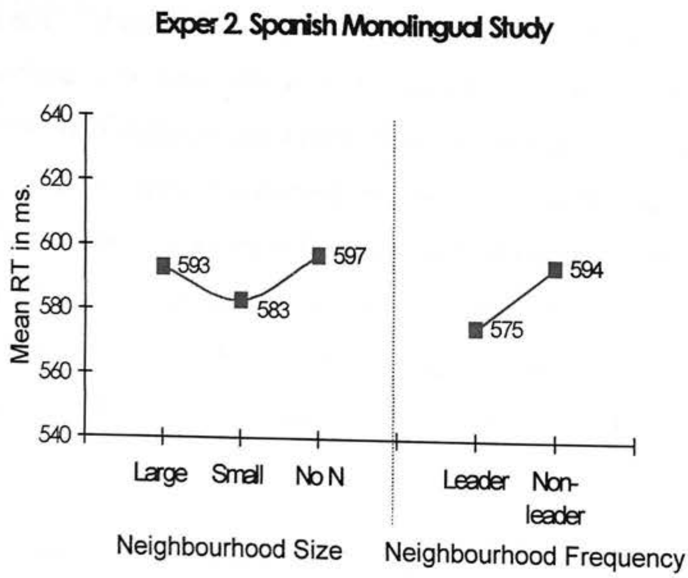

Figure 7.1. Spanish Monolingual Study. *Profile plot of RTs to words, according to N and NF.*

The interaction between Word Frequency and N was significant in the by-subjects analysis. In this interaction, a rather striking effect was that high frequency words with no neighbours elicited faster responses than other high frequency words (both large and small N), whereas low frequency words with no neighbours were reacted to more slowly than other low frequency words (see Figure 7.2).

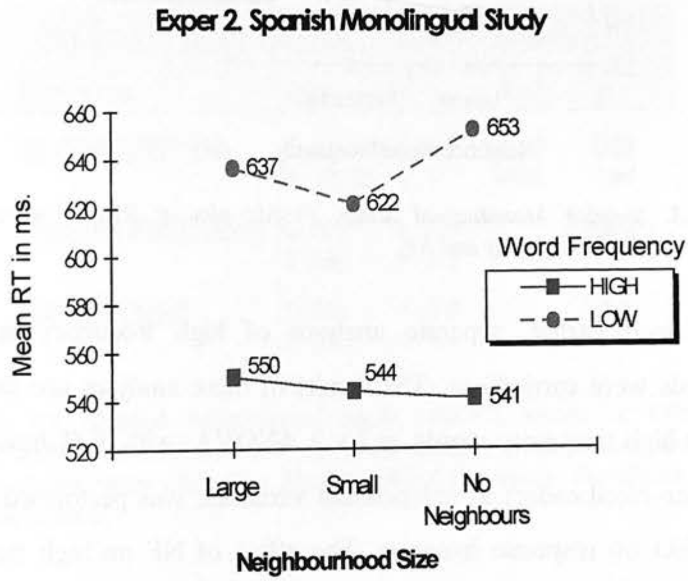

Figure 7.2. Spanish Monolingual Study. *Profile plot of RTs to words, according to Word Frequency, and N.*

The interaction between Word Frequency and NF was also significant in the subject data. Having higher frequency neighbours had an inhibitory effect, which seemed stronger in the case of low frequency words (29 ms) than in the case of high frequency words (only 8 ms). This interaction is illustrated in Figure 7.3.

frequency neighbours was detrimental for item recognition (see Figure 7.1). As hypothesised, words that were NF leaders were responded to 19 ms faster than nonleaders.

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EFFECTS	F_S & F_i	MSE	$p <$
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	F_i (1,144) = 135.0	2545	*.001*
NEIGHB. SIZE (N)	F_S(2,124) = 8.1	836	*.001*
	F_i (2,144) = 1.4	2545	*.237*
NEIGHB. FREQ. (NF)	F_S (1,62) = 22.7	878	*.001*
	F_i (1,116) = 4.8	2188	*.031*
WF x N	F_S(2,124) = 12.5	756	*.001*
	F_i (2,144) = 1.7	2545	*.188*
WF x NF	F_S (1,62) = 9.7	753	*.003*
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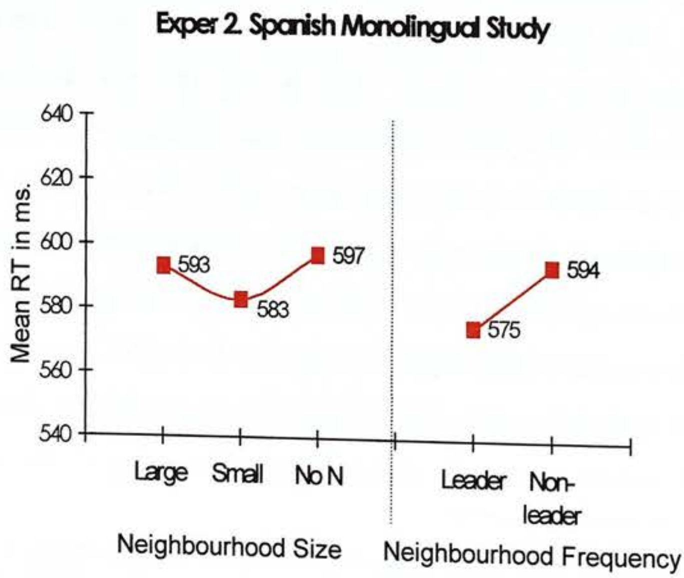

Figure 7.1. Spanish Monolingual Study. *Profile plot of RTs to words, according to N and NF.*

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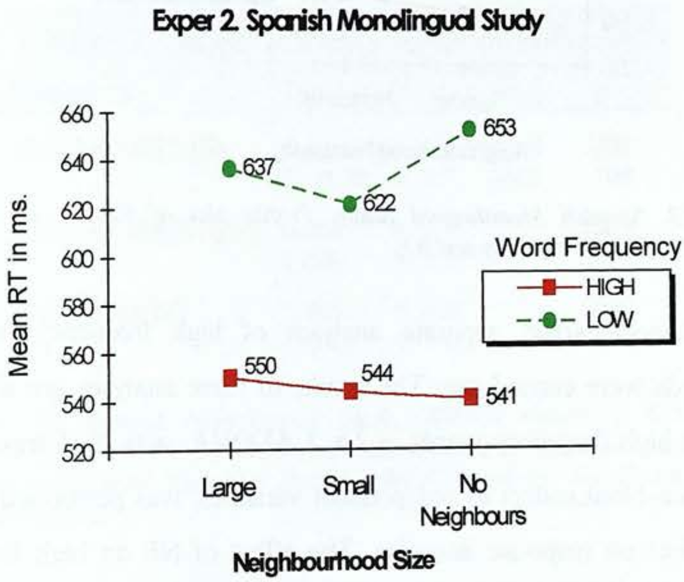

Figure 7.2. ***Spanish Monolingual Study.*** *Profile plot of RTs to words, according to Word Frequency, and N.*

The interaction between Word Frequency and NF was also significant in the subject data. Having higher frequency neighbours had an inhibitory effect, which seemed stronger in the case of low frequency words (29 ms) than in the case of high frequency words (only 8 ms). This interaction is illustrated in Figure 7.3.

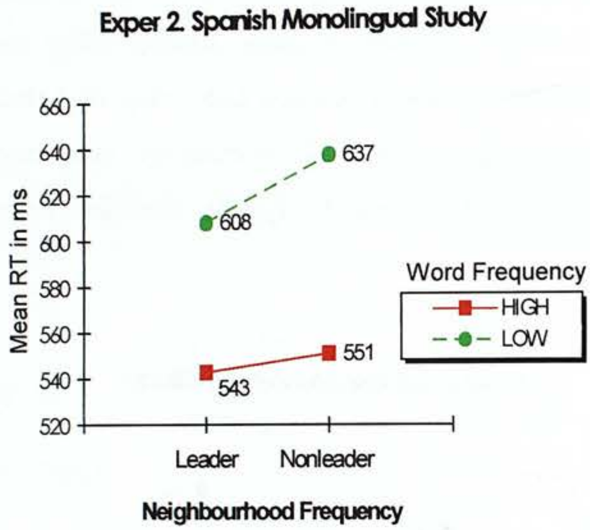

Figure 7.3. Spanish Monolingual Study. *Profile plot of RTs to words, according to Word Frequency and NF.*

As explained earlier, separate analyses of high frequency and low frequency words were carried out. The results of these analyses are shown in Table 7.8. For high frequency words, a 2 x 2 ANOVA, with N (Large–Small) and NF (Leader–NonLeader) as independent variables, was performed. N had no reliable effect on response latencies. The effect of NF on high frequency words only approached significance in the subject data set, with a tendency for high frequency words to be reacted to faster when they were NF leaders than when they were not leaders (the difference was 8 ms). The interaction between N and NF was not statistically reliable.

As already stated, a 2 x 2 ANOVA could not be carried out on low frequency word data because there was one category missing. Instead, the following analyses were performed:

- a one-way ANOVA for N (Large – Small – No Neighbours)
- a comparison of means for NF (Leader – Nonleader)
- a comparison of means for Small N (NF Leader – NF Nonleader)

CORRECT RESPONSES (High Freq words only)			
EFFECTS	F_S & F_i	MSE	*p* <
NEIGHB. SIZE (N)	$F_S(1,62) = 3.0$	925	*.087*
	$F_i < 1$		
NEIGHB. FREQ. (NF)	$F_S(1,62) = 3.9$	798	*.052*
	$F_i(1,56) = 1.1$	662	*.303*
N x NF	$F_S(1,62) = 3.2$	433	*.077*
	$F_i < 1$		

CORRECT RESPONSES (Low Freq words only)			
EFFECTS	Tests	MSE	*p* <
NEIGHB. SIZE (N)	$F_S(2,124) = 12.9$	1149	*.001*
	$F_i(2,72) = 1.7$	4452	*.194*
NEIGHB. FREQ. (NF)	$t_S(62) = 4.6$		*.001*
	$t_i(58) = 1.8$		*.072*
SMALL N x NF	$t_S(62) = 3.9$		*.001*
	$t_i(28) = 1.5$		*.145*

Table 7.8. Spanish Monolingual Study. *ANOVA results of CORRECT RESPONSES to HIGH and LOW frequency words, for subject and item data. N= Neighbourhood Size; NF= Neighbourhood Frequency. Significant results are highlighted.*

The comparison of means was done using paired-samples *t*-tests for the subject data, and independent-samples *t*-tests for the item data. N was found to have a significant effect on low frequency words for subjects. However, the pattern of results is surprising: large N words showed inhibitory effects relative to small N (a disadvantage of 15 ms), but they showed facilitatory effects relative to words with no neighbours (an advantage of 16 ms). NF also had a significant effect on low frequency words in the subject data. NF leaders were processed 29 ms faster than NF nonleaders. An identical pattern was found in the comparison of NF leaders and NF nonleaders within small neighbourhoods, with a significant mean difference in the by-subjects analysis (the advantage for NF leaders was also 29 ms).

7.4.2. ERROR RATES

The overall error rate in the experiment was 5.8% (see detailed results on Table 7.6 above). Average number of incorrect responses to words were submitted to exactly the same analyses as RT for correct responses; that is, a repeated-measures ANOVA for subject data and an ANOVA for item data. F results are provided in Table 7.9.

INCORRECT RESPONSES			
EFFECTS	F_S & F_i	MSE	$p <$
WORD FREQ. (WF)	F_S (1,62) = 102.7	1.9	*.001*
	F_i (1,144) = 31.3	30.7	*.001*
NEIGHB. SIZE (N)	F_S (2,124) = 4.9	0.8	*.013*
	F_i (2,144) = 1.1	30.7	*.348*
NEIGHB. FREQ (NF)	F_S (1,62) = 93.4	1.3	*.001*
	F_i (1,116) = 5.5	26.5	*.021*
WF x N	F_S (2,124) = 1.8	.6	*.168*
	F_i (2,144) = 1.6	30.7	*.199*
WF x NF	F_S (1,62) = 76.4	1.3	*.001*
	F_i (1,116) = 3.8	26.5	*.054*

Table 7.9. Spanish Monolingual Study. *ANOVA results of INCORRECT RESPONSES to words, for subject and item data. WF= Word Frequency; N= Neighbourhood Size; NF= Neighbourhood Frequency. Significant results are highlighted.*

The main effect of Word Frequency on error rates to words was significant for both subject and material data. This meant that participants committed significantly fewer mistakes in responding to high frequency words (1.7%) than in responding to low frequency words (9.8%). The effects of N were significant in the subject data, in that words belonging to small neighbourhoods were processed more accurately (mistakes: 4.4%) than words with large neighbourhoods (mistakes: 6.7%) or words with no neighbours (mistakes: 6.5%). It was interesting that the same surprising results for N in RT to words should be obtained with error rates. The effect of NF was significant both in the subject and item analyses. Subjects made fewer errors to words that were NF leaders (2.8%) than to words that were NF nonleaders (6.6%). Again, this pattern was similar to the one observed in latencies of correct responses.

The interaction between Word Frequency and N was not significant. There was a reliable interaction between Word Frequency and NF, both in the subject and item data. More mistakes were made to low frequency words with higher frequency neighbours (11.1%) than to low frequency words with no higher frequency neighbours (4%). Error rates in high frequency words were not affected by NF.

As regards error rates in high frequency words, N showed a significant effect [F_s (2,124) = 7.97, MSE = .40, $p < .001$; $F_i < 1$], with 'no neighbours' as the category for which subjects committed significantly fewer mistakes[18]. The interaction between N and NF was not statistically reliable [$F_s < 1$ and $F_i < 1$]. For low frequency words with small neighbourhoods, there was a significant inhibitory effect of NF [t_s (62) = 4.9, $p < .001$; t_i (28) = 1.6, $p < .118$]. Subjects made significantly more errors when the words were NF nonleaders (9.8%) than when the words were NF leaders (4%). In sum, results for error rates fully replicate those obtained for RT with correct responses.

Here is a summary of the results of the Spanish Monolingual Study in relation to the hypotheses made at the start of the experiment:

[18] The percentages of mistakes for high frequency words in the different N categories were as follows: Large N, 1.7%; Small N, 2%; and No N, 1.2%. However significant, these figures must be interpreted with caution because the actual number of mistakes for high frequency words was very low.

1. The first hypothesis was that high frequency words would be processed faster and more accurately than low frequency words (the **word frequency effect**). This study confirmed the hypothesis.

2. The second hypothesis was that words belonging to large neighbourhoods would be processed faster and more accurately than words from small neighbourhoods (the **neighbourhood size effect**). This hypothesis was not confirmed. The opposite was found in this study: it was words belonging to small neighbourhoods, not large neighbourhoods, that were recognised both faster and more accurately.

3. The third hypothesis was that words that are frequency leaders in their neighbourhood would be processed faster and more accurately than NF nonleaders (the **neighbourhood frequency effect**). This hypothesis was clearly confirmed with the Spanish data.

7.5. DISCUSSION

The main results of this experiment about neighbourhood effects on visual word recognition in Spanish were as follows:

1. NF had an inhibitory effect on response time. Words with higher frequency neighbours were processed both more slowly and less accurately than words without higher frequency neighbours.

2. N interacted with Word Frequency. There were significant inhibitory effects of N with low frequency words, which disappeared with high frequency words.

3. NF interacted with Word Frequency. Having higher frequency neighbours was more detrimental on the speed and accuracy of recognition of low frequency words.

4. Both the Spanish Monolingual Study and the English Monolingual Study showed robust word frequency effects, but these effects were particularly strong with Spanish stimuli.

The most salient finding of this experiment was a clear inhibitory NF effect, observed both for latency data and error data (see Figure 7.3, shown earlier). This finding replicates inhibitory results of NF obtained in previous studies, studies which were done with different languages, mostly Dutch, French and Spanish, but also English. They were also done with different experimental paradigms, not only those requiring speeded word identification, but also with normal silent reading (Carreiras *et al.*, 1997; Grainger, 1990; Grainger *et al.*, 1989, 1992; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Huntsman & Lima, 1996; Perea, 1993; Pollatsek *et al.*, 1999; Perea & Pollatsek, 1998). Particularly relevant to the results of this experiment are the results obtained by Carreiras *et al.* (1997) with Spanish stimuli, which this study fully replicates.

Not all studies on Neighbourhood Frequency, have yielded inhibitory effects. Some experiments (Forster & Shen, 1996; Sears *et al.*, 1995) have conveyed null effects of NF in lexical decision tasks. These experiments, however, differed in two important respects from other studies, including this one, where inhibitory effects of NF were found. The two aspects were faster overall RT and higher error rates, which were the result of the instructions emphasising speed over accuracy in the lexical decision. Perea and Rosa (2000) have argued that faster responses and more mistakes show a more 'superficial' level of processing, and that this could account for the null effects of NF obtained by Sears and colleagues, and by Fosters and Shen.[19].

The picture revealed by the effect of N in the Spanish Monolingual Study was more complex than that of NF effects. The results of N in this study were not conclusive. As stated earlier, experimental data about the effects of N are not consistent. A good number of previous studies have obtained facilitatory effects of N in lexical decision tasks (Andrews, 1989, 1992; Bozon & Carbonnel, 1996; Carreiras *et al.*, 1997 [LDT with density blocking[20]]; Foster & Shen, 1996; Johnson & Pugh, 1994; Pollatsek *et al.*, 1999; Sears *et al.*, 1995). However, some researchers have failed to replicate those results (Carreiras *et al.*, 1997 [LDT without density blocking]; Coltheart *et al.*, 1977; Grainger *et al.*, 1989; Mathey & Zagar, 1996; Paap & Johansen; 1994; Ziegler & Perry, 1998). Particularly relevant were the null effects of N for words in the standard LDT of Carreiras *et al.* (1997). In the light of the conflicting evidence, two questions need to be addressed in connection with the results of this experiment. First, why effects of N were observed for Spanish and not for English; and second, why the results for Spanish were significant but not clearly facilitatory or inhibitory.

First, we will look at the question of the different results for N in the two monolingual studies. As argued when discussing the results of Experiment 1, the higher mean frequency of the stimuli in the English Study could account for

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[19] It should be noted here that no significant NF effects were observed in the English Monolingual Study either. As I argued, this lack of effect could have been due mostly to the relatively high word frequency of the stimuli.

[20] Carreiras *et al.* (1997) manipulated the number of neighbours of word and nonwords, in an LDT where word stimuli were density-blocked (large N words and small N words were presented in two different blocks) and nonwords were not. They found that effects of large N were facilitatory for words and inhibitory for nonwords.

the null effects of N. In the Spanish experiment, the mean frequency for high frequency words was only 229 opm (*vs* 600 opm for the English experiment) and just 6 opm for low frequency words (*vs* 41 opm for the English experiment). This lower mean frequency may explain the presence of N effects in the Spanish data, as it has been shown that lower frequency words are more sensitive than high frequency words to neighbourhood effects (Andrews, 1989).

The second question has to do with the nature of N effects. Figure 7.2 (already shown) illustrates how, in the present experiment, low frequency words from large neighbourhoods were processed more slowly than words from small neighbourhoods (inhibitory effect) but faster than words with no neighbours (facilitatory effect).

The contradiction implicit in the pattern shown by low frequency words relative to high frequency words may not be as puzzling as it might first appear. We need to consider experiments that have carefully looked at effects of N and NF together. Some researchers (Carreiras *et al.*, 1997; Paap & Johansen, 1994; Pollatsek *et al.*, 1999) have argued that higher frequency neighbours are 'competitors', and that lower frequency neighbours are 'helpers'. Facilitatory effects of large N have been registered mostly in experiments where the number of higher frequency neighbours was controlled (Carreiras *et al.*, 1997; Forster & Shen, 1996; Perea, 1993; Sears *et al.*, 1995). In these studies, the facilitatory effects could have been caused by a larger number of lower frequency neighbours. In Andrews' (1989, 1992) experiments, where NF was not controlled, the reported facilitatory effects of N could have been caused by the effects of a greater number of lower frequency neighbours, more so than by the number of neighbours *per se*. In the current Spanish study the large N category in low frequency words consisted only of NF nonleaders, i.e. all the stimuli had higher frequency neighbours. Now, if it is true that higher frequency neighbours are competitors and that lower frequency neighbours are helpers, this could explain the inhibitory effects observed (in relation to the 'No N' category), since all the words had at least one strong competitor. Furthermore, the irregular pattern of N effects on low frequency words shows that N alone is not the determinant factor that some researchers argue (Andrews, 1997).

Why the hypothesised facilitatory effects of N were not obtained could be due to the different nature of orthography in English and Spanish. Andrews (1997), who found clear facilitatory effects of N, indicated that language may be a determinant factor in the nature of N effects, and that some of the effects described in the literature could be specific to the English language. In particular, Andrews suggested that 'facilitatory effects of neighbourhood size in English may arise because orthographic bodies play a more important role in lexical retrieval than they do in languages with a more consistent orthographic-to-phonological mapping' (Andrews, 1997: 458). This could explain why some studies with French or Spanish, languages with a more consistent orthography-phonology relationship, have either found no N effect or the effects were inhibitory. It should be noted that Carreiras *et al.* (1997), working with Spanish stimuli, obtained facilitatory effects of N only in a LDT with density blocking[21], and that they did not find this facilitatory effect with the standard LDT. The findings of my experiment are consistent with the language specific view of N effects.

The direction and degree of N effects can also be influenced by instructions about the task given to participants in experiments. As noted

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[21] Carreiras *et al.* (1997) manipulated N such that words were presented in two separate blocks of large and small neighbourhoods, along with nonwords which could belong to either large or small neighbourhoods; that is, density blocking affected only the critical words. Their assumption was that this presentation would improve discrimination of words *vs* nonwords and should translate into higher facilitatory effects of neighbourhood size for word stimuli. Results showed that their assumption was correct.

earlier, Carreiras *et al.* (1997) have suggested that emphasising accuracy over speed and using nonwords with large neighbourhoods may reduce the facilitatory effect of N for low frequency words. In studies where speed was stressed over accuracy (Grainger & Jacobs, 1996), an increase in the facilitatory effects of N was found. It is worth noting that in the present experiment accuracy and speed were stressed to the same degree, and that the error rate was 5.8%. This contrasts with error rates of over 10% registered in other experiments, which emphasised speed and which found facilitatory effects of large N (for example, Sears *et al.*, 1995; Forster & Shen, 1996). It is probable that if accuracy is stressed, participants would adopt a 'making sure' approach to the lexical decision, which in turn would give rise to 'strategic' checking processes in the LDT and to a decrease in the facilitatory effect of N.

One final comment on methodology. It is somewhat puzzling that most studies on N effects only include two levels of N: large and small neighbourhoods. The present experiment included a third condition –no neighbours– which is arguably essential in establishing the facilitatory or inhibitory nature of N. I agree with Perea and Rosa (2000) in that research should perhaps be more imaginative in the manipulation of this variable, getting away from the dichotomous approach of high and low density and moving towards greater number of neighbourhood size conditions.

The conclusion of this experiment is that, whereas expected inhibitory effects of NF were robust and consistent with results of other experiments, the nature of N effects is much less straightforward and perhaps less influential in (Spanish) lexical processing than NF.

Chapter 8

Experiment 3: Language-Block Study[1] of Neighbourhood Effects with Bilingual Speakers of English and Spanish

Experiment 3 investigated if neighbourhood effects observed in visual word recognition with monolingual speakers were also observed with bilingual speakers. Specifically, the study was designed to examine if neighbourhood

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[1] I named Experiment 3 'Language-Block Study' because the presentation of the bilingual stimuli was blocked for language. All the English items were presented in one block, and all the Spanish items were presented in another block.

effects observed in English and Spanish were language specific for bilingual speakers of those languages. There were five independent variables in this study. Native Language was the only between-subjects variable. The other four variables were Target Language (English, Spanish), Word Frequency (High, Low), Neighbourhood Size (Large, Small), and Neighbourhood Frequency (Leader, Nonleader). Eighty bilingual speakers of English and Spanish (forty native speakers of English and forty native speakers of Spanish) were tested in a lexical decision task, with English and Spanish stimuli arranged in two separate language blocks. The main results of Experiment 3 were as follows:

1. For all participants, the main effect of NF was significantly inhibitory. Effects of N were significantly facilitatory with low frequency words.
2. For English items, facilitatory effects of N were observed for all speakers. NF had no significant effects in lexical performance across speakers.
3. For Spanish items, N did not yield significant differences. NF showed highly inhibitory effects in the performance of both groups of speakers.
4. For English speakers, N interacted with target language. Results showed facilitatory effects of N for English items, and inhibitory effects of NF for Spanish items.
5. For Spanish speakers, N showed robust facilitatory effects across languages.
6. Low frequency items of both languages showed higher sensitivity to neighbourhood effects than higher frequency items.

Results are discussed and compared with neighbourhood effects found in monolingual processing of English and Spanish in previous experiments.

8.1. INTRODUCTION AND HYPOTHESES

The results from Experiments 1 and 2 suggested that effects of neighbourhood vary according to the experimental language. In English, neighbourhood size and neighbourhood frequency were facilitatory for low frequency words: large neighbourhoods and higher frequency neighbours improved lexical processing. In contrast, in Spanish, neighbourhood frequency was clearly inhibitory: NF nonleaders were reacted to more slowly and less accurately than NF leaders. In addition, the size of neighbourhood had no significant effect on Spanish word recognition. In the discussion of the results of the previous experiments, it was suggested that the different effects that neighbourhoods have in English, compared to other languages (e.g. Spanish) may be due to one or both of the following reasons:

- The differences in spelling-to sound consistencies between English (deep orthography) and Spanish (shallow orthography).
- The differences in the role of syllabic structure in both languages.

It has been strongly argued (Andrews, 1997; Treiman *et al.*, 1995; Ziegler & Perry, 1998; Ziegler *et al.* 2001) that N, in the form of body neighbours or rime units, may play a special role in English processing, because they help English readers to bridge the gap between the idiosyncrasies of the English spelling and the phonological system. In other words, body neighbours are particularly relevant in English because they represent an effective interface between phonology and orthography. Spanish readers, on the other hand, do not need to develop any extra sensitivity to help in the orthography-to-phonology mapping, because of the high levels of spelling-to-sound consistencies in this language.

Furthermore, some studies have shown that Spanish readers are strongly influenced by syllabic structure (Carreiras *et al.*, 1993; Domínguez *et al.*, 1997; Perea & Carreiras, 1998). Conversely, English syllables have much more blurred boundaries and their role in word recognition is arguably less influential than in Spanish (Perea & Carreiras 1998).

The previous arguments lead to the question of whether the language specificity of neighbourhood effects, observed in monolingual speakers of two languages differing in orthographic depth, is also observed in bilingual speakers of those languages. The answer to this question has implications for models of bilingual word recognition. This was the issue addressed in Experiment 3. In more particular terms, the aim of the experiment was to investigate to what extent the neighbourhood effects observed in native speakers of English and native speakers of Spanish were also observed in second language speakers of those languages.

Experiment 3 was a bilingual replication of the previous English and Spanish Monolingual Studies. Both the subjects and the stimuli were bilingual. The relevance of a bilingual experiment such as this is twofold:

1. It allows the study of neighbourhood effects for second language speakers. For example, the researcher can explore whether the facilitatory effects of N observed in many studies in English, with English native speakers, are also present when Spanish speakers process English stimuli.

2. Similarly, it allows the researcher to see how 'robust' neighbourhood effects are across languages. For example, if facilitatory effects of N are found for English items but not for Spanish items, and inhibitory effects of NF are present for English and Spanish items, it would be reasonable to argue that NF effects are more powerful or robust than

N effects.

Experiment 3 was a novel experiment, in that:

1. The group of bilingual speakers included native speakers of both languages, not only one language.
2. The experimental languages were English and Spanish.
3. The variables, Word Frequency, Neighbourhood Size and Neighbourhood Frequency, were manipulated orthogonally, in both languages.
4. All the subjects were tested under all the experimental conditions.

Experiment 3 worked on the general assumption that neighbourhood effects are language specific. In particular, the experimental hypotheses of the study were as follows:

1. For English stimuli, words from large neighbourhoods are processed more rapidly than words from small neighbourhoods (facilitatory effects of N in English), both for L1 and L2 speakers.
2. For English stimuli, words that are neighbourhood frequency nonleaders are recognised more rapidly than words that are NF leaders (facilitatory effects of NF in English), both for L1 and L2 speakers.
3. For Spanish stimuli, neighbourhood size has no effect on lexical processing time (null effects of N in Spanish) either for L1 or L2 speakers.
4. For Spanish stimuli, words that are neighbourhood frequency nonleaders are recognised more slowly than words that are NF leaders (inhibitory effects of NF in Spanish) both for L1 and L2 speakers.

8.2. VARIABLES

The dependent variables were reaction times (RT) to correct responses in a lexical decision task, measured to the nearest millisecond, and percentages of incorrect responses. There were five independent variables: Target Language (TL), Word Frequency (WF), Neighbourhood Size (N) and Neighbourhood Frequency (NF), as within-subjects variables, and Native Language as a between-subjects variable. The operational definitions of these variables were kept as similar as possible to those used in the two previous studies. However, because of the bilingual nature of this experiment, some adjustments had to be made for word frequency (see section 8.2.2).

8.2.1. TARGET LANGUAGE (TL)

There were two conditions in the Target Language variable, English and Spanish:

1. **English stimuli**: These were English real words and English nonwords.

2. **Spanish stimuli**: These were Spanish real words and Spanish nonwords.

In each language, the nonwords were orthographically legal and pronounceable letter strings. These showed a high degree of word-likeness in the corresponding language, as they had been formed by changing, adding or deleting real English and Spanish words. All the stimuli were presented in two language blocks, an English block and a Spanish block, such that targets of both languages were never mixed.

8.2.2. WORD FREQUENCY (WF)

Estimates of word frequency were based on the same frequency counts as those used for the English and Spanish monolingual studies (Kuçera & Francis, 1967, for English; and Alameda & Cuetos, 1995, for Spanish). There were two levels of word frequency: 'high' and 'low' frequency.

1. **High Frequency Words**: In both languages these items had a written frequency of at least 150 occurrences per million (opm). Examples of these words are *many* (1030 opm) and *cosa* [thing] (465.5 opm).

2. **Low Frequency Words**: These items had a frequency no higher than 55 opm and no lower than 25 opm. Examples of words in this category are *rope* (40 opm) and *mayo* [may] (38 opm).

The operational definition of the variable Word Frequency was the same as that of the English Monolingual Study, but was different from the one used in the Spanish Study. In the latter study, the frequency of the low frequency words was much lower than in the current experiment[2]. This change in the definition of 'low frequency' words was introduced for the following three reasons:

- In the Spanish Monolingual Study the frequency of the low frequency words would have been too low (no higher than 12 opm) for non-

[2] The change in the operational definition of Word Frequency meant a shift upwards of the frequency brackets for both levels of the variable, but particularly for low frequency words. The low frequency words in the Spanish Monolingual Study ranged from 0.5 to 12 opm, and in the Language-Block Study the range was 25 to 55 opm. I am aware that what is here called 'low frequency' words could be considered 'medium frequency' words by other researches (Van Heuven *et al,*, 1998). However, I have preferred to maintain the term 'low frequency', for consistency, throughout the thesis.

native speakers of Spanish to comfortably recognise the words in that category (even for advanced L2 speakers)[3]. Had that very low frequency been kept in this bilingual experiment, non-native subjects might simply have classed the corresponding words as nonwords, and the lexical decision would have lost its purpose.

- Very low frequency specifications make it more difficult to find appropriate stimuli and can lead to 'empty' categories in the experimental design (e.g. in the Spanish Monolingual Study). Empty categories are best avoided, as they impose many limitations on the statistical analysis.
- It would be easier to compare results across languages[4], by making the operational definition of Word Frequency for both languages exactly the same.

8.2.3. NEIGHBOURHOOD SIZE (N)

The variable Neighbourhood Size, based on Coltheart *et al.*'s (1977) definition of 'neighbour', had two levels in both languages, 'large' and 'small' neighbourhoods[5], with the following operational definitions:

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[3] Bijeljac-Babic *et al.* (1997) have found that second language speakers are very likely to process higher frequency words as lower frequency words.

[4] Some aspects of the results of the two monolingual studies were not fully comparable because there were considerable differences in the word frequency categories.

[5] In order for the experimental design to be fully factorial, this study did not include a 'No neighbours' category (which the Spanish Study did). A 'No Neighbours' level of N cannot, by definition, be crossed with the two levels of the NF (Frequency Leader and Nonleader).

1. **Large neighbourhoods** had 7 neighbours or more.

2. **Small neighbourhoods** had 6 neighbours or less.

8.2.4. NEIGHBOURHOOD FREQUENCY (NF)

The variable Neighbourhood Frequency referred to the frequency of the neighbours. This variable had two levels: 'NF leader' and 'NF nonleader'.

1. **Neighbourhood Frequency Leaders** had no higher frequency neighbours.

2. **Neighbourhood Frequency Nonleaders** had one or more higher frequency neighbours in their neighbourhood.

8.2.5. NATIVE LANGUAGE (NL)

Native language was the only between-subjects variable. Subjects were chosen to fit one of two categories:

1. **Native Speaker of English** with advanced level of Spanish as a second language.

2. **Native Speaker of Spanish** with advanced level of English as a second language.

For the purpose of the study, the definition of 'advanced level' of L2 meant L2 competence similar or superior to the level required by The University of Edinburgh for academic purposes.

8.3. METHOD

8.3.1. SUBJECTS

Eighty bilingual speakers[6] of English and Spanish participated in the Language-Block Study. Forty were native speakers of English with advanced knowledge of Spanish, and forty were native speakers of Spanish with advanced knowledge of English. All the participants were unpaid volunteers and none of them had taken part in the earlier studies. They all had normal or corrected-to-normal vision.

The English native speakers were all students in their Final Year of a Spanish Degree at the University of Edinburgh. The vast majority of them had studied Spanish formally for six or more years (four of which were at university level). All of them had spent at least six months in a Spanish speaking country within the eighteen months previous to the experiment. The Spanish speakers were all students at The University of Edinburgh. Thirty of them were postgraduate students and ten were 'Erasmus' students. All of them had passed an English language exam compulsory for foreign students studying at Edinburgh University. All the Spanish speakers had lived in Great Britain at least for the six months previous to the experiment. The level of the L2 competence of both groups of speakers could be described as that of 'advanced learners'. However, as a group, the Spanish speakers were more fluent (perhaps

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[6] As stated in Chapter 1, the term 'bilingual speaker' is used here in its strictly etymological sense, that is to refer to 'somebody who speaks two languages', with no reference to how competent the speaker is in either language.

also more competent) in English than the English speakers were in Spanish, because the Spaniards were living in Britain at the time of testing[7].

Before the experiment, participants were informally interviewed about their linguistic background, time of L2 study, length of stay in English and Spanish speaking countries, perceived level of L2 competence, formal education and hand dominance.

8.3.2. STIMULI AND DESIGN

The five independent variables, described earlier, fitted a 2 x [2 x2 x2 x 2] mixed experimental design: Native Language (English, Spanish) x [Target Language (English, Spanish) x Word Frequency (High, Low) x Neighbourhood Size (Large, Small) x Neighbourhood Frequency (Leader, Nonleader)].

The complete set of experimental items was made up of 86 English words and 88 Spanish words. The English stimuli were all four-letter words, and they were the same as those used in the English Monolingual Study (see section 6.3.2 for details, and Table 6.1 for the complete list). The Spanish stimuli were put together specifically to meet the operational definitions of the independent

[7] The level of the L2 of all the participants was 'advanced', but this did not mean that L2 competence was homogeneous. It only meant that the participants' L2 competence was 'at least' advanced. In fact, many of the Spanish native speakers had lived and studied in Britain for three or four years and their level of English could be considered proficient or even near-native.

variables. As in the preparation of the stimuli for the Spanish Monolingual Study, the following criteria[8] were taken into consideration:

- balanced word length
- same grammatical category (singular nouns)
- no written accents[9]
- neutral and concrete meaning

The Spanish stimuli consisted of 47 four-letter words, 32 five-letter words and 9 three-letter words[10]. Average word length was 4.3, and 92 % of the words were bisyllabic, 7% were monosyllabic and only 1% were trisyllabic[11]. The complete set of Spanish stimuli is presented in Table 8.1.

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[8] The criterion that 'words should not be neighbours of each other', which was initially included as a selection criteria, had to be abandoned. This criterion would have reduced the number of stimuli so much that it would have rendered the selection process almost impossible.

[9] See Footnote n.8 in Chapter 7 (Experiment 2) for an explanation of why it is relevant to exclude words with a written accent from LDT in Spanish.

[10] This is similar to Experiment 2, where word length had to be extended from four letters to three and five. It would have been impossible to draw enough Spanish experimental items on the basis of four-letter words alone. I am fully aware that word length may be a relevant factor in lexical processing time (Álvarez *et al.*, 1999). However, in interactive activation models (McClelland & Rumelhart, 1981), all the letters of a short word, like the words in this experiment, can be processed simultaneously, without any time cost.

[11] Compare these figures with those of the English stimuli. English stimuli were all four-letter words, of which 86% were monosyllabic items and 14% were bisyllabic. The differences in word length and syllable structure, between the Spanish stimuli and the English stimuli, are a reflection of the different characteristics of the two lexicons.

HIGH FREQUENCY WORDS											
LARGE NEIGHBOURHOOD						SMALL NEIGHBOURHOOD					
LEADER			NONLEADER			LEADER			NONLEADER		
Item	WF	N	Item	WF	N	Item	WF	N	Item	WF	N
alma	164.5	9	*cabo*	187	15	*aire*	288	5	*casi*	705	5
bajo	449.5	11	*cada*	996.5	19	*algo*	984.5	4	*coche*	150.5	2
boca	200	14	*caso*	476.5	19	*amor*	379.5	3	*estar*	323	2
duda	230	10	*cosa*	465.5	17	*bien*	1227	3	*fin*	511.5	4
lado	374	13	*dado*	186	9	*cine*	217.5	3	*haber*	365	3
mano	549.5	15	*dos*	1432.5	12	*hecho*	570	5	*mil*	152	3
mesa	234.5	12	*hijo*	268	12	*hora*	322.5	4	*obra*	290	5
nada	1048.5	10	*modo*	458	18	*lugar*	499	5	*padre*	513.5	4
poco	862.5	15	*pelo*	152.5	17	*mundo*	887.5	4	*saber*	286	5
ser	1733.5	9	*pesar*	202	11	*piel*	163	5	*uno*	994	5
todo	2194.5	14	*solo*	287.5	9	*tres*	553	5	*voz*	413.5	5
vez	1418.5	9	*vino*	179.5	9						

LOW FREQUENCY WORDS											
LARGE NEIGHBOURHOOD						SMALL NEIGHBOURHOOD					
LEADER			NONLEADER			LEADER			NONLEADER		
Item	WF	N	Item	WF	N	Item	WF	N	Item	WF	N
ama	40.5	10	*boda*	35.5	11	*baile*	39.5	3	*conde*	40	4
barra	45.5	11	*canto*	36.5	10	*clima*	36.5	2	*eco*	38.5	2
cita	38.5	10	*fijo*	25	13	*disco*	25	4	*falda*	37	5
nota	48.5	13	*mapa*	25	16	*fumar*	32.5	4	*fase*	35	3
paseo	45	9	*mayo*	38	10	*hogar*	46.5	2	*jugar*	49	4
seda	32	9	*misa*	31.5	13	*letra*	45	2	*junio*	25.5	3
			paro	26	18	*leve*	32	3	*lecho*	36	5
			pico	27	10	*local*	41	3	*lista*	37.5	4
			roto	44.5	16	*metro*	37	3	*macho*	28.5	4
			suma	48.5	9	*plan*	43	4	*nacer*	30	4
			trato	37	10	*rumbo*	30	4	*norma*	29	3
			vela	27	11	*usar*	25	3	*sabor*	29	3

Table 8.1. Language-Block Study. *Complete set of NEW SPANISH EXPERIMENTAL ITEMS. WF= Word Frequency[12]; N= Number of Neighbours. LEADER= The most frequent word in its neighbourhood. NONLEADER= Not the most frequent word in its neighbourhood.*

[12] Word Frequency counts are given in 'occurrences per million' words (opm). The decimal points are the result of converting the Alameda and Cuetos (1995) 'occurrences per **two** million' into 'occurrences per **one** million'.

The general statistics for the English[13] and the Spanish stimuli are presented in Table 8.2.

1. TARGET LANGUAGE: ENGLISH ITEMS

N SIZE →	LARGE NEIGHBOURHOOD				SMALL NEIGHBOURHOOD					
N FREQ →	LEADER		NONLEAD		LEADER		NONLEAD		OVERALL	
WORD FREQUENCY ↓	WF	N	WF	N	WF	N	WF	N	Mean WF	Range for WF
HIGH	921	12.7	257	12.4	597	2.9	652	4.3	600	161 – 3941
LOW	47	8.1	42	15.8	42	3.1	37	3.9	41	29 – 55
MEAN N	12.6				3.4					
RANGE FOR N	7 – 24				1 – 6					

2. TARGET LANGUAGE: SPANISH ITEMS

N SIZE →	LARGE NEIGHBOURHOOD						SMALL NEIGHBOURHOOD							
N FREQ →	LEADER			NONLEAD			LEADER			NONLEAD			OVERALL	
WORD FREQUENCY ↓	WF	WL	N	WF	WL	N	WF	WL	N	WF	WL	N	Mean WF	Range for WF
HIGH	788	3.8	11.7	441	4	13.9	554	4.3	4.2	428	4.1	3.9	553	150 – 2194
LOW	42	4.2	10.3	33	4.2	12.2	36	4.7	3.1	35	4.7	3.7	36	25 – 49
MEAN N	12.1						3.7							
RANGE FOR N	9 – 19						2 – 5							
MEAN WL	4.05						4.45							

Table 8.2. Language-Block Study. *Statistics of English and Spanish experimental words according to Word Frequency (WF), Neighbourhood Size (N) and Word Length (WL).*

[13] The statistics of the English experimental items are the same as those presented in section 6.3.2 of Chapter 6 (Experiment 1). They are presented here for ease of comparison with the statistics of the Spanish experimental items. The English table has no reference to word length, as all the items were four-letter words.

A further 86 English nonwords and 88 Spanish nonwords were used to complete the lexical decision materials. These were drawn from the pool of English and Spanish nonwords used in Experiments 1 and 2.

8.3.3. PROCEDURE

Participants were tested individually in a quiet room, in a single session lasting about twenty minutes. They were informed that the experiment comprised two parts: an English part, which only contained English stimuli, and a Spanish part, which only contained Spanish stimuli. They were told about the mechanics of the lexical decision task. Briefly, subjects had to respond to a letter string presented on a computer screen. By pressing one of two buttons on a response box, they had to say if the letter string was a real word (in the relevant language of the block). Instructions were given verbally at the beginning of the testing session and in the participant's native language. Instructions were repeated on the screen, prior to each block, in the language of the block. Emphasis was both on speed and accuracy of performance.

To control the effects of the order of presentation of the language blocks, half the English native speakers and half the Spanish native speakers did the English block first, and the Spanish block second. The remaining participants did the Spanish block first and the English block second. The order of stimulus presentation within each block was automatically randomised by the computer programme every time the experiment was run. Each block was preceded by a 12-trial practice session in the corresponding language. None of the practice stimuli was part of the experimental set. Between the two language blocks, the subjects were invited to rest briefly.

The computer equipment and the characteristics of the task itself were identical to those of Experiments 1 and 2. The basic sequence that participants could see on the screen was as follows: a 500-ms fixation point, followed by a letter string that disappeared with the subject's response (word or nonword). Immediately afterwards a new sequence started. RT to the nearest millisecond, and accuracy of response, were automatically recorded by the computer. All the participants were tested on all the experimental stimuli.

8.4. RESULTS

All the results given are for responses to words[14]. Answers shorter than 300 ms or longer than 1500 ms (0.31% of correct responses) were removed from the statistical analysis[15]. Mean RT for correct responses and error rates (4.96%) were calculated separately for English native speakers and Spanish native speakers, both for English and Spanish items[16]. Table 8.3 shows RT for the five independent variables: Native Language (NL), Target Language (TL), Word Frequency (WF), Neighbourhood Size (N) and Neighbourhood Frequency (NF). Table 8.4 presents RT results for correct responses and error rates for all the conditions of the experimental design.

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[14] Because of an error, the data of three Spanish items (*ser*, *pasar*, and *bien*) was collected twice for every individual. As each word belonged to a different experimental condition, it was decided to discard the data of these three items from the analysis altogether.

[15] See footnote n.14 on 'outliers' in Chapter 7 (Experiment 2).

[16] All the calculations for the experiment were done on SPSS 9.0 for Windows. I followed the recommendations made by Kinnear and Gray (1997) in the preparation and analysis of data.

1. ENGLISH SPEAKERS

1. ENGLISH ITEMS

WORD FREQUENCY	NEIGHBOUR. SIZE LARGE	NEIGHBOUR. SIZE SMALL	NEIGHBOUR. SIZE *RT DIFFER*	NEIGHBOUR. FREQ. LEAD	NEIGHBOUR. FREQ. NON-LEAD	NEIGHBOUR. FREQ. *RT DIFFER*	MEAN RT
HIGH	462	463	*−1*	464	460	*+4*	462
LOW	480	495	*−15*	488	487	*+1*	488
RT DIFFER	*−18*	*−32*		*−24*	*−27*		
MEAN RT	471	479	*−8*	476	474	*+2*	475

2. SPANISH ITEMS

WORD FREQUENCY	NEIGHBOUR. SIZE LARGE	NEIGHBOUR. SIZE SMALL	NEIGHBOUR. SIZE *RT DIFFER*	NEIGHBOUR. FREQ. LEAD	NEIGHBOUR. FREQ. NON-LEAD	NEIGHBOUR. FREQ. *RT DIFFER*	MEAN RT
HIGH	542	532	*+10*	530	543	*−13*	537
LOW	608	591	*+17*	590	609	*−19*	599
RT DIFFER	*−66*	*−59*		*−60*	*−66*		
MEAN RT	575	562	*+13*	560	576	*−16*	568

2. SPANISH SPEAKERS

1. ENGLISH ITEMS

WORD FREQUENCY	NEIGHBOUR. SIZE LARGE	NEIGHBOUR. SIZE SMALL	NEIGHBOUR. SIZE *RT DIFFER*	NEIGHBOUR. FREQ. LEAD	NEIGHBOUR. FREQ. NON-LEAD	NEIGHBOUR. FREQ. *RT DIFFER*	MEAN RT
HIGH	530	529	*+1*	525	534	*−9*	529
LOW	569	585	*−16*	588	566	*+22*	577
RT DIFFER	*−39*	*−56*		*−63*	*−32*		
MEAN RT	550	557	*−7*	556	550	*+6*	553

2. SPANISH ITEMS

WORD FREQUENCY	NEIGHBOUR. SIZE LARGE	NEIGHBOUR. SIZE SMALL	NEIGHBOUR. SIZE *RT DIFFER*	NEIGHBOUR. FREQ. LEAD	NEIGHBOUR. FREQ. NON-LEAD	NEIGHBOUR. FREQ. *RT DIFFER*	MEAN RT
HIGH	534	536	*−2*	525	545	*−20*	535
LOW	544	563	*−19*	547	560	*−13*	553
RT DIFFER	*−10*	*−27*		*−22*	*−15*		
MEAN RT	539	549	*−10*	536	553	*−17*	544

Table 8.3. Language-Block Study. *Results for words for the INDEPENDENT VARIABLES. Mean RT in ms to correct responses. RT DIFFER= Difference in mean RT between the two levels of a variable. MEAN RT= RT when both levels of a variable are combined.*

1. ENGLISH SPEAKERS

TARG. LANG	1. ENGLISH ITEMS						2. SPANISH ITEMS					
N SIZE	LARGE NEIGHBOURHOOD			SMALL NEIGHBOURHOOD			LARGE NEIGHBOURHOOD			SMALL NEIGHBOURHOOD		
N FREQ	LEADER	NON-LEADER	*RT DIFFER*	LEADER	NON-LEADER	*RT DIFFER*	LEADER	NON-LEADER	*RT DIFFER*	LEADER	NON-LEADER	*RT DIFFER*
HIGH	464 [2.3]	459 [2.5]	*+5*	465 [3.3]	462 [2.5]	*+3*	534 [2.7]	550 [4.5]	*–16*	527 [1.8]	537 [5.2]	*–10*
LOW	479 [5.3]	480 [4.0]	*–1*	496 [7.1]	495 [4.8]	*+1*	603 [11.7]	612 [8.5]	*–9*	577 [11.0]	606 [15.4]	*–29*

2. SPANISH SPEAKERS

TARG. LANG	1. ENGLISH ITEMS						2. SPANISH ITEMS					
N SIZE	LARGE NEIGHBOURHOOD			SMALL NEIGHBOURHOOD			LARGE NEIGHBOURHOOD			SMALL NEIGHBOURHOOD		
N FREQ	LEADER	NON-LEADER	*RT DIFFER*	LEADER	NON-LEADER	*RT DIFFER*	LEADER	NON-LEADER	*RT DIFFER*	LEADER	NON-LEADER	*RT DIFFER*
HIGH	523 [0.6]	536 [2.7]	*–13*	527 [0.8]	531 [1.7]	*–4*	522 [2.9]	546 [3.4]	*–24*	527 [0.7]	545 [3.4]	*–18*
LOW	576 [4.4]	562 [4.0]	*+14*	599 [9.8]	571 [11.0]	*+28*	544 [3.3]	543 [3.7]	*+1*	549 [4.8]	576 [6.0]	*–27*

Table 8.4. Language-Block Study. *Results for words in ALL the EXPERIMENTAL CONDITIONS. Mean RT to correct responses in ms, and Error Rates in percentages in brackets. RT DIFFER= Difference in mean RT between two levels of the same variable.*

Mean RT for correct responses and error rates were calculated across subjects and items, and separate analyses of variance (ANOVAs) were performed on each set of data. A repeated-measures ANOVA was applied on the subject data, where TL, WF, N and NF were used as within-subjects factors and NL was used as between-subjects factor. An ANOVA was carried out on the item data, where all five independent variables were used as between-subjects factors. The F results of the ANOVAs are given as F_s for subjects, and F_i for items[17]. The *p* level for significant results (the probability of being wrong in rejecting the null hypothesis) was set at 0.05.

8.4.1. RESPONSE LATENCIES FOR CORRECT ANSWERS

The complexity of the factorial design of the experiment made it advisable to have further tests on major subsets of data, to complement the results of the comprehensive ANOVA on response latencies to words. This would serve to increase the power of the analysis. Thus, partial ANOVAs were performed for the following sets of data: the two groups of native speakers, the two target languages and the two sets of low frequency items (English and Spanish). Given the large number of variables, it was considered more meaningful to look at the data from several angles. This section, therefore, presents the results of the experiment under four headings:

1. All speakers and all items
2. English and Spanish native speakers
3. English and Spanish experimental items
4. English and Spanish low frequency items

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[17] See footnote n.11 on the use of F_s and F_i in Chapter 6 (Experiment 1).

Only significant results will be discussed in the main text.

8.4.1.1. ALL SPEAKERS AND ALL ITEMS

Table 8.5 shows the details of the general ANOVA results for all the variables and their interactions, and for all the participants in the experiment, both globally (All Speakers) and separately by Native Language. The two columns of results are presented here for contrast, although the details referring to data by Native Language will be discussed in section 8.4.1.2.

The main effect of Target Language was highly significant (both in the by-subjects and by-items analyses): English items were responded to faster than Spanish items (42 ms faster). The effect of Target Language by Native Language was also very robust (subject and item data), showing the expected advantage of L1 processing over L2 processing. This means that participants responded significantly faster to items in their native language. The Word Frequency effect was also very robust[18].

[18] As expected, the Word Frequency effect was significant in the subject and item data. High frequency words were processed 38 ms faster than low frequency words by All Speakers. Word Frequency was also significant by Native Language (subject data). This interaction reflected that the high frequency advantage was larger for the English speakers (44 ms advantage) than for Spanish speakers (33 ms advantage).

OVERALL RESULTS						
	ALL SPEAKERS			**BY NATIVE LANGUAGE**		
EFFECTS	F_S (1,78) F_i (1,312)	MSE	$p<$	F_S (1,78) F_i (1,312)	MSE	$p<$
LANGUAGE (TL)	F_S = 71.4	7939	*.001*	F_S = 105.4	7939	*.001*
	F_i = 110.9	1371	*.001*	F_i = 159.6	1371	*.001*
WORD FRQ. (WF)	F_S = 299.8	1571	*.001*	F_S = 6.1	1571	*.016*
	F_i = 102.3	1371	*.001*	F_i = 1.3	1371	*.259*
NEIGHB.SIZE (N)	F_S = 2.5	1454	*.120*	F_S = 6.6	1454	*.012*
	F_i = 2.1	1371	*.152*	F_i = 1.8	1371	*.175*
NEIGHB.FRQ (NF)	F_S = 6.2	1848	*.015*	F_S < 1		
	F_i = 2.4	1371	*.120*	F_i < 1		
TL x WF	F_S < 1			F_S = 68.2	1321	*.001*
	F_i < 1			F_i = 18.3	1371	*.001*
TL x N	F_S = 3.8	1835	*.056*	F_S = 6.8	1835	*.011*
	F_i < 1			F_i = 1.9	1371	*.165*
TL x NF	F_S = 20.8	1678	*.001*	F_S < 1		
	F_i = 6.2	1371	*.013*	F_i < 1		
WF x N	F_S = 7.2	1188	*.009*	F_S = 2.7	1188	*.102*
	F_i = 3.0	1371	*.084*	F_i < 1		
WF x NF	F_S = 2.5	1518	*.119*	F_S = 7.6	1518	*.007*
	F_i < 1			F_i = 1.9	1371	*.171*
N x NF	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
TL x WF x N	F_S = 1.6	1287	*.214*	F_S = 1.6	1287	*.215*
	F_i < 1			F_i < 1		
TL x WF x NF	F_S = 2.4	1267	*.122*	F_S = 1.5	1267	*.230*
	F_i < 1			F_i < 1		
TL x N x NF	F_S = 2.4	1990	*.129*	F_S < 1		
	F_i = 1.0	1371	*.307*	F_i < 1		
WF x N x NF	F_S = 2.3	1355	*.132*	F_S < 1		
	F_i < 1			F_i < 1		
TL x WF x N x NF	F_S = 4.4	1331	*.039*	F_S < 1		
	F_i < 1			F_i < 1		

NOTE: First column: Effects of TL= Target Language, WF= Word Frequency, N= Neighbourhood Size, NF= Neighbourhood Frequency. Second column: Results for All Speakers (Overall). Third column: Results by Native Language.

Table 8.5. Language-Block Study. *ANOVA results of CORRECT RESPONSES, for subject and item data. Significant results are highlighted.*

The effect of N was not significant in the All-Speakers analysis (although it was in the by Native-Language). In contrast, the effect of NF was statistically reliable (All-Speakers, subject data). NF leaders had a processing advantage of 6 ms over NF nonleaders. This advantage was small but significant. NF did not interact with Native Language. These results show that NF had a more powerful effect than N, as it was significant in the overall data and it was not affected by the first language. Conversely, N was only significant in the by-Native-Language analysis.

The interactions of Target Language with Word Frequency, and of Target Language with N, were not significant for All Speakers. By contrast, The interaction of Target Language and NF was highly significant (subject and item analysis). NF was clearly inhibitory in Spanish items (see Figure 8.1): Spanish NF nonleaders took 16 ms longer to be recognised than NF leaders. This inhibitory effect of NF for Spanish is again quite robust, as it was returned by the All-Speakers data.

Word Frequency and N interacted significantly in the overall subject data (see Figure 8.2). Words from large neighbourhoods were recognised faster (9 ms), but only when those words were low frequency words[19]. The interaction between Word Frequency and NF was not significant.

[19] With high frequency words, large N had a slightly inhibitory effect (2 ms). This effect was not significant.

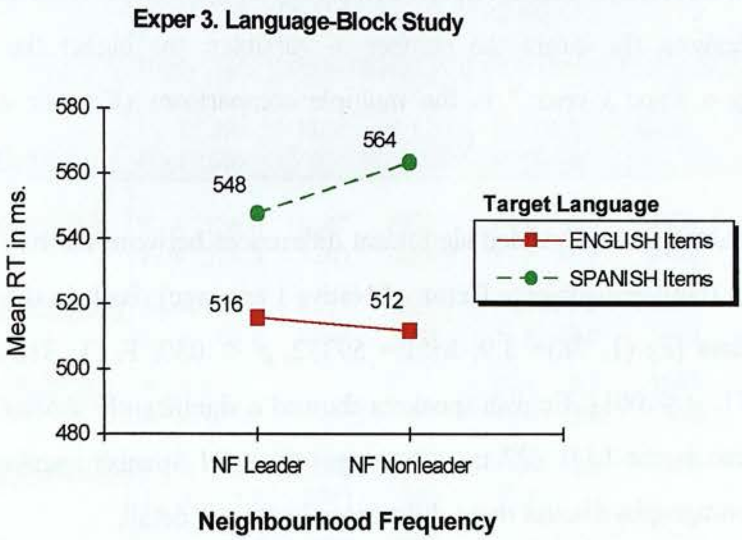

Figure 8.1. Language-Block Study. *Profile of the interaction between Target Language and Neighbourhood Frequency.*

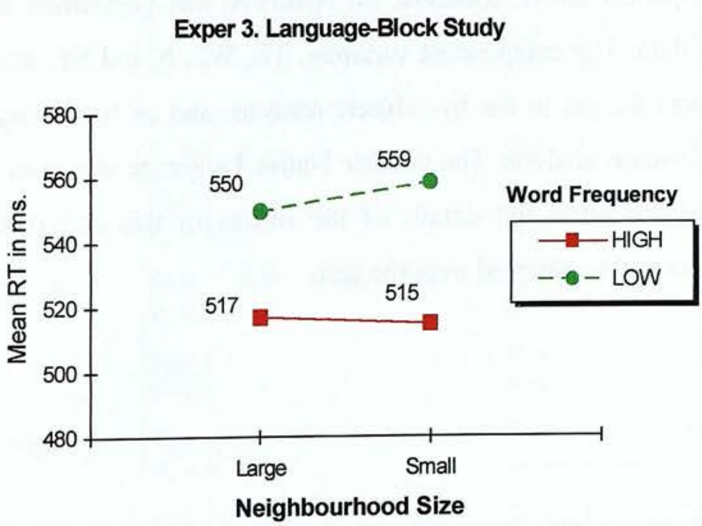

Figure 8.2. Language-Block Study. *Profile of the interaction between Word Frequency and Neighbourhood Size.*

The overall ANOVA returned a significant effect for the interaction TL x WF x N x NF. However, this interaction should be taken very cautiously, if not disregarded altogether, because of the complexity of the experimental design. In factorial designs, the larger the number of variables, the higher the risk of committing a Type I error[20] in the multiple comparisons (Kinnear & Gray, 1997).

The ANOVA also yielded significant differences between the two groups of speakers (between-subjects factor of Native Language), both in the subject and item data [F_S (1, 78)= 3.9, MSE= 59332, $p < .050$; F_i (1, 312)= 43.8, MSE= 1371, $p < .001$]. English speakers showed a significantly shorter overall reaction time in the LDT (27 ms advantage) than did Spanish speakers. The following paragraphs discuss these differences in greater detail.

8.4.1.2. ENGLISH AND SPANISH NATIVE SPEAKERS

To further explore the significant differences between English native speakers and Spanish native speakers, an ANOVA was performed on each separate set of data. The independent variables, TL, WF, N and NF, were used as within-subjects factors in the by-subjects analysis, and as between-subjects factors in the by-items analysis. The variable Native Language was used to split the data. Table 8.6 gives full details of the results of this ANOVA. Only significant results will be referred to in the text.

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[20] Manuals of statistics very often discuss two types of statistical errors in connection with the rejection of the *null hypothesis*: Type I error and Type II error. A **Type I error** is made if the researcher rejects the *null hypothesis* when in fact it should not be rejected. Conversely, **a Type II error** happens if the researcher accepts the *null hypothesis* when there are real differences between the experimental and the control groups (Hatch & Lazaraton, 1991). In complex factorial designs, the dangers of a Type I error creeping in increase considerably, and the researcher should be alert not to attach too much relevance to interactions, which may come out as significant in the statistical analysis but which are due more to chance than to real effects. (Howell, 1997; Kinnear & Gray, 1997).

	RESULTS BY NATIVE LANGUAGE					
	ENGLISH SPEAKERS			**SPANISH SPEAKERS**		
EFFECTS	F_S (1,39) F_i (1,156)	MSE	*p* <	F_S (1,39) F_i (1,156)	MSE	*p* <
LANGUAGE (TL)	F_S= 125.8	11057	*.001*	F_S= 2.7	4821	*.107*
	F_i = 274.3	1341	*.001*	F_i = 2.2	1402	*.143*
WORD FRQ. (WF)	F_S= 194.9	1577	*.001*	F_S=110.6	1565	*.001*
	F_i = 64.6	1341	*.001*	F_i = 39.5	1402	*.001*
NEIGHB.SIZE (N)	F_S < 1			F_S= 8.1	1545	*.007*
	F_i < 1			F_i = 3.8	1402	*.052*
NEIGHB. FRQ (NF)	F_S = 4.1	1860	*.049*	F_S= 2.2	1836	*.142*
	F_i = 1.6	1341	*.201*	F_i < 1		
TL x WF	F_S= 40.8	1364	*.001*	F_S= 27.8	1279	*.001*
	F_i = 11.7	1341	*.001*	F_i = 6.9	1402	*.009*
TL x N	F_S= 11.1	1707	*.002*	F_S< 1		
	F_i = 2.3	1341	*.130*	F_i < 1		
TL x NF	F_S= 6.7	2060	*.013*	F_S= 16.6	1297	*.001*
	F_i = 2.7	1341	*.103*	F_i = 3.6	1402	*.061*
WF x N	F_S< 1			F_S= 10.7	1039	*.002*
	F_i < 1			F_i = 3.2	1402	*.077*
WF x NF	F_S< 1			F_S= 14.8	959	*.001*
	F_i < 1			F_i = 2.5	1402	*.114*
N x NF	F_S< 1			F_S< 1		
	F_i < 1			F_i < 1		
TL x WF x N	F_S= 2.7	1464	*.105*	F_S< 1		
	F_i < 1			F_i < 1		
TL x WF x NF	F_S< 1			F_S= 6.6	733	*.014*
	F_i < 1			F_i < 1		
TL x N x NF	F_S< 1			F_S= 2.4	2160	*.131*
	F_i < 1			F_i < 1		
WF x N x NF	F_S= 1.3	970	*.269*	F_S= 1.1	1739	*.295*
	F_i < 1			F_i < 1		
TLxWFxNxNF	F_S= 1.4	1667	*.249*	F_S= 3.7	995	*.062*
	F_i < 1			F_i < 1		

Table 8.6. Language-Block Study. *ANOVA results for ENGLISH and SPANISH SPEAKERS, for subject and item data. Significant results are highlighted.*

Target Language returned a highly significant effect for the English speakers (subject and item analyses) but not for the Spanish speakers. English speakers responded to English items considerably faster (93 ms) than they did to Spanish items, while Spanish speakers processed Spanish items only marginally faster (9 ms) than English items. This result was surprising, as it gave Spanish speakers no processing advantage for their L1. The effect of word frequency was very reliable for both groups[21].

N showed no effect on English speakers' RT, but revealed a robust facilitatory effect with Spanish speakers (significant for both subject and item data), who recognised words with many neighbours 9 ms faster than words with few neighbours (see Figure 8.3). NF showed marginally inhibitory effects for English speakers (subject data), who reacted more slowly (14 ms) to NF nonleaders than to NF leaders. There were no effects of NF for Spanish speakers.

[21] The effect of word frequency was significant in the subject and item data for both groups: high frequency words were processed faster than low frequency words (88 ms faster by English speakers and 66 ms faster by Spanish speakers).

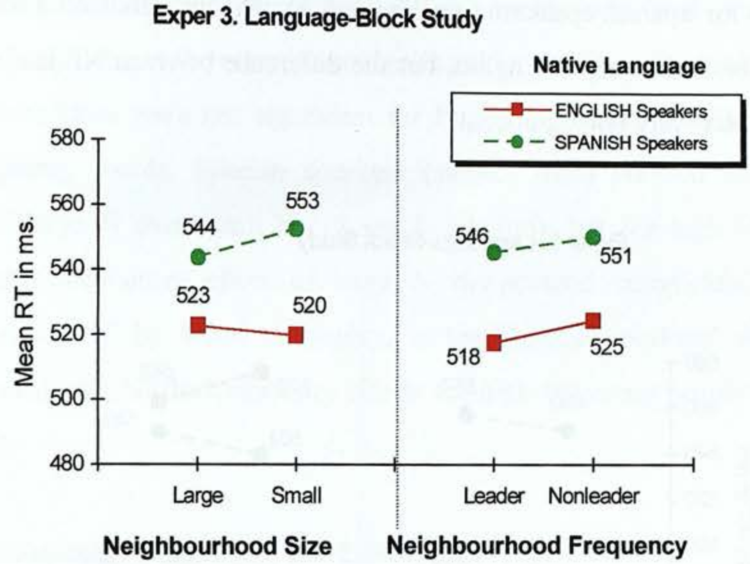

Figure 8.3. Language-Block Study. *Profiles of the interactions between Native Language and N, and Native Language and NF.*

Target Language interacted very significantly with Word Frequency[22]. Target Language also interacted significantly with N for the English speakers (subject data): N had facilitatory effects for English items (8 ms in favour of words with large N), and inhibitory effects for Spanish items (13 ms delay for words with large N), as shown in Figure 8.4. Target Language interacted significantly with NF and the pattern of interaction was the same in both groups of speakers (subject data). NF effects were clearly inhibitory for Spanish items: both English and Spanish speakers showed considerable delay in processing NF nonleaders relative to NF leaders. This delay was 16 ms for English speakers

[22] The effect of Target Language by Word Frequency showed significant results for both groups of speakers, in the subject as well as item data. The pattern of this interaction is the same with both groups: the difference in processing high and low frequency words is larger for L1 items than for L2 items. In the English speakers' data, the RT difference between high and low frequency words was 26 ms for the English items and 62 ms for the Spanish items. In the Spanish-speaking group, this difference was 48 ms for the English items and 18 ms for Spanish the items.

and 17 ms for Spanish speakers (see Figure 8.5). The data showed a tendency for NF to be facilitatory in English, but the difference between NF leaders and NF nonleaders were not significant.

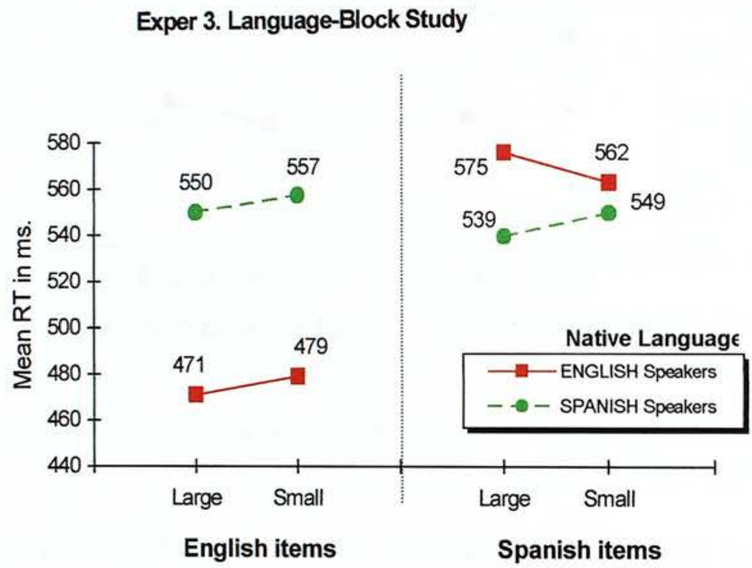

Figure 8.4. Language-Block Study*. Profile of the interaction between Target Language and N.*

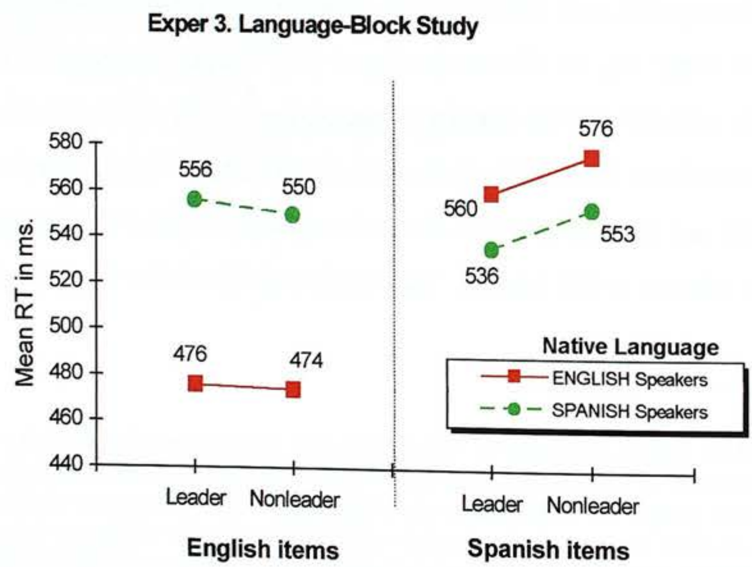

Figure 8.5. Language-Block Study*. Profile of the interaction between Target Language and NF.*

Interactions of Word Frequency and N, on the one hand, and Word Frequency and NF, on the other, were significant for the Spanish speakers' RT. These interactions were not significant for English speakers. Specifically, for low frequency words, Spanish speakers (subject data) showed facilitatory effects of large N over small N (18 ms facilitation), but for high frequency words, this facilitatory effect of large N disappeared completely. In the interaction of NF by Word Frequency, in the Spanish speakers' data (by-subjects analysis), NF had inhibitory effects for high frequency words (a delay of 15 ms).

8.4.1.3. ENGLISH AND SPANISH EXPERIMENTAL ITEMS

In order to further explore the idea of language specificity of neighbourhood effects in English and Spanish items, separate ANOVAs were conducted on each set of data. Word frequency, N and NF were used as within-subjects factors, and Native Language as between-subjects factor in a repeated measures ANOVA for subject analysis. The same four variables were used as between-subjects factors in an ANOVA for item analysis. Table 8.7 shows all the results by Target Language for All Speakers and by Native Language.

RESULTS BY TARGET LANGUAGE: ENGLISH ITEMS

EFFECTS	ALL SPEAKERS F_S (1,78) / F_i (1,156)	MSE	*p* <	BY NATIVE LANGUAGE F_S (1,78) / F_i (1,156)	MSE	*p* <
WORD FRQ. (WF)	F_S = 135.5	1572	*.001*	F_S = 13.0	1572	*.001*
	F_i = 67.5	930	*.001*	F_i = 7.2	930	*.008*
NEIGHB.SIZE (N)	F_S = 7.4	1383	*.008*	F_S < 1		
	F_i = 3.4	930	*.065*	F_i < 1		
NEIGHB.FRQ (NF)	F_S = 2.8	1132	*.099*	F_S < 1		
	F_i < 1			F_i < 1		
WF x N	F_S = 8.3	1129	*.005*	F_S < 1		
	F_i = 2.9	930	*.089*	F_i < 1		
WF x NF	F_S = 6.0	1140	*.016*	F_S = 9.9	1140	*.002*
	F_i = 1.6	930	*.214*	F_i = 2.7	930	*.102*
N x NF	F_S = 1.2	1258	*.282*	F_S = 1.0	1258	*.319*
	F_i < 1			F_i < 1		
WF x N x NF	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		

RESULTS BY TARGET LANGUAGE: SPANISH ITEMS

EFFECTS	ALL SPEAKERS F_S (1,78) / F_i (1,156)	MSE	*p* <	BY NATIVE LANGUAGE F_S (1,78) / F_i (1,156)	MSE	*p* <
WORD FRQ. (WF)	F_S = 196.2	1320	*.001*	F_S = 60.0	1320	*.001*
	F_i = 43.0	1813	*.001*	F_i = 11.1	1813	*.001*
NEIGHB.SIZE (N)	F_S < 1			F_S = 11.6	1906	*.001*
	F_i < 1			F_i = 2.9	1813	*.091*
NEIGHB.FRQ (NF)	F_S = 18.1	2394	*.001*	F_S < 1		
	F_i = 6.3	1813	*.013*	F_i < 1		
WF x N	F_S < 1			F_S = 3.8	1346	*.053*
	F_i < 1			F_i < 1		
WF x NF	F_S < 1			F_S = 1.2	1645	*.267*
	F_i < 1			F_i < 1		
N x NF	F_S = 1.5	2253	*.222*	F_S < 1		
	F_i < 1			F_i < 1		
WF x N x NF	F_S = 4.7	1871	*.033*	F_S < 1		
	F_i = 1.3	1813	*.252*	F_i < 1		

Table 8.7. Language-Block Study. *ANOVA results for ENGLISH and SPANISH EXPERIMENTAL ITEMS, for subject and item data. Results given for All Speakers (Overall) and for Speakers by Native Language. Significant results are highlighted.*

As expected, Word Frequency was highly significant in both languages[23]. N had a significant facilitatory effect on English items (subject data) but not on Spanish items. Specifically, English words from large N were recognised 8 ms before English words from small N (see Figure 8.6). Conversely, NF had no significant effect on English items but it was highly significant for Spanish items (both in the by-subjects and by-items analyses). This robust NF effect was of an inhibitory nature, and it was represented by a 16-ms delay in the recognition of Spanish NF nonleaders in comparison to NF leaders (see Figure 8.6). The effects of N and NF observed so far agreed with the general results found in the monolingual studies.

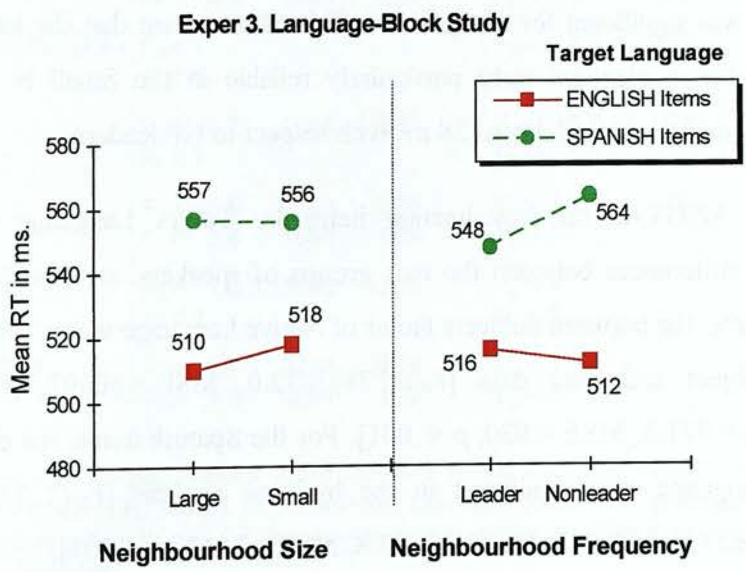

Figure 8.6. Language-Block Study. *Profiles of the interactions between Target Language and N, and Target Language and NF.*

[23] Significant effects of Word Frequency were found in the subject as well as in the item analysis. In particular, the advantage of high frequency words over low frequency words gave a 36-ms difference for English items, and a 40-ms difference for Spanish items.

Word Frequency showed significant interaction effects with N and with NF for English items (subject data) but not for Spanish items. N had a significant facilitatory effect on English low frequency words but had no effect at all on high frequency words: low frequency words with large N showed a processing advantage of 16 ms over words with small N, and this held for All Speakers. NF also had a significant facilitatory effect in low frequency words: low frequency NF nonleaders were processed 11 ms faster than NF leaders. This difference disappeared for high frequency words. The interaction Word Frequency by NF in English items was particularly significant for Spanish speakers: NF nonleaders produced a 22-ms improvement over NF leaders.

Finally, for Spanish items, the three-way interaction, Word Frequency by N by NF, was significant for all Speakers. This effect meant that the inhibitory effects of NF nonleaders were particularly reliable in the Small N of low frequency words, with a delay of 28 ms with respect to NF leaders.

The ANOVAs on experimental items by Target Language yielded significant differences between the two groups of speakers, as expected. For English items, the between-subjects factor of Native Language was reliable both in the subject and item data [$F_S\,(1, 78) = 32.0$, MSE = 30597, $p < .001$; $F_i\,(1, 156) = 271.3$, MSE = 930, $p < .001$]. For the Spanish items, the effect of Native Language was significant in the by-items analysis [$F_S\,(1, 78) = 2.5$, MSE = 36675, $p < .117$; $F_i\,(1, 156) = 13.8$, MSE = 1813, $p < .001$].

8.4.1.4. LOW FREQUENCY ITEMS

In order to examine if low frequency (LF) words were more sensitive to neighbourhood effects than the full set of stimuli, the set of LF data was submitted to the same analyses carried out on the complete set of RT data. Table 8.8 shows global results for All Speakers and for Speakers by Native Language. Table 8.9 presents results for both groups of native speakers separately, and Table 8.10 gives results for items according to Target Language. Only the most relevant results will be discussed, with reference to the three tables. Figure 8.7 shows a comparison of relevant profile plots for the full set of data and the LF set.

OVERALL RESULTS FOR LOW FREQUENCY WORDS						
	ALL SPEAKERS			BY NATIVE LANGUAGE[24]		
EFFECTS	F_S (1,78) F_i (1,156)	MSE	$p<$	F_S (1,78) F_i (1,156)	MSE	$p<$
LANGUAGE (TL)	F_S= 60.0 F_i = 43.9	5155 1891	.001 .001	F_S=143.2 F_i =103.0	5155 1891	.001 .001
NEIGHB.SIZE (N)	F_S= 7.6 F_i = 3.6	1521 1891	.007 .059	F_S= 7.9 F_i = 1.7	1521 1891	.006 .195
NEIGHB.FRQ (NF)	F_S< 1 F_i < 1			F_S= 3.8 F_i < 1	2027	.055
TL x N	F_S= 4.2 F_i < 1	1936	.043	F_S= 6.3 F_i = 1.3	1936 1891	.014 .260
TL x NF	F_S= 16.5 F_i = 3.4	1783 1891	.001 .069	F_S= 1.1 F_i < 1	1783	.288
N x NF	F_S= 1.3 F_i < 1	1868	.255	F_S< 1 F_i < 1		
TL x N x NF	F_S= 4.7 F_i = 1.5	2248 1891	.034 .229	F_S< 1 F_i < 1		

Table 8.8. Language-Block Study. *ANOVA results for LOW FREQUENCY EXPERIMENTAL ITEMS, for subject and item data. Results are given for All Speakers (Overall) and for Speakers by Native Language. Significant results are highlighted.*

[24] The general ANOVA on low frequency words returned a significant difference between the two groups of speakers (between-subjects factor of Native Language) in the item data [F_S (1, 78)= 2.3, MSE= 32906, p < .135; F_i (1, 156)= 10.8, MSE= 1891, p < .001]. This significant difference matched the difference observed in the analysis of the full set of data.

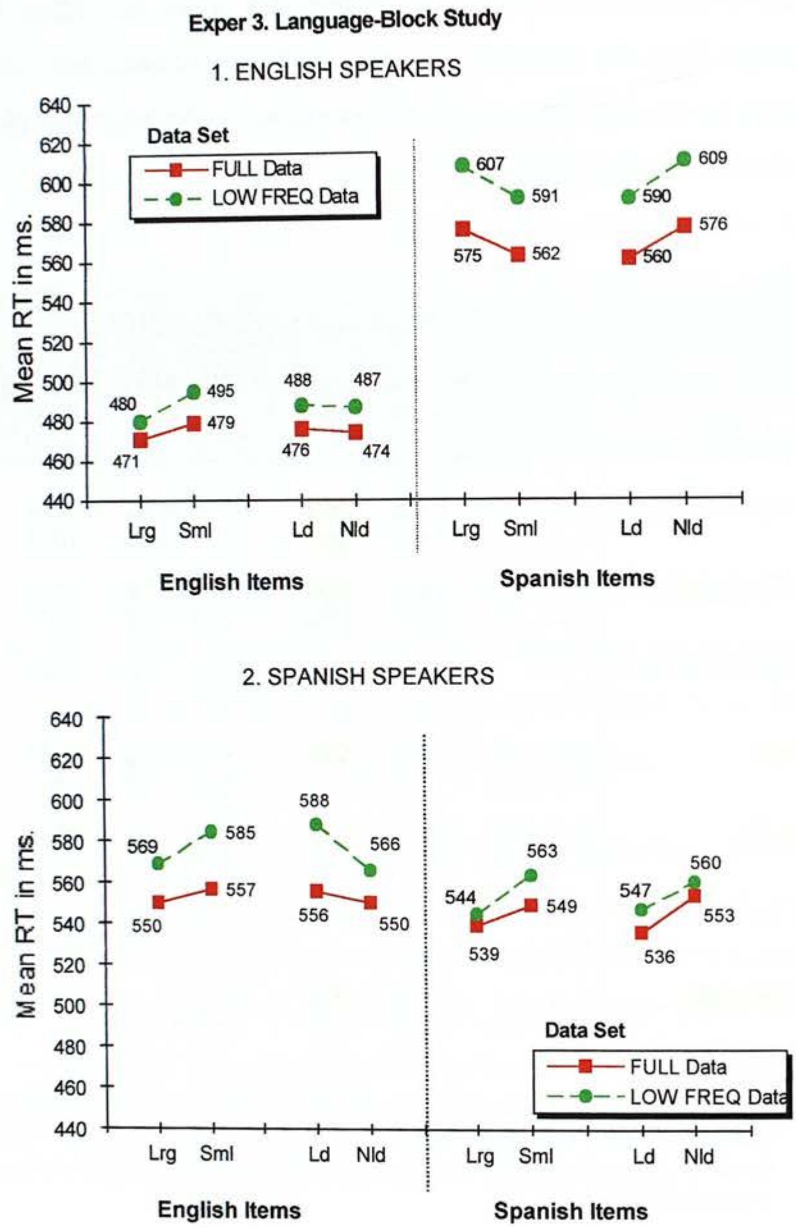

***Figure 8.7. Language-Block Study**. Profile comparing the results of the FULL DATA and the LOW FREQUENCY DATA, for N (Large, Small) and NF (Leader, Nonleader), for each Target Language (English Items, Spanish Items). Separate plots for Native Language (English Speakers, Spanish Speakers).*

Target Language showed a very strong effect both for All Speakers (subject and item data) and for speakers by Native Language: English LF items were responded to faster (44 ms) than Spanish items. The expected L1 processing advantage was also significant (subject and item data): L1 advantage was 111 ms for English speakers and 24 ms for Spanish speakers. This L1 processing advantage was significant for both groups of speakers, but it was significantly greater for English speakers than for Spanish speakers. Relative to the full data, these results are meaningful in two ways. On the one hand, the L1 processing advantage for LF items was significant for both groups of speakers, compared to the full data set, where L1 advantage was significant only for English speakers. On the other hand, the difference in the L1 advantage between English speakers and Spanish speakers was larger for the LF words than for the full set of words. This latter point highlights a potential difference in L2 competence between the two groups of speakers. Generally, these results showed that lower frequency words were more sensitive to processing differences than words of higher frequency.

RESULTS BY NATIVE LANGUAGE FOR LOW FREQUENCY WORDS

EFFECTS	ENGLISH SPEAKERS F_S (1,39) / F_i (1,78)	MSE	$p <$	SPANISH SPEAKERS F_S (1,39) / F_i (1,78)	MSE	$p <$
LANGUAGE (TL)	F_S = 143.4	6986	*.001*	F_S = 13.8	3325	*.001*
	F_i = 144.7	1839	*.001*	F_i = 6.0	1943	*.016*
NEIGHB.SIZE (N)	$F_S < 1$			F_S = 18.9	1252	*.001*
	$F_i < 1$			F_i = 5.0	1943	*.028*
NEIGHB.FRQ (NF)	F_S = 3.3	2213	*.078*	$F_S < 1$		
	$F_i < 1$			$F_i < 1$		
TL x N	F_S = 11.3	1791	*.002*	$F_S < 1$		
	F_i = 1.5	1839	*.219*	$F_i < 1$		
TL x NF	F_S = 3.0	2694	*.093*	F_S = 26.9	872	*.001*
	$F_i < 1$			F_i = 2.5	1943	*.115*
N x NF	$F_S < 1$			$F_S < 1$		
	$F_i < 1$			$F_i < 1$		
TL x N x NF	F_S = 1.0	2608	*.318*	F_S = 4.6	1888	*.038*
	$F_i < 1$			$F_i < 1$		

Table 8.9. Language-Block Study. *ANOVA results of LOW FREQUENCY WORDS for ENGLISH and SPANISH SPEAKERS, for subject and item data. Significant results are highlighted.*

RESULTS FOR LOW FREQUENCY ENGLISH ITEMS

EFFECTS	ALL SPEAKERS F_S (1,78) F_i (1,80)	MSE	$p<$	BY NATIVE LANGUAGE[25] F_S (1,78) F_i (1,80)	MSE	$p<$
NEIGHB.SIZE (N)	F_S = 13.6	1445	*.001*	F_S < 1		
	F_i = 5.1	1220	*.026*	F_i < 1		
NEIGHB.FRQ (NF)	F_S = 7.5	1291	*.008*	F_S = 6.8	1291	*.011*
	F_i = 1.7	1220	*.198*	F_i = 1.6	1220	*.205*
N x NF	F_S = 1.1	1243	*.291*	F_S = 1.1	1242	*.291*
	F_i < 1			F_i < 1		

RESULTS FOR LOW FREQUENCY SPANISH ITEMS

EFFECTS	ALL SPEAKERS F_S (1,78) F_i (1,80)	MSE	$p<$	BY NATIVE LANGUAGE F_S (1,78) F_i (1,76)	MSE	$p<$
NEIGHB.SIZE (N)	F_S < 1			F_S = 12.1	2012	*.001*
	F_i < 1			F_S = 2.0	2596	*.156*
NEIGHB.FRQ (NF)	F_S = 8.3	2520	*.005*	F_S < 1		
	F_i = 1.7	2596	*.193*	F_S < 1		
N x NF	F_S = 4.0	2874	*.048*	F_S < 1		
	F_i = 1.4	2596	*.242*	F_S < 1		

Table 8.10. Language-Block Study. *ANOVA results for ENGLISH and SPANISH LOW FREQUENCY ITEMS, for subject and item data. Results given for All Speakers (Overall) and for Speakers by Native Language. Significant results are highlighted.*

The data of low frequency words returned a small, though significant, facilitative effect of N for All Speakers (Table 8.8): words with large N were recognised 8 ms faster than words with small N. Since the effects of N were not

[25] The ANOVAs on low frequency experimental items conveyed highly significant differences between the two groups of speakers, both in the subject and item data. For low frequency English items, the between-subjects factor of Native Language gave the following F values: F_S (1, 78)= 37.2, MSE= 17250, $p < .001$; F_i (1, 80)= 147.7, MSE= 1220, $p < .001$. For low frequency Spanish items, the values were: F_S (1, 78)= 8.2, MSE= 20811, $p < .005$; F_i (1, 76)= 16.3, MSE= 2596, $p < .001$.

significant for All Speakers in the full data, these results show that low frequency words are more sensitive to neighbourhood effects than words from higher frequencies. Results by Native Language (Table 8.9) showed facilitative effects of large N for Spanish speakers (18-ms improvement) but not for English speakers. Results by Target Language (Table 8.10) showed that large N was clearly advantageous for processing English items (subject and item data), as the analysis returned significant facilitatory effects for All the Speakers (16-ms). N showed no reliable effects on Spanish items. This pattern of results mirrors the pattern obtained for the full data.

Neighbourhood Frequency showed no significant effects in the analysis for All Speakers or by Native Language (see Table 8.8 and Table 8.9 and Figure 8.7). Effects of Neighbourhood Frequency were statistically reliable in the by-Target-Language analysis (see Table 8.10). For All Speakers, NF nonleaders proved facilitative for English items (subject data) and inhibitory for Spanish items (subject data), exactly as predicted at the beginning of the study[26]. In particular, English NF nonleaders showed a processing advantage of 12 ms over NF leaders, while Spanish NF nonleaders showed a disadvantage of 16 ms. These significant results showed that English low frequency items were more sensitive to neighbourhood effects than higher frequency items. Results for Spanish items were the same as those observed in the full data analysis.

The conclusion from the analysis of LF items was that these words are more sensitive than higher frequency words to processing differences between L1 and L2, as well as more sensitive to the effects of N and NF. This finding has practical implications for experimental research, discussed in Chapter 10.

[26] The facilitatory effects of NF for English items were only a trend in the full data set, which turned significant in the LF data. In the full data, English NF nonleaders showed a processing advantage of 4 ms, whereas in the LF data this difference was 12 ms.

8.4.2. ERROR RATES

The general rate of incorrect responses was 5% (see full details on Table 8.4, shown earlier). Mean numbers of mistakes were analysed following exactly the same procedure as for correct answers. F values of the by-subjects and by-items analyses are given as F_s and F_i in Table 8.11 and Table 8.12.

Target Language[27] and Word Frequency[28] showed highly significant effects, both in All Speakers and in Speakers by-Native-Language.

The main effect of Neighbourhood Size was significantly facilitative in the analysis by All Speakers: fewer mistakes were made in responding to words from large N (4.1%) than in responding to words from small N (5.6%). The interaction N by Word Frequency was also significant, with improved accuracy in the recognition of low frequency words with large N: subjects made fewer mistakes in recognising low frequency words from large N (4.4%) than in recognising words from small N (8.7%).

Large N was significantly facilitatory with Spanish speakers, who made fewer errors to words with large N (3.1%) than to words with small N (4.7%). N interacted significantly with Target language in the by-Native-Language analysis: for Spanish speakers the facilitatory effects of N were only significant for English items, not for Spanish items.

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[27] Results for Target Language show that English items were responded to more accurately than Spanish items (8.3% *vs* 11.1%). Target Language by Native Language showed the expected L1 processing advantage. English speakers committed significantly fewer mistakes to L1 items than to L2 items (3.9% *vs* 7.6%). Error rates differences were not statistically significant for Spanish speakers, which reproduced the pattern of right responses to words.

[28] As expected, results for Word frequency were also highly reliable (with 2.5% of mistakes for high frequency words and 6.6% of mistakes for low frequency words). The interaction between Target Language and Word Frequency was significant in the by-Native-Language analysis.

OVERALL RESULTS FOR INCORRECT RESPONSES						
	ALL SPEAKERS			BY NATIVE LANGUAGE		
EFFECTS	F_S (1,78) F_i (1,312)	MSE	*p* <	F_S (1,78) F_i (1,312)	MSE	*p* <
LANGUAGE (TL)	F_S= 12.0 F_i = 3.8	.83 6.88	*.001* *.053*	F_S= 28.9 F_i = 9.5	.83 6.88	*.001* *.002*
WORD FRQ. (WF)	F_S= 99.6 F_i = 40.1	.92 6.88	*.001* *.001*	F_S= 2.7 F_i = 1.1	.92 6.88	*.104* *.300*
NEIGHB.SIZE (N)	F_S= 12.3 F_i = 3.8	.77 6.88	*.001* *.051*	F_S< 1 F_i < 1		
NEIGHB.FRQ (NF)	F_S= 3.4 F_i < 1	.66	.067	F_S= 1.3 F_i < 1	.66	*.258*
TL x WF	F_S= 1.2 F_i < 1	.77	*.267*	F_S= 33.9 F_i = 10.5	.77 6.88	*.001* *.001*
TL x N	F_S= 1.9 F_i < 1	.60	*.175*	F_S= 6.2 F_i = 1.2	.60 6.88	*.015* *.281*
TL x NF	F_S= 3.5 F_i = 1.0	.56 6.88	*.066* *.309*	F_S= 3.3 F_i < 1	.56	*.073*
WF x N	F_S= 26.6 F_i = 5.5	.47 6.88	*.001* *.019*	F_S= 6.2 F_i < 1	.47	*.015*
WF x NF	F_S= 3.7 F_i < 1	.45	*.058*	F_S< 1 F_i < 1		
N x NF	F_S= 3.1 F_i < 1	.69	*.081*	F_S< 1 F_i < 1		
TL x WF x N	F_S< 1 F_i < 1			F_S= 4.3 F_i = 1.1	.68 6.88	*.042* *.294*
TL x WF x NF	F_S< 1 F_i < 1			F_S< 1 F_i < 1		
TL x N x NF	F_S= 5.1 F_i = 1.4	.64 6.88	*.027* *.238*	F_S= 1.7 F_i < 1	.64	*.194*
WF x N x NF	F_S= 1.8 F_i < 1	.54	*.180*	F_S= 1.3 F_i < 1	.54	*.249*
TL x WF x N x NF	F_S< 1 F_i < 1			F_S= 2.7 F_i < 1	.58	*.107*

Table 8.11. Language-Block Study. *ANOVA results of INCORRECT RESPONSES, for subject and item data. Results are given for All Speakers (Overall) and for Speakers by Native Language. Significant results are highlighted.*

RESULTS BY NATIVE LANGUAGE FOR INCORRECT RESPONSES						
	ENGLISH SPEAKERS			**SPANISH SPEAKERS**		
EFFECTS	F_S (1,39) F_i (1,156)	MSE	*p* <	F_S (1,39) F_i (1,156)	MSE	*p* <
LANGUAGE (TL)	F_S= 29.1 F_i = 11.8	1.12 7.37	*.001* *.001*	F_S= 2.8 F_i < 1	.55	*.103*
WORD FRQ. (WF)	F_S= 53.5 F_i = 25.4	1.16 7.37	*.001* *.001*	F_S= 47.1 F_i = 15.1	.68 6.39	*.001* *.001*
NEIGHB.SIZE (N)	F_S= 3.1 F_i = 1.3	.99 7.37	*.085* *.258*	F_S= 12.3 F_i = 2.7	.54 6.39	*.001* *.099*
NEIGHB.FRQ (NF)	F_S< 1 F_i < 1			F_S= 4.7 F_i = 1.2	.63 6.39	*.036* *.279*
TL x WF	F_S= 22.1 F_i = 6.6	.83 7.37	*.001* *.011*	F_S= 12.2 F_i = 4.0	.70 6.39	*.001* *.047*
TL x N	F_S< 1 F_i < 1			F_S= 11.2 F_i = 1.6	.40 6.39	*.002* *.200*
TL x NF	F_S= 6.5 F_i = 1.6	.58 7.37	*.015* *.209*	F_S< 1 F_i < 1		
WF x N	F_S= 3.1 F_i < 1	.54	*.087*	F_S= 34.4 F_i = 6.0	.40 6.39	*.001* *.016*
WF x NF	F_S= 2.2 F_i < 1	.61	*.145*	F_S= 1.5 F_i < 1	.29	*.226*
N x NF	F_S= 2.1 F_i < 1	.86	*.154*	F_S= 1.0 F_i < 1	.53	*.320*
TL x WF x N	F_S= 1.6 F_i < 1	.73	*.211*	F_S= 2.8 F_i < 1	.62	*.101*
TL x WF x NF	F_S< 1 F_i < 1			F_S< 1 F_i < 1		
TL x N x NF	F_S= 5.3 F_i = 1.7	.76 7.37	*.026* *.195*	F_S< 1 F_i < 1		
WF x N x NF	F_S= 2.7 F_i < 1	.63	*.109*	F_S< 1 F_i < 1		
TL x WF x N x NF	F_S= 1.5 F_i < 1	.69	*.226*	F_S= 1.1 F_i < 1	.47	*.291*

Table 8.12. Language-Block Study. *ANOVA results of INCORRECT RESPONSES to words from English Speakers and Spanish Speakers, for subject and item data. Significant results are highlighted.*

N interacted significantly with Word Frequency for All Speakers. This interaction reflected significant facilitatory effects of large N for low frequency words: All Speakers made fewer mistakes for low frequency words when these words belonged to large N (5.6%) than when they belonged to small N (8.7%). In addition, in the by-Native-Language analysis, this interaction was only significant in the Spanish Speakers' data, where the improving effects were very robust (subject and item data): Spanish speakers made 3.8% of mistakes to words from large N of low frequency words, compared to 8.7% of mistakes to words from small N.

The main effect of Neighbourhood Frequency was not statistically reliable for All Speakers. However, NF was significant for Spanish speakers: they made more mistakes (4.5%) in responding to words with higher frequency neighbours than in responding to words without higher frequency neighbours (3.4%). Furthermore, NF interacted significantly with Target Language in the English speakers' data: NF was facilitatory for English items (3.4% of errors for NF nonleaders *vs* 4.5% for NF leaders), and it was inhibitory for Spanish items (7% of mistakes for NF leaders *vs* 8.4 % for NF nonleaders).

The ANOVA yielded a significant difference between the two groups of speakers both in the subject and item data [F_S (1, 78)= 7.8, MSE= 1.90, $p <$ .007; F_i (1, 312)= 6.4, MSE= 6.88, $p <$ .012]. English speakers made significantly fewer mistakes than did Spanish speakers (8.35% and 11.12%, respectively).

The general conclusion from the error data analysis is that effects observed for N and NF in accuracy of response fully mirror the effects obtained for speed of response.

Having analysed the results of Experiment 3 in detail, the experimental hypotheses formulated at the beginning of the study can now be examined in the light of those results:

1. The first hypothesis stated that English stimuli with large N are processed more rapidly than stimuli with small N, both for L1 and L2 speakers. The facilitative effects of N observed in this experiment confirmed this hypothesis.

2. The second hypothesis stated that English words that are NF nonleaders are processed more rapidly than NF leaders, both for L1 and L2 speakers. The study did not confirm this hypothesis for the full data. However, results showed that the hypothesis was true for English low frequency words.

3. The third hypothesis stated that N has no significant effects on Spanish lexical processing, either for L1 or for L2 speakers. This hypothesis was confirmed by the results obtained in the study.

4. The fourth hypothesis stated that Spanish Neighbourhood Frequency nonleaders are processed more slowly than NF leaders, both for L1 and L2 speakers. This experimental hypothesis was also confirmed by the results of the experiment.

8.5. DISCUSSION

The main results of the Language-Block Study, in relation to neighbourhood effects in bilingual processing, can be summarised as follows:

1. For all participants, effects of N were facilitatory for low frequency words.

2. For all participants, the main effect of NF was inhibitory for both high and low frequency words.

3. For English items, effects of N were facilitatory for all speakers, while NF had no significant effects in lexical performance across speakers.

4. For Spanish items, N did not yield significant differences for participants as a whole, whereas NF showed highly inhibitory effects in the performance of both groups of speakers.

5. For English speakers, N interacted with target language: results showed facilitatory effects of N for English items and inhibitory effects of NF for Spanish items.

6. For English speakers, NF was marginally inhibitory in items of both target languages.

7. For Spanish speakers, N showed robust facilitatory effects across both languages.

8. Relative to higher frequency items, low frequency items of both languages showed higher sensitivity to L1 and L2 processing differences. The low frequency items were also more sensitive to the effects of N and NF.

At first glance, the general results of this bilingual experiment could be taken as an illustration of what has been called the 'neighbourhood paradox' (Mathey, 2001; Sears *et al.*, 1995), outlined in Chapter 4. On the one hand, the effects of large N were facilitatory and the effects of NF nonleaders were inhibitory. On the other hand, and this is the apparent 'paradox', words that have many neighbours (facilitatory effects) typically have higher frequency neighbours (inhibitory effects) (Andrews, 1997; Frauenfelder *et al.*, 1993). A closer inspection of the results of the study, however, reveals that the inhibitory effects of NF are more robust than the facilitatory effects of N: whereas the facilitatory effects of N were only observed with low frequency words, the inhibitory effects of NF were obtained for the full set of data. Thus, although the 'initial paradox' (Mathey, 2001) still remains, these results show that the terms of the paradox may be biased towards a greater influence of NF.

The major finding of this study is that neighbourhood effects are language specific. For the particular languages of English and Spanish, the results of this experiment indicate that the language specificity of neighbourhood effects present the following pattern. In English lexical processing, neighbourhood size plays a more influential role than neighbourhood frequency, and the nature of this role is facilitatory. By contrast, in Spanish lexical processing, neighbourhood frequency is the factor that plays a determinant role, and the nature of this role is inhibitory. These results support the hypothesis of language specificity of the role of neighbours (Andrews, 1997). In addition these results are in agreement with the experimental data geared toward testing that hypothesis offered by Ziegler and Perry (1998) and Ziegler *et al.* (2001). These authors have presented evidence to argue that deep orthography in English may be at the root of the facilitatory effects of N, such that neighbours play a special role in helping readers to bridge the gap between the spelling-to-sound inconsistencies peculiar to English. In shallow languages (e.g. Spanish), the role of N is not as relevant, as neighbours do not fulfil the special role of aiding in the print-to-sound mapping (null effects of N in shallow languages have been found by Carreiras *et al.*, 1997; Grainger, 1990; Grainger *et al.*, 1989, 1992; Zagar & Mathey, 2000). There are no other bilingual studies[29] that have

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[29] If there are such experiments, I have not come across any reference to them in my literature review.

systematically manipulated neighbourhood parameters, to address the issue of the relevance of the experimental language (in particular of English and Spanish). Consequently, this is one of the first experiments offering specific evidence in support of the language-specific hypothesis of neighbourhood effects.

For the two languages of study, the results of this experiment confirmed the hypothesis that neighbourhood effects remain the same whether language processing takes place as native language or as second language. English native speakers showed facilitatory effects of N for English items and inhibitory effects of NF for Spanish items. The results for Spanish native speakers also mirrored this pattern. This means that, in general, the nature of neighbourhood effects relates more to language specific factors (e.g. depth of orthography) than to factors associated with the native language of the subject.

There are two aspects in the results of this study that are worth pointing out. The first one is related to the English native speakers, and the second one is related to the Spanish native speakers.

In this study, the stimuli that made up the English block were identical to the stimuli used in the English Monolingual Study (Experiment 1). Thus, in theory, the results observed with monolingual English speakers in Experiment 1 should be very similar to the results obtained with bilingual English native speakers for the English block of Experiment 3. However, a comparison of those results shows that there are some differences in the patterns (see Figure 8.8). The most striking one is that the mean RTs are noticeably faster for the bilingual speakers than for the monolingual speakers (overall RT for bilinguals was 475 ms, compared to 507 ms for monolinguals). This pattern of faster processing by the bilingual speakers is surprising, because the instructions to do the lexical task, as quickly and as accurately as possible, were exactly the same for both groups[30]. Another difference in the results is that N returned significant facilitatory effects for the bilingual speakers and no significant results for the monolingual speakers (for whom the facilitatory effects of N were only a slight trend). Significant main effects of NF were not found in either group.

These different results obtained from two separate groups of English speakers, with identical English stimuli, identical equipment, and in exactly the same physical environment, highlight the fact that there may be factors, other than the experimental ones, influencing the outcome of experiments. Unfortunately, because the stimuli that made up the Spanish block of this experiment, and the stimuli of the Monolingual Spanish Study were not identical (crucially, they differed in word frequency), comparisons of results similar to those done for the English speakers cannot be carried out for the Spanish speakers. Further discussion concerning methodological aspects of the experiments will be done in Chapter 10.

[30] Interestingly, the overall error percentages of both groups were very similar: 4 % for the bilingual speakers and 4.1 % for the monolingual speakers. This means that bilingual speakers were faster in their lexical decisions, at no cost to accuracy.

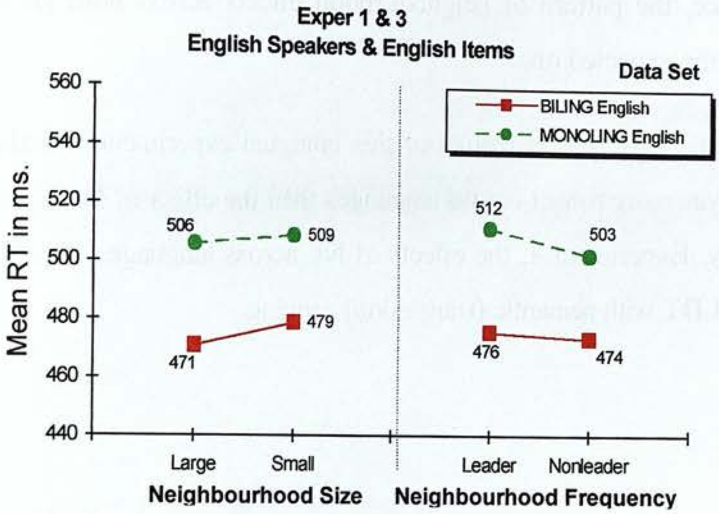

Figure 8.8. Experiments 1 & 3. *Profile comparing the results of bilingual and monolingual English speakers with English items, in the two experiments.*

A second unexpected result of this study was the facilitatory effect of N in Spanish items showed by Spanish speakers. This result was unexpected because, for the most part, previous research has found null effects of N for languages with shallow orthography (Carreiras *et al.*, 1997, Experiment 2; Grainger & Jacobs, 1996; Mathey & Zagar, 1996). It is worth remembering that the pattern of results for N in the Spanish Monolingual Study were somewhat inconclusive (Large N words were processed more slowly than words with few neighbours, but faster than words without neighbours). These results are difficult to interpret and more research is needed, specifically addressing this issue.

Finally, a comment about the L2 competence of the bilingual participants. The results of the study show that the L1 processing advantage of the Spanish speakers was much smaller (9 ms) than the L1 processing advantage of the English speakers (93 ms). These differences could be taken as a sign that the Spanish speakers were more proficient in their L2 than the English speakers in their L2. What is more relevant, however, is that, despite these differences in

L2 competence, the pattern of neighbourhood effects across both groups of speakers was the expected one.

One of the most salient results of this bilingual experiment was that the effect of NF was more robust across languages than the effect of N. In the next bilingual study, Experiment 4, the effects of NF across languages were further explored in a LDT with semantic (translation) priming.

Chapter 9

Experiment 4: Bilingual Priming Study[1] of Neighbourhood Effects with Bilingual Speakers of English and Spanish

Experiment 4 explored effects of neighbourhood frequency in a bilingual LDT with semantic (translation) priming. Specifically, the experiment was aimed at studying the effects of NF of targets and primes in bilingual lexical processing. There was one dependent variable, RT in the LDT. There were five

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[1] I named this experiment 'Bilingual Priming Study' because it was a lexical decision task with semantic (translation) priming, where targets in one language were primed by words in another language.

independent variables: Target Language (English, Spanish), Word Frequency (High, Low), Priming Condition (Unrelated, Translation), Neighbourhood Frequency (NF Leader, NF Nonleader) and Native Language (English, Spanish). NF was determined for targets (NF of Targets) and for primes (NF of Primes). Targets in one language were always primed by a word in the other language. Targets were presented in two language blocks. An inhibitory effect of NF of Targets and NF of Primes was anticipated: NF nonleader targets would be inhibited by their higher frequency neighbours, and NF nonleader primes would be less effective primes than NF leader primes. Sixty-four bilingual speakers of English and Spanish (thirty-two native speakers of English and thirty-two native speakers of Spanish) were tested. The main results of the experiment were as follows:

1. Highly significant priming results were observed in both language directions. These results were considerably larger in the L1→L2 direction.

2. NF of Targets was significantly facilitatory in the overall results. This pattern was observed particularly with Spanish speakers and with Spanish items.

3. No overall effect of NF of Primes was found. However, this variable did interact with Target Language: primes were more effective when they were NF leaders in English and when they were NF nonleaders in Spanish.

4. Low frequency items showed greater sensitivity to the effects studied in the experiment.

9.1. INTRODUCTION AND HYPOTHESES

It has already been highlighted that the research field of bilingual neighbourhood effects is largely 'uncharted territory' (Van Heuven *et al.*, 1998), as cross-language studies of neighbourhood effects are extremely scarce. Furthermore, such studies have only investigated the effects of neighbourhood size. Thus, research into neighbourhood frequency in bilingual processing is even more scarce. To the best of my knowledge no such study has yet been published. Experiment 4 will therefore be one of the first studies in this area.

The results of the three previous experiments gave support to the idea that neighbourhood effects are language specific. Experiment 3 showed that English was particularly sensitive to facilitatory effects of large neighbourhoods , and that Spanish was particularly sensitive to the inhibitory nature of having higher frequency neighbours.

Experiment 3 also indicated that in the context of bilingual processing of English and Spanish, NF was a much more influential factor across languages than N was. To investigate this aspect further, Experiment 4 explored the effects of NF in a bilingual lexical decision task with semantic (translation) priming. This task taps two different levels of knowledge: lexical knowledge (to which 'lexical similarity' is related) and semantic knowledge (related to 'conceptual similarity'). In this experiment, the assumptions about tapping lexical similarity are taken from the notion of neighbourhood, and the assumptions about cross-linguistic conceptual similarity are taken from the asymmetrical conceptual relationship between L1 and L2.

Thus, this experiment adopted the assumptions of the Bilingual Interactive Activation (BIA) Model (Dijkstra & Van Heuven, 1998; Grainger, 1993; Grainger & Dijkstra, 1992, Van Heuven *et al.*, 1998) and the Revised Hierarchical Model (Kroll & De Groot, 1997; Kroll & Stewart, 1994). As

Grainger and Dijkstra (1992) have pointed out, the BIA Model is primarily concerned with the early stages of lexical access in bilingual speakers. For later stages of lexical processing, like those involved in translation priming, a model like the Revised Hierarchical Model is more suitable.

The architecture of the BIA model envisages the existence of two language nodes, which are mutually inhibitory. These language nodes send excitatory messages to word nodes in their own lexicon, and inhibitory messages to word nodes in the lexicon of the other language. The model also allows for one of the language nodes to be 'heightened' if the speaker has expectations that the next input is likely to be in that particular language. The BIA Model (in fact the monolingual IA) predicts that a word that has higher frequency neighbours (NF nonleader), will be recognised more slowly than a word which has no higher frequency neighbours, because these higher neighbours send inhibitory messages to other similar words, including the target.

The Revised Hierarchical Model predicts translation asymmetry (Kroll & De Groot, 1997; Kroll & Stewart, 1994): translation from L1 to L2 (L1→L2) takes longer and is less accurate than L2→L1. According to the model, L1→L2 translation is more likely to engage conceptual mediation than L2→L1, as words in the L1 lexicon are biased towards conceptual links (as illustrated in Figure 5.1, Chapter 5). This circuitous route from L1 to L2 takes longer than the route L2→L1 (as L2 words are biased towards stronger lexical links with L1 words). Evidence obtained with the semantic (translation equivalents) priming paradigm (Keatley *et al.*, 1994 –Experiment 3) has revealed priming effects consistent with the predictions of the model, i.e. that translation priming effects are also asymmetrical: larger priming effects are obtained in the L1→L2 direction than in the L2→L1 direction. This happens because L1 words are more likely to tap their respective meanings and, therefore, are more likely to be more effective primes than L2 words.

In a cross-language translation priming LDT (where prime and target belong to different languages), in which primes and targets have been manipulated according to NF, two events can be anticipated:

- NF nonleader targets will be inhibited by their higher frequency neighbours.
- NF nonleader primes will be less effective primes than NF leader primes, because they are inhibited by their higher frequency neighbours (which are stronger primes, as they do not suffer the detrimental influence of higher frequency competitors).

Thus, Experiment 4 was designed to test three categories of hypotheses, based on predictions from the BIA Model and the Revised Hierarchical Model

- Hypotheses for neighbourhood frequency:

  1. NF nonleader targets are recognised more slowly than NF leader targets (inhibitory effects of NF).
  2. NF nonleader primes are less effective primes than NF leader primes[2].

- Hypotheses for cross-language priming:

  3. There are cross-language priming effects in both languages.

[2] The effectiveness of the primes was measured in terms of the differences in RT between the 'unrelated' and 'translation' categories in the variable Priming Condition.

4. L1→L2 priming effects are stronger than L2→L1 priming effects.

• Hypotheses for NF effects across languages:

5. If hypothesis 1 is true, the inhibitory effects of NF nonleader targets are stronger for L2 NF nonleader targets (L1→L2 priming condition) than for L1.

6. If hypothesis 2 is true, the reduced effectiveness of NF nonleader primes will be greatest for L2 NF nonleader primes (L2→L1 priming condition).

Planned comparisons were also made, to explore if low frequency items were more sensitive to neighbourhood frequency effects and cross-language priming effects, than the full set of items.

9.2. VARIABLES

Reaction time (RT) in ms to a lexical decision task was the dependent variable. There were five independent variables: Target Language (TL), Word Frequency (WF), Priming Condition (P), Neighbourhood Frequency (NF) and Native Language (NL).

9.2.1. TARGET LANGUAGE (TL)

This was a bilingual experiment with stimuli in English and Spanish.

1. **English stimuli**: These were English words (primes and targets) and English nonwords.

2. **Spanish stimuli**: These were Spanish words (primes and targets) and Spanish nonwords.

The target language was presented in blocks, so that in one half of the experiment all the targets were English, and in the other half, all the targets were Spanish.

9.2.2. WORD FREQUENCY (WF)

Word frequencies were taken from written word frequency counts by Kuçera & Francis (1967) for English words, and by Alameda & Cuetos (1995) for the Spanish ones. The frequency count units was number of 'occurrences per million' words (opm)[3]. There were two conditions in word frequency: 'high' and 'low' frequency.

1. **High Frequency Words** in both languages had a written frequency of at least 150 opm.
2. **Low Frequency Words** had a written frequency no higher than 55 opm[4].

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[3] As mentioned in Experiments 2 and 3, Alameda and Cuetos' (1995) frequency counts were given as number of 'occurrences per **two** million' words. The frequency counts offered by these authors were recalculated, such that all frequencies used in the experiment (for English and Spanish words) were 'occurrences per million' words.

[4] The frequency range of low frequency words in this experiment was 20–55 opm. But when compared with the frequency of low frequency words of other experiments (Andrews, 1989, 1992; Carreiras *et al.*, 1997; Sears, *et al.*, 1995) this range could be considered 'medium frequency'. However, the label 'low frequency' was maintained for consistency of description of the variable Word Frequency across all the experiments.

Given the bilingual nature of the study, low frequency words could not be of too low a frequency, or there would be a risk that bilingual speakers would not be able to recognise those words as real words in the lexical task. Furthermore, it has been argued that, in relation to the L2 lexicon, there is a larger gap between written frequency and 'experiential' frequency[5] (Connine *et al.*, 1990; Gernsbacher, 1985). In other words, L2 speakers are more likely not to have encountered low frequency words as often as native speakers. So there were grounds for raising the frequency bracket of low frequency words, while at the same time still claiming that those words could be considered low frequency words (Bijeljac-Babic *et al.*, 1997).

9.2.3. PRIMING CONDITION (P)

This was a cross-linguistic semantic priming experiment. Critical stimuli were presented in pairs. The first member of the pair was the prime (one language) and the second member of the pair was the target (the other language). Targets were always primed by real words in the other language: English targets were primed by Spanish words, and Spanish targets were primed by English words. There were two levels in the Priming Condition of the targets: 'unrelated primes' and 'translation primes'.

1. **Unrelated Primes**: Prime and target had no obvious connection in meaning, as happens in the pairs *piel–THINK* or *mono–WOUND* for

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[5] This of course raises the question that, although low frequency words in both languages belonged to the same frequency bracket (20–55 opm) the 'experiential frequency' of those words was likely to be different for first language compared to second language speakers. This discrepancy between print word frequency and experiential frequency would affect both languages in the same way. For a more detailed account of 'experiential frequency' or 'word familiarity' see section 3.3.5 in Chapter 3 (Word Frequency Effects).

English targets, and in the pairs *magic–SUCIO* or *fruit–OREJA*[6] for Spanish targets.

2. **Translation Primes**: Prime and target were direct translations of each other. Examples of translation pairs are *ver–SEE* or *premio–PRIZE* for English, and *hand–MANO* or *father–PADRE* for Spanish.

9.2.4. NEIGHBOURHOOD FREQUENCY (NF)

The variable Neighbourhood Frequency was a measure of the frequency of a word in relation to its neighbours. The basic distinction in this variable was between an 'NF leader' and an 'NF nonleader'.

1. **Neighbourhood Frequency Leaders** had no higher frequency neighbours.

2. **Neighbourhood Frequency Nonleaders** had one or more higher frequency neighbours in their neighbourhood.

As said before, all the stimuli were presented in pairs. NF was only relevant in the 'translation' priming condition. Both primes and targets were selected for their NF, which resulted in two versions of the NF variable: NF of Targets and NF of Primes. Targets and primes were selected to fill the categories of NF leaders and NF nonleaders. The crossing of these two sub-variables (2 x 2) produced four different categories of prime-target pairs:

[6] *Piel* means 'skin', and *mono* means 'monkey'. *Sucio* means 'dirty', and *oreja* means 'ear'.

1. **NF Leader Prime – NF Leader Target**. Examples of pairs in this level are *puerta–DOOR*[7] for English, and *three–TRES* for Spanish.

2. **NF Nonleader Prime – NF Leader Target**. Illustrations of this category are the pairs *junto–NEXT* and *world–MUNDO*[8].

3. **NF Leader Prime – NF Nonleader Target**. Examples of these pairs are *sudor–SWEAT*[9] for English, and *house–CASA* for Spanish.

4. **NF Nonleader Prime –NF Nonleader Target**. Examples are the pairs *cara–FACE*[10] and *mud–BARRO*.

9.2.5. NATIVE LANGUAGE (NL)

Bilingual subjects fitted one of two categories:

1. **Native Speaker of English** with advanced level of Spanish as a second language.

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[7] *Puerta* has a frequency of 410 opm and it is the most frequent word in a neighbourhood of 6 neighbours. *Door*'s frequency is 312 opm, and it is the most frequent item in a neighbourhood of 5.

[8] The word *world*, for example, has a frequency of 787 opm, and it is less frequent than its neighbour *would* (2714 opm). *Mundo*, on the other hand, with a frequency of 887.5 opm is the most frequent neighbour in a neighbourhood of 4.

[9] The word *sudor* has a written frequency of 40 and is the frequency leader in a neighbourhood of 2. *Sweat*, on the other hand, has a frequency of 23, belongs to a neighbourhood of 4 and is not the most frequent item is the neighbourhood, as the word *sweet* (70 opm) is more frequent.

[10] *Cara* has a frequency of 315 opm and, in its numerous neighbourhood, many neighbours are more frequent, for example the word *para* (5746.5 opm). *Face* has a frequency of 371 opm, and in its neighbourhood *fact* is more frequent (447 opm).

2. **Native Speaker of Spanish** with advanced level of English as a second language.

9.3. METHOD

9.3.1. SUBJECTS

Sixty-four bilingual speakers[11] of English and Spanish took part in this experiment. Most of these subjects had taken part in Experiment 3[12]. Half the subjects were native speakers of English and the other half were native speakers of Spanish. They all took part in the study on a voluntary basis and they received no compensation for their participation. Subjects had normal or corrected-to-normal vision. The participants came from the same populations of The University Edinburgh students as the participants in the earlier bilingual study. What was said in section 8.3.1 about linguistic competence and education of subjects there can be applied here.

All the English native speakers were Final Year students of a Spanish Degree, and they had recently spent at least between six and twelve months in a Spanish speaking country. The Spanish native speakers were either undergraduates or postgraduates students, residing in Edinburgh at the time of the experiment, and they had had an experience of between six months and four

[11] As specified in Chapter 1 (Introduction), 'bilingual speaker' here refers to a speaker who speaks two languages, but not necessarily with comparable level of competence.

[12] This circumstance was not considered material for the results of the current experiment, as three months had elapsed between the participation in the two experiments.

years living in Britain. Speakers of both groups perceived themselves as advanced speakers of the second language.

Prior to taking part in the actual experiment, all participants answered informal questions about their linguistic experience, education and work and hand dominance.

9.3.2. STIMULI AND DESIGN

The stimuli included 148 Spanish–English pairs and 180 English–Spanish pairs[13]. The unrelated pairs were used as control pairs. Another 148 Spanish word / English nonword pairs and 180 English word / Spanish nonword pairs were included in the experiment for the purpose of the lexical decision task. Nonwords were drawn from the set of English and Spanish nonwords used in Experiment 3.

In the critical pairs (translated condition) and in the control pairs (unrelated condition), both members of the pair belonged to the same word frequency band: high frequency targets were primed by high frequency primes, and low frequency targets were primed by low frequency primes[14].

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[13] The uneven distribution of pairs across languages and across the experimental conditions was a result of the limitations encountered in the stimulus selection process. For some categories it was very difficult to find suitable items without seriously compromising the operational definition of the independent variables.

[14] Frequency parity of prime and target was a natural consequence of using translation, as the frequencies of translation equivalents tend to correlate directly: a high frequency word in one language usually translates into a high frequency equivalent in the other language. As a result, a point was made of maintaining this frequency parity not only in the translation pairs but also in the unrelated pairs.

The study fitted a 2 x [2 x 2 x 2 x 2] mixed experimental design: Native Language (English, Spanish) x [Target Language (English, Spanish) x Word Frequency (High, Low) x Neighbourhood Frequency (Leader, Nonleader) x Priming Condition (Unrelated, Translation)].

As explained before, the experimental stimuli were made up of translated pairs and unrelated pairs, with each member of the pair being from a different language. Putting the translation pairs together had to be a meticulous task, which followed the steps described below.

- Finding high frequency Spanish words[15] with high frequency English translation. The same was done for low frequency words.

- For each member of the pair, it was noted whether they were NF leaders or nonleaders.

- Pairs were assigned to either English or Spanish, and this determined which word was to act as a related prime and which as a target. Pairs were also put in the right frequency bracket.

- English targets and Spanish targets were assigned to one of the four NF conditions described in section 9.2.4, depending on whether prime or target were NF leaders or nonleaders.

- When translation pairs had been assigned to all 16 categories (two target languages x two levels of word frequency x 4 levels of NF), a similar number of unrelated pairs were created. In these new pairs,

[15] The Spanish words were chosen from Alameda and Cuetos' (1995) dictionary. The English words were chosen from the MRC Psycholinguistic Database (described in Coltheart, 1981).

targets were the same as in the related condition and primes were words of similar frequency but completely unrelated in meaning.

Apart from the specifications of the independent variables, the following criteria[16] were considered relevant in the final selection of the critical pairs.

- Cognate / non-cognate relationship. As cognates (words of very similar spelling and meaning in both languages) have been shown to have a special status in interlanguage priming (Bowers, Mimouni & Arguin, 2000; DeGroot, 1992b, 1993; De Groot *et al.*, 1994; De Groot & Nas, 1991; Sánchez-Casas, 1999), non-cognate pairs were preferred to cognate pairs. In this experiment, the proportion was 313 non-cognate pairs and 15 true cognates.

- Unique / multiple translation. An effort was made to ensure that words had a unique translation, or that the most frequent translation was used for words with more than one meaning[17].

This process resulted in 148 Spanish–English pairs (74 translated pairs and 74 unrelated pairs) and 180 English–Spanish pairs (90 translated pairs and 90 unrelated pairs), distributed across the experimental conditions in the manner shown on Table 9.1 and Table 9.2. In the tables, the first word of the pair was the prime[18] and the second word (in bold) was the target.

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[16] Variables like number of neighbours, length of word, nature of word meaning (concrete, or abstract) or grammatical category, were aspects initially taken into consideration but had to be disregarded at later stages of the stimulus selection process, as it would have been impossible to find enough pairs for the experiment.

[17] Occasionally, the most obvious translation did not result in a word that had the required word frequency or the required NF.

[18] Unrelated primes appear twice on the stimulus tables because there were two presentation lists, and the unrelated primes were the same on both lists (see section 9.3.3 Procedure).

1. ENGLISH TARGETS

NF TARGET →	1. LEADER (Target)				2. NONLEADER (Target)			
NF PRIME →	1 LEADER (Prime) **[1]**		2 NONLEADER (Prime) **[2]**		1 LEADER (Prime) **[3]**		2 NONLEADER (Prime) **[4]**	
PRIMING →	UNRELATED	TRANSLATION	UNRELATED	TRANSLATION	UNRELATED	TRANSLATION	UNRELATED	TRANSLATION
WORD FREQUENCY ↓	alma-**mother**	madre-**mother**	pesar-**two**	dos-**two**	calle-**cut**	partir-**cut**	por-**face**	cara-**face**
	boca-**other**	otro-**other**	cuando-**have**	haber-**have**	gente-**much**	mucho-**much**	con-**alone**	solo-**alone**
	cama-**clear**	claro-**clear**	mayor-**next**	junto-**next**	pelo-**way**	manera-**way**	pero-**see**	ver-**see**
	cielo-**soon**	pronto-**soon**	peor-**know**	saber-**know**	gente-**now**	ahora-**now**		
	cine-**force**	fuerza-**force**			cuanto-**top**	arriba-**top**		
	duda-**field**	campo-**field**			calle-**five**	cinco-**five**		
	falta-**better**	mejor-**better**			pelo-**end**	final-**end**		
	hora-**back**	fondo-**back**			quien-**look**	mirada-**look**		
HIGH	paso-**point**	punto-**point**			fuera-**night**	noche-**night**		
	piel-**money**	dinero-**money**			porque-**live**	vivir-**live**		
	siglo-**less**	menos-**less**						
FREQ	vista-**air**	aire-**air**						
	alma-**true**	cierto-**true**						
	cama-**body**	cuerpo-**body**						
WORDS	siglo-**form**	forma-**form**						
	cine-**fact**	hecho-**fact**						
	hora-**side**	lado-**side**						
	duda-**new**	nuevo-**new**						
	piel-**think**	pensar-**think**						
	vista-**door**	puerta-**door**						
	cielo-**sure**	seguro-**sure**						
	boca-**earth**	tierra-**earth**						
	paso-**all**	todo-**all**						
	falta-**time**	vez-**time**						
	oso-**slight**	leve-**slight**	rosa-**hidden**	oculto-**hidden**	cena-**tale**	relato-**tale**	beso-**dawn**	alba-**dawn**
	sed-**deny**	negar-**deny**	rosa-**blind**	ciego-**blind**	eco-**throw**	echar-**throw**	cita-**fifth**	quinto-**fifth**
	oso-**border**	orilla-**border**	asco-**ice**	hielo-**ice**	nota-**cry**	llanto-**cry**	fama-**skirt**	falda-**skirt**
LOW	sed-**hurry**	prisa-**hurry**			tren-**sick**	harto-**sick**	hilo-**lake**	lago-**lake**
					pata-**calm**	calma-**calm**	mayo-**sale**	venta-**sale**
FREQ					tren-**shut**	cerrar-**shut**	muro-**cup**	taza-**cup**
					cena-**bend**	curva-**bend**	hilo-**cape**	capa-**cape**
WORDS					mono-**wound**	herida-**wound**	muro-**load**	cargo-**load**
					polo-**aim**	rumbo-**aim**	beso-**win**	ganar-**win**
					eco-**sweat**	sudor-**sweat**	mayo-**sheet**	hoja-**sheet**
					cima-**treat**	tratar-**treat**	cita-**pause**	pausa-**pause**
					nota-**sell**	vender-**sell**	fama-**plate**	plato-**plate**
							mando-**prize**	premio-**prize**
							hogar-**beam**	rayo-**beam**

Table 9.1. Bilingual Priming Study. *Complete set of Spanish–ENGLISH pairs, for the 'Unrelated' and 'Translation' Priming Conditions.*

2. SPANISH TARGETS

NF TARGET →	1. LEADER (Target)				2. NONLEADER (Target)			
NF PRIME →	1 LEADER (Prime) [1]		2 NONLEADER (Prime) [2]		1 LEADER (Prime) [3]		2 NONLEADER (Prime) [4]	
PRIMING →	UNRELATED	TRANSLATION	UNRELATED	TRANSLATION	UNRELATED	TRANSLATION	UNRELATED	TRANSLATION
WORD FREQUENCY ↓ HIGH FREQ WORDS	seem-**bueno** show-**cambio** find-**encima** tell-**hasta** keep-**largo** must-**lugar** week-**medio** well-**muerte** home-**muy** year-**propio** truth-**salir** more-**tener** well-**amor** truth-**frente** more-**mano** keep-**mesa** home-**negro** year-**papel** tell-**parte** seem-**poder** must-**suelo** week-**tipo** show-**tres** find-**viejo**	good-**bueno** change-**cambio** above-**encima** until-**hasta** long-**largo** place-**lugar** half-**medio** death-**muerte** very-**muy** own-**propio** leave-**salir** have-**tener** love-**amor** front-**frente** hand-**mano** table-**mesa** black-**negro** paper-**papel** part-**parte** power-**poder** floor-**suelo** type-**tipo** three-**tres** old-**viejo**	line-**cuatro** city-**donde** open-**hacer** need-**hombre** ever-**mismo** mind-**tarde** line-**cerca** open-**decir** mind-**guerra** hardly-**lejos** ever-**libro** need-**mundo** city-**pasado** inside-**vida**	four-**cuatro** where-**donde** make-**hacer** man-**hombre** same-**mismo** late-**tarde** near-**cerca** say-**decir** war-**guerra** far-**lejos** book-**libro** world-**mundo** past-**pasado** life-**vida**	brown-**alto** music-**casa** heart-**cuarto** court-**hijo** space-**obra** level-**uno**	high-**alto** house-**casa** room-**cuarto** son-**hijo** work-**obra** one-**uno**	matter-**caso** office-**coche** across-**cosa** moment-**muerto** figure-**nombre** period-**padre**	case-**caso** car-**coche** thing-**cosa** dead-**muerto** name-**nombre** father-**padre**
LOW FREQ WORDS	luxury-**docena** branch-**marina** branch-**azar** luxury-**nube**	dozen-**docena** navy-**marina** random-**azar** cloud-**nube**	jungle-**abrigo** limit-**anillo** fruit-**banda** engine-**sabio** museo-**trampa** limit-**arena** jungle-**cantar** recent-**criada** person-**disco** engine-**fumar** museum-**nave** fruit-**oreja** strong-**pecado**	coat-**abrigo** ring-**anillo** band-**banda** wise-**sabio** trap-**trampa** sand-**arena** sing-**cantar** maid-**criada** disk-**disco** smoke-**fumar** craft-**nave** ear-**oreja** sin-**pecado**	cycle-**broma** magic-**sucio** salary-**crear** magic-**ira** cycle-**reina** depend-**sal** oxygen-**salto**	joke-**broma** dirty-**sucio** create-**crear** anger-**ira** queen-**reina** salt-**sal** jump-**salto**	golden-**barro** iron-**conde** ugly-**fila** false-**hueso** devil-**llenar** worthy-**palo** guard-**rastro** estate-**saco** ugly-**barba** golden-**dicha** false-**macho** devil-**pez** iron-**raro** worthy-**red** estate-**suma** guard-**trato**	mud-**barro** count-**conde** row-**fila** bone-**hueso** fill-**llenar** stick-**palo** trail-**rastro** bag-**saco** beard-**barba** joy-**dicha** male-**macho** fish-**pez** rare-**raro** net-**red** sum-**suma** treat-**trato**

Table 9.2. Bilingual Priming Study. *Complete set of English–SPANISH pairs, for the 'Unrelated' and 'Translation' Priming Conditions.*

Table 9.3 shows the frequency means for the experimental pairs. The WF range for high frequency words was 150 to 3941 opm, with a mean of 544. The WF range for low frequency words was 20 to 55 opm, and the mean was 35.

1. ENGLISH EXPERIMENTAL TARGETS

NF TARGET	1. LEADER (Target)				2. NONLEADER (Target)			
NF PRIME	1 LEADER (P) **[1]**		2 LEADER (P) **[2]**		1 LEADER (P) **[3]**		4 NONLEADER (P) **[4]**	
WORD FREQ	Spanish PRIMES	English TARGETS	Spanish PRIMES	English TARGETS	Spanish PRIMES	English TARGETS	Spanish PRIMES	English TARGETS
HIGH	534	611	595	1067	403	524	404	446
LOW	36	39	36	37	34	35	33	35

2. SPANISH EXPERIMENTAL TARGETS

NF TARGET	1. LEADER (Target)				2. NONLEADER (Target)			
NF PRIME	1 LEADER (P) **[1]**		2 LEADER (P) **[2]**		1 LEADER (P) **[3]**		4 NONLEADER (P) **[4]**	
WORD FREQ	English PRIMES	Spanish TARGETS	English PRIMES	Spanish TARGETS	English PRIMES	Spanish TARGETS	English PRIMES	Spanish TARGETS
HIGH	554	444	552	594	948	467	220	355
LOW	39	29	36	31	39	35	37	34

Table 9.3. Bilingual Priming Study. *Mean word frequencies of Primes and Targets for English and Spanish experimental items in the 'Translation' Priming Condition.*

All the stimuli finally selected were divided into two presentation lists, A and B, which respected the experimental design. Each language presentation list contained half the related pairs and half the control unrelated pairs. The translated targets of presentation list A were the unrelated targets on list B, and the unrelated targets of list A were the translated targets on list B. There was a presentation list A and B for each language. For example, English presentation list A contained the pairs *madre–MOTHER* (translation) and *beso–DAWN* (unrelated), whereas English presentation list B contained the pairs *alma–MOTHER* (unrelated) and *alba–DAWN* (translation). In the same way, Spanish presentation list A contained pairs like *good–BUENO* (translation) and *golden–BARRO* (unrelated), and Spanish presentation list B contained pairs like *seem–BUENO* (unrelated) and *mud–BARRO* (translation). The two presentation lists were thus counterbalanced such that no word appeared more than once on every presentation list, and every target was translation-primed on one list and unrelated-primed on the other.

The Target Language was presented in blocks. There were two orders of presentation:

1. • English targets presentation A block
   • Spanish targets presentation A block

2. • English targets presentation B block
   • Spanish targets presentation B block

As well as the critical stimuli, both presentations included the same set of word / nonwords English pairs and word / nonword Spanish pairs.

9.3.3. PROCEDURE

Subjects were tested in a quiet room for about 15 minutes. The experimental session also included an informal interview. Participants were informed that they were going to do an experiment about English and Spanish letter strings, and that some of those strings were real English or Spanish words (like *time* or *silla* [chair]) and that some were not real words in either language, like *holpe*. Letter strings appeared in pairs, one string after the other. The first letter string was always in big red letters and the second string always appeared in smaller black letters. Subjects were specifically instructed to ignore the first member of the pair and only to respond to the second member. They were asked to decide if the black letter string (the second one) was a true English word (or a Spanish word, depending on the language block). If they thought it was a true word, they had to press the YES-button on the response box with their dominant hand, and if they thought it was not a true word, they had to press the NO-button with the other hand. They were asked to react as quickly and as accurately as possible.

The experiment comprised four blocks: practice session 1, language block 1 (either English or Spanish), practice session 2, and language block 2 (either Spanish or English). The practice sessions contained twelve prime–target pairs each, with targets in the language of the block following. None of those pairs appeared later in the experiment. After the first session practice, subjects could ask any questions, were reminded that both speed and accuracy were important, and that they only had to react to the second letter string of the pair (always in black lettering). Between language blocks, they were encouraged to rest their eyes for a few seconds before proceeding.

The physical characteristics of the letter strings and the precise sequence of events that participants saw on the screen were as follows:

- A letter string (prime, in one language) in lowercase 48-point red courier appeared, centred on a white screen for 700 ms.
- A blank screen followed for 100 ms.
- A letter string (target, in the other language) in lowercase 24-point black courier that terminated with the subject's response, or after a 2000-ms timeout.
- Exactly one second afterwards, another pair sequence started.

The order of language block presentation was controlled. Each group of native speakers was randomly divided into four subgroups, with equal numbers of participants each.

- Group 1 did Presentation A, with the English block first and the Spanish block last.
- Group 2 did Presentation A, with the Spanish block first and the English block last.
- Group 3 did Presentation B, with the English block first and the Spanish block last.
- Group 4 did Presentation B, with the Spanish block first and the English block last.

The order of stimuli presentation was randomised by the computer with every run of the experiment.

9.4. RESULTS

The results presented here are for correct responses to target words. Incorrect responses to words (4.3% of all the answers) and responses shorter than 300 ms or longer than 1500 ms (1.1% of the correct answers) were discarded from the statistical analysis[19]. Mean RT for every condition of the experiment was calculated across subjects and items[20]. Table 9.4 shows average RT for English native speakers, both for English and Spanish targets. Table 9.5 presents similar results for Spanish native speakers. These tables also show the strength and direction of the priming effects (*RT DIF*). When the RT difference between the two priming conditions (unrelated, translation) was positive (positive priming), recognition of the translation-primed targets was faster than recognition of the non-translated primed targets. A negative difference (negative priming) means that translation priming was detrimental for recognition of the targets. A preliminary look at the RT results shows that in all experimental conditions but one, there were positive priming effects. In some cases the priming effects were quite considerable (up to 116 ms).

[19] See footnote n.14 on 'outliers' in Chapter 7 (Experiment 2).

[20] All the calculations of this experiment were conducted with SPSS 9.0 for Windows. Preparation and analysis of data were done following indications made by Kinnear and Gray (1997).

1. ENGLISH NATIVE SPEAKERS

LANG	1 ENGLISH EXPERIMENTAL TARGETS														
NF TGT	1. LEADER (Target)						2. NONLEADER (Target)								
NF PRM	1 LEADER (Prime) **[1]**			2 NONLEADER (Prime) **[2]**			1 LEADER (Prime) **[3]**			2 NONLEADER (Prime) **[4]**			**OVERALL**		
PRIMING	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*
HIGH	475	459	*+16*	477	429	*+48*	475	478	*–3*	479	427	*+52*	476	448	*+28*
LOW	517	501	*+16*	493	442	*+51*	516	486	*+30*	509	492	*+17*	509	480	*+28*
Mean	496	480	*+16*	485	435	*+49*	496	482	*+14*	494	460	*+34*	492	464	*+28*

LANG	2 SPANISH EXPERIMENTAL TARGETS														
NF TGT	1. LEADER (Target)						2. NONLEADER (Target)								
NF PRM	1 LEADER (Prime) **[1]**			2 NONLEADER (Prime) **[2]**			1 LEADER (Prime) **[3]**			2 NONLEADER (Prime) **[4]**			**OVERALL**		
PRIMING	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*
HIGH	569	513	*+56*	544	495	*+49*	542	508	*+34*	548	499	*+49*	551	504	*+47*
LOW	700	635	*+65*	627	598	*+29*	654	538	*+116*	636	589	*+47*	654	590	*+64*
Mean	634	574	*+60*	585	547	*+39*	598	523	*+75*	592	544	*+48*	603	547	*+56*

Table 9.4. Bilingual Priming Study. *Results for ENGLISH SPEAKERS. Mean RT in ms to words for ALL the EXPERIMENTAL CONDITIONS, for English and Spanish items. RT DIF = Strength of priming effects.*

2. SPANISH NATIVE SPEAKERS

LANG	1 ENGLISH EXPERIMENTAL TARGETS														
NF TGT	1. LEADER (Target)						2. NONLEADER (Target)								
NF PRM	1 LEADER (Prime) [1]			2 NONLEADER (Prime) [2]			1 LEADER (Prime) [3]			2 NONLEADER (Prime) [4]			OVERALL		
PRIMING	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*
HIGH	538	512	*+26*	541	494	*+47*	545	495	*+50*	555	499	*+56*	545	500	*+45*
LOW	607	557	*+50*	617	528	*+89*	578	536	*+42*	597	551	*+47*	600	543	*+57*
Mean	572	534	*+38*	579	511	*+68*	562	515	*+46*	576	524	*+51*	572	521	*+51*

LANG	2 SPANISH EXPERIMENTAL TARGETS														
NF TGT	1. LEADER (Target)						2. NONLEADER (Target)								
NF PRM	1 LEADER (Prime) [1]			2 NONLEADER (Prime) [2]			1 LEADER (Prime) [3]			2 NONLEADER (Prime) [4]			OVERALL		
PRIMING	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*	UNREL	TRANSL	*RT DIF*
HIGH	552	499	*+52*	530	505	*+25*	525	491	*+34*	533	472	*+61*	535	492	*+43*
LOW	606	572	*+34*	554	521	*+33*	524	509	*+15*	560	537	*+23*	561	535	*+26*
Mean	579	536	*+43*	542	513	*+29*	524	500	*+25*	546	504	*+42*	548	513	*+35*

Table 9.5. Bilingual Priming Study. *Results for SPANISH SPEAKERS. Mean RT in ms to words for ALL the EXPERIMENTAL CONDITIONS, for English and Spanish items. RT DIF = Strength of priming effects.*

The analysis of the data was performed at two different levels:

- At the level of targets according to their neighbourhood frequency (NF of TARGETS).
- At the level of targets according to the neighbourhood frequency of their primes (NF of PRIMES).

In addition, the corresponding subsets of low frequency data were analysed in a similar manner and results compared with those of the full set of data. At both levels of analysis, by-subjects and by-items separate ANOVAs were performed. F results for the ANOVAs are given as F_s for subjects and F_i for items. The p level to reject null hypotheses was set at 0.05.

The results are presented under the following headings:

1. Response latencies according to NF of Targets
    - 1.1. NF of Targets in full data
    - 1.2. NF of Targets in low frequency data
2. Response latencies according to NF of Primes
    - 1.1. NF of Primes in full data
    - 1.2. NF of Primes in low frequency data

9.4.1. RESPONSE LATENCIES ACCORDING TO NF OF TARGETS

9.4.1.1. NF OF TARGETS IN FULL DATA

This section presents the results obtained for experimental targets according to their own NF (NF leader targets, NF nonleader targets). For the by-subjects analysis at NF of TARGETS level, a repeated-measures ANOVA was conducted, which had Native Language as a between-subjects factor, and Target Language, Word Frequency, NF of Targets and Priming Condition as within-subjects factors. For the by-items analysis, an ANOVA was conducted that had all the variables just mentioned as between-subjects factors[21].

The ANOVA results for RT, according to the NF of the targets, are shown in the next three tables. Table 9.6 presents details of the general results for All Speakers and by Native Language[22]. Table 9.7 gives results for English and Spanish speakers separately. Table 9.8 shows details of results for each target language.

As expected, the ANOVAs on experimental items by Target Language (Table 9.8) yielded significant differences between the two groups of speakers. For English items, the between-subjects factor of Native Language was reliable, both in the subject and item data [F_S (1, 62) = 18.6, MSE = 64600, $p < .001$; F_i (1, 264) = 120.1, MSE = 1593, $p < .001$]. For the Spanish items, the effect of Native Language was also significant in the by-subjects and the by-items analyses [F_S (1, 62) = 5.4, MSE = 92795, $p < .023$; F_i (1, 328) = 74.5, MSE = 1791, $p < .001$]. The larger effects of Native Language observed for Spanish targets with respect to English targets, meant that the two groups of speakers varied considerably in their competence of Spanish but not in English. In other words, the Spanish bilinguals were more proficient bilinguals.

[21] Note that both 'unrelated' targets and 'translation' targets were included in these ANOVAs.

[22] ANOVA results for the between-subjects factor of Native Language was not significant for subject data but it was for item data [$F_s < 1$; F_i (1, 624) = 6.5, MSE = 1783, p < .011].

OVERALL RESULTS FOR NF OF TARGETS						
EFFECTS	**ALL SPEAKERS**			**BY NATIVE LANGUAGE**		
	F_S (1, 62) F_i(1, 624)	MSE	*p* <	F_S (1, 62) F_i (1, 624)	MSE	*p* <
LANGUAGE (TL)	F_S = 47.9	17137	*.001*	F_S = 94.9	17137	*.001*
	F_i = 101.7	1783	*.001*	F_i = 209.4	1783	*.001*
WORD FREQ (WF)	F_S = 158.1	9011	*.001*	F_S = 6.6	9011	*.013*
	F_i = 168.4	1783	*.001*	F_i = 7.9	1783	*.005*
NF OF TARGET (TG.NF)	F_S = 12.6	4115	*.001*	F_S = 2.1	4115	*.148*
	F_i = 3.8	1783	*.049*	F_i < 1		
PRIMING (P)	F_S = 124.1	7397	*.001*	F_S < 1		
	F_i = 126.2	1783	*.001*	F_i < 1		
TL x WF	F_S = 14.3	5236	*.001*	F_S = 36.3	5236	*.001*
	F_i = 7.7	1783	*.006*	F_i = 26.9	1783	*.001*
TL x TG.NF	F_S = 14.8	5129	*.001*	F_S < 1		
	F_i = 2.5	1783	*.115*	F_i < 1		
TL x P	F_S < 1			F_S = 10.4	5808	*.002*
	F_i < 1			F_i = 6.1	1783	*.014*
WF x TG.NF	F_S = 5.3	3849	*.024*	F_S < 1		
	F_i < 1			F_i < 1		
WF x P	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
TG.NF x P	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
TL x WF x TG.NF	F_S = 3.2	3637	*.079*	F_S = 2.9	3637	*.096*
	F_i < 1			F_i < 1		
TL x WF x P	F_S < 1			F_S = 3.6	4692	*.063*
	F_i = 3.2	1783	*.073*	F_i < 1		
TL x TG.NF x P	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
WF x TG.NF x P	F_S < 1			F_S = 5.5	4155	*.022*
	F_i < 1			F_i = 3.1	1783	*.081*
TLxWFxTG.NFxP	F_S = 2.1	4175	*.152*	F_S < 1		
	F_i = 3.5	1783	*.062*	F_i < 1		

NOTE. First column: Effects of TL = Target Language, WF = Word Frequency, TG.NF = Neighbourhood Frequency of Targets, P = Priming Condition. Second column: Results for All Speakers (Overall). Third column: Results by Native Language.

Table 9.6. Bilingual Priming Study. *ANOVA results for responses of ALL SPEAKERS to targets according to NF of TARGETS (for subject and item data). Significant results are highlighted.*

RESULTS OF NF OF TARGETS BY NATIVE LANGUAGE						
EFFECTS	**ENGLISH SPEAKERS**			**SPANISH SPEAKERS**		
	F_S (1, 31) F_i(1, 296)	MSE	*p* <	F_S (1, 31) F_i (1, 296)	MSE	*p* <
LANGUAGE (TL)	F_S = 101.1	23545	*.001*	F_S = 6.4	10729	*.017*
	F_i = 267.3	1878	*.001*	F_i = 6.2	1528	*.013*
WORD FREQ (WF)	F_S = 116.5	8871	*.001*	F_S = 49.2	9151	*.001*
	F_i = 117.7	1878	*.001*	F_i = 56.2	1528	*.001*
NF OF TARGET (TG.NF)	F_S = 1.7	5154	*.198*	F_S = 16.8	3077	*.001*
	F_i = 1.6	1878	*.206*	F_i = 5.7	1528	*.018*
PRIMING (P)	F_S = 86.1	5214	*.001*	F_S = 49.1	9578	*.001*
	F_i = 59.8	1878	*.001*	F_i = 69.4	1528	*.001*
TL x WF	F_S = 35.5	7102	*.001*	F_S = 3.9	3370	*.057*
	F_i = 28.7	1878	*.001*	F_i = 1.2	1528	*.275*
TL x TG.NF	F_S = 12.5	4462	*.001*	F_S = 4.1	5796	*.053*
	F_i = 3.7	1878	*.054*	F_i = 3.9	1528	*.048*
TL x P	F_S = 8.7	5446	*.006*	F_S = 2.7	6170	*.109*
	F_i = 2.3	1878	*.133*	F_i = 4.2	1528	*.040*
WF x TG.NF	F_S = 2.4	3299	*.128*	F_S = 2.9	4400	*.099*
	F_i < 1			F_i < 1		
WF x P	F_S < 1			F_S < 1		
	F_i = 1.1	1878	*.289*	F_i < 1		
TG.NF x P	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
TL x WF x TG.NF	F_S = 5.1	4305	*.031*	F_S < 1		
	F_i = 1.8	1878	*.179*	F_i < 1		
TL x WF x P	F_S = 1.1	4165	*.292*	F_S = 2.5	5219	*.123*
	F_i < 1			F_i = 2.9	1528	*.087*
TL x TG.NF x P	F_S = 1.4	4364	*.233*	F_S < 1		
	F_i < 1			F_i < 1		
WF x TG.NF x P	F_S = 2.3	3101	*.136*	F_S = 3.2	5210	*.084*
	F_i < 1			F_i = 2.2	1528	*.137*
TLxWFxTG.NFxP	F_S = 2.7	3387	*.110*	F_S < 1		
	F_i = 2.5	1878	*.115*	F_i < 1		

Table 9.7. Bilingual Priming Study. *ANOVA results for responses of ENGLISH and SPANISH SPEAKERS to targets according to NF of TARGETS (subject and item data). Significant results are highlighted.*

RESULTS OF NF OF TARGETS BY TARGET LANGUAGE: ENGLISH ITEMS						
EFFECTS	**ALL SPEAKERS** F_S (1, 62) F_i(1, 264)	MSE	*p* <	**BY NATIVE LANGUAGE** F_S (1, 62) F_i (1, 264)	MSE	*p* <
WORD FREQ (WF)	F_S = 84.6	4994	*.001*	F_S = 3.7	4994	*.059*
	F_i = 43.1	1593	*.001*	F_i = 1.2	1593	*.265*
NF OF TARGET (TG.NF)	F_S < 1			F_S = 3.5	3313	*.065*
	F_i < 1			F_i < 1		
PRIMING (P)	F_S = 51.6	7773	*.001*	F_S = 4.2	7773	*.044*
	F_i = 59.8	1593	*.001*	F_i = 2.4	1593	*.120*
WF x TG.NF	F_S < 1			F_S = 1.7	4054	*.194*
	F_i < 1			F_i < 1		
WF x P	F_S < 1			F_S < 1		
	F_i = 1.5	1593	*.214*	F_i < 1		
TG.NF x P	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
WF x TG.NF x P	F_S = 1.9	4194	*.178*	F_S = 1.4	4194	*.234*
	F_i = 2.1	1593	*.150*	F_i < 1		

RESULTS OF NF OF TARGETS BY TARGET LANGUAGE: SPANISH ITEMS						
EFFECTS	**ALL SPEAKERS** F_S (1, 62) F_i(1, 328)	MSE	*p* <	**BY NATIVE LANGUAGE** F_S (1, 62) F_i (1, 328)	MSE	*p* <
WORD FREQ (WF)	F_S = 116.4	9252	*.001*	F_S = 25.1	9252	*.001*
	F_i = 157.9	1791	*.001*	F_i = 35.6	1791	*.001*
NF OF TARGET (TG.NF)	F_S = 21.4	5931	*.001*	F_S < 1		
	F_i = 16.7	1791	*.001*	F_i < 1		
PRIMING (P)	F_S = 95.9	5431	*.001*	F_S = 5.1	5431	*.028*
	F_i = 72.6	1791	*.001*	F_i = 4.2	1791	*.041*
WF x TG.NF	F_S = 9.2	3432	*.004*	F_S = 1.1	3432	*.304*
	F_i = 3.5	1791	*.063*	F_i < 1		
WF x P	F_S < 1			F_S = 2.9	6480	*.096*
	F_i < 1			F_i = 2.4	1791	*.122*
TG.NF x P	F_S < 1			F_S < 1		
	F_i < 1			F_i < 1		
WF x TG.NF x P	F_S < 1			F_S = 4.5	4137	*.038*
	F_i = 1.1	1791	*.291*	F_i = 2.8	1791	*.093*

Table 9.8. Bilingual Priming Study. *ANOVA results for responses to ENGLISH and SPANISH EXPERIMENTAL ITEMS, according to NF of TARGETS (for subject and item data). Significant results are highlighted.*

The main effects of Target Language[23] and Word Frequency[24] showed very robust effects in the analyses, both of the single group of All Speakers and of the two groups of speakers taken separately. The details of the significant results of these variables are offered outside the main text. Generally, English items were recognised significantly faster than Spanish items; also L1 items were processed faster than L2 items. The interaction between Target Language and Word Frequency was also significant[25].

In the following paragraphs the results of two effects that were the main focus of this study are presented: the effects of NF of Targets and the effects of Priming Condition. Results of ANOVA for NF of Targets were highly significant in responses for All speakers (subject and item data, Table 9.6) and particularly in responses from Spanish speakers (subject and item data, Table 9.7). For All Speakers, the effect of NF of Targets was facilitatory: targets that were NF nonleaders were recognised faster (10 ms) than targets that were NF

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[23] Similar to the previous experiments, English items were generally recognised faster than Spanish items, with a difference of 41 ms, significant for both subject and item data (mean RT to English targets was 512 ms, and 552 ms to Spanish targets). English and Spanish speakers showed the expected advantage in processing L1 relative L2 (by-subjects and by-items analyses). Specifically, English speakers recognised English targets 97 ms faster than Spanish targets, and Spanish speakers recognised Spanish targets 16 ms faster than English targets. This smaller, though still significant, L1 processing advantage shown by Spanish speakers (similar to that in Experiment 3) could be indicative of a more balanced bilingual competence in comparison with the English speakers.

[24] Word frequency yielded very significant results in all cases (by-subjects and by-items analyses). Taken together, participants responded 53 ms faster to high frequency words than to low frequency words (mean RT to high frequency words was 506 ms, and 559 ms to low frequency words).

[25] The interaction between Target Language and Word Frequency was also significant (subject and item data). It was Spanish targets that were most sensitive to the effect of Word Frequency. The average difference in RT between responses given to high and low Spanish items was 65 ms. This difference was 40 ms for the English items. Table 9.8 shows that Word Frequency is significant in Spanish items by Native Language. This interaction is a reflection that English speakers showed the larger L1 processing advantage, and that they were slowest in responding to low frequency items in their L2 (Spanish items).

leaders[26]. When considering both groups of speakers independently, NF of Targets was only significant for Spanish speakers' data (subject and items data, Table 9.7), which also showed facilitatory effects [27].

Effects of NF of Targets were also statistically reliable in the interaction with Target Language, both in the subject and item data (Tables 9.6 and 9.8, Spanish items). In the All-Speakers analysis for Spanish items, NF nonleader targets were accessed 23 ms faster than NF leader targets[28]. This pattern of results (see Figure 9.1), runs contrary to the experimental hypothesis about NF of Targets, namely that NF of Targets would have an inhibitory, not facilitatory, effect on lexical processing. Even more surprising was that it was the Spanish items that were particularly susceptible to this facilitation effect.

NF of Targets interacted significantly with Word Frequency in results for All Speakers (subject data, Table 9.6) and in results for the Spanish language (significant for subject data, item data approached significance Table 9.8). NF of Targets was significantly facilitatory for low frequency items, where NF nonleader targets were reacted to, on average, 16 ms faster than NF leader targets[29].

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[26] Average RT for NF leader targets was 538 ms, and average RT for NF nonleader targets was 528 ms.

[27] Mean response times for Spanish speakers according to Target-NF were 546 ms for NF leader targets, and 531 ms for NF nonleader targets.

[28] Mean RT for Spanish experimental items was 564 ms for NF leader targets, and 541 ms for NF nonleader targets.

[29] Average response time for low frequency NF leader targets was 567 ms; for NF nonleader targets this average was 551 ms.

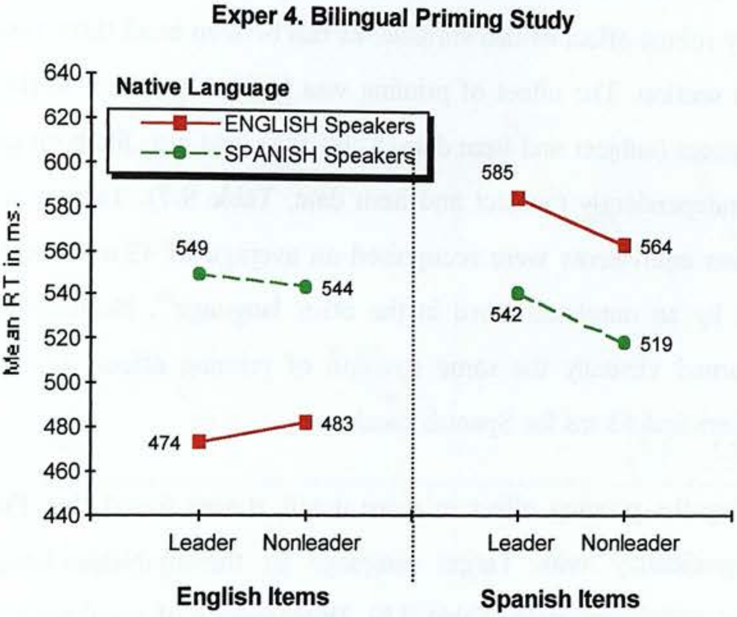

Figure 9.1. Bilingual Priming Study. *Profile of results for Native Language, Target language and NF of TARGETS (Leader, Nonleader).*

The three-way interaction NF of Targets by Word Frequency by Target Language was statistically reliable for English speakers (subject data, Table 9.7) and for Spanish items (subject data, Table 9.8). Spanish low frequency NF nonleader targets were processed faster than NF leader targets. The advantage was 34 ms in favour of nonleader targets[30]. Again, these interactions point towards a facilitatory effect of higher frequency neighbours in the recognition of the targets. These results deviate from the pattern of results observed in Experiments 2 and 3, where NF clearly had an inhibitory effect on lexical recognition.

[30] Mean RT for Spanish low frequency items was 602 ms for NF leader targets and 568 ms for NF nonleader targets.

As regards the effect of Priming Condition (Priming), all the results showed a very robust effect of this variable, as can be seen in all three tables of results in this section. The effect of priming was highly significant in the data from All Speakers (subject and item data, Table 9.6), and also for both groups of speakers independently (subject and item data, Table 9.7). Targets primed with translation equivalents were recognised an average of 43 ms faster than those primed by an unrelated word in the other language[31]. Both groups of speakers returned virtually the same strength of priming effects (41 ms for English speakers and 43 ms for Spanish speakers).

Exploring the priming effect in more detail, it was found that Priming interacted significantly with Target language in the by-Native-Language analysis (subject and item data, Table 9.8). Both groups of speakers showed larger priming effects in the L1→L2 direction than in the L2→L1 direction. The recognition advantage of translated targets relative to non-translated targets was as follows. For English speakers, the advantage was 28 ms for English targets (L2→L1) and 56 ms for Spanish targets (L1→L2). For Spanish speakers, the translation advantage was 51 ms for English targets (L1→L2), and 35 ms for Spanish targets (L2→L1)[32]. This priming pattern was exactly the pattern hypothesised in the design of the experiment. The effect of the L1→L2 advantage priming can be seen in the longer, deeper lines that link unrelated and translated items for the L1→L2 priming direction in Figure 9.2. The interaction between NF of Targets and Priming was not significant in all cases (all $F_s < 1$ and $F_i < 1$).

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[31] Targets primed by unrelated primes showed a mean RT of 554 ms; targets primed by translation equivalents showed a mean RT of 511 ms.

[32] See Tables 9.4 and 9.5 shown earlier for details of *RT DIF* (difference between unrelated and translated targets).

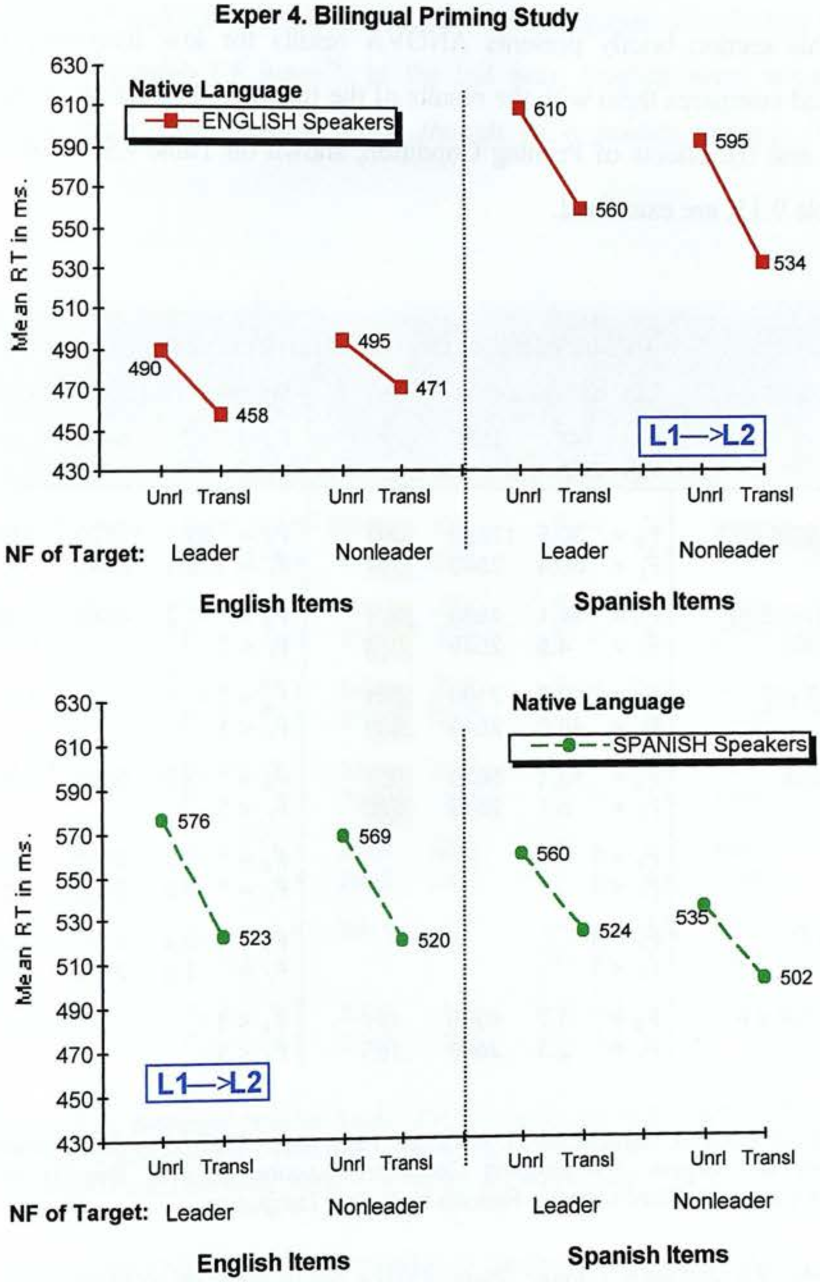

Figure 9.2. ***Bilingual Priming Study.*** *Profile of results for PRIMING CONDITION (Unrelated, Translation) according to NF of TARGETS (Leader, Nonleader). Separate graphs for Native Language.*

9.4.1.2. NF OF TARGETS IN LOW FREQUENCY DATA

This section briefly presents ANOVA results for low frequency (LF) items, and compares them with the results of the full data. The effects of NF of Targets and the effects of Priming Condition, shown on Table 9.9, Table 9.10 and Table 9.11, are examined.

	RESULTS FOR LOW FREQUENCY ITEMS					
EFFECTS	**ALL SPEAKERS**			**BY NATIVE LANGUAGE**[33]		
	F_S (1, 62) F_i(1, 260)	MSE	*p* <	F_S (1, 62) F_i (1, 260)	MSE	*p* <
LANGUAGE (TL)	F_S = 39.5 F_i = 60.4	17626 2549	*.001* *.001*	F_S = 83.1 F_i = 110.1	17626 2549	*.001* *.001*
NF OF TARGET (TG.NF)	F_S = 14.1 F_i = 4.5	4888 2549	*.001* *.035*	F_S = 1.2 F_i < 1	4888	*.269*
PRIMING (P)	F_S = 68.7 F_i = 48.6	7194 2549	*.001* *.001*	F_s < 1 F_i < 1		
TL x TG.NF	F_S = 13.1 F_i = 5.1	5628 2549	*.001* *.025*	F_S = 2.3 F_i < 1	5628	*.135*
TL x P	F_s < 1 F_i < 1			F_S = 8.1 F_i = 4.9	8700 2549	*.006* *.027*
TG.NF x P	F_s < 1 F_i < 1			F_S = 3.4 F_i = 1.5	4757 2549	*.067* *.222*
TL x TG.NF x P	F_S = 1.7 F_i = 2.1	6935 2549	*.191* *.155*	F_s < 1 F_i < 1		

NOTE. First column: Effects of TL = Target Language, TGT.NF = Neighbourhood Frequency of Targets. P = Priming Condition. Second column: Results for All Speakers (Overall). Third column: Results by Native Language.

Table 9.9. Bilingual Priming Study. *ANOVA results for LOW FREQUENCY ITEMS for ALL SPEAKERS, according to NF of TARGETS (for subject and item data). Significant results are highlighted.*

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[33] ANOVA results for between-subjects factor of Native Language were not significant [$F_s < 1$; $F_i < 1$].

The effect of Target Language was highly significant (subject and item data, Tables 9.9 and 9.10). English LF items were recognised significantly faster (52 ms) than Spanish LF items[34]. In the full data, English items were also recognised faster than Spanish items, though by a smaller amount (40 ms faster).

RESULTS BY NATIVE LANGUAGE FOR LOW FREQUENCY ITEMS														
EFFECTS	**ENGLISH SPEAKERS**								**SPANISH SPEAKERS**					
	F_S (1, 31) F_i(1, 130)			MSE	$p<$				F_S (1, 31) F_i (1, 130)			MSE	$p<$
LANGUAGE (TL)	F_S = 82.5 F_i = 144.9			25357 2932	*.001* *.001*				F_S = 7.1 F_i = 4.3			9896 2166	*.012* *.039*
NF OF TARGET (TG.NF)	F_S = 3.2 F_i = 1.3			5285 2932	*.083* *.256*				F_S = 12.9 F_i = 3.7			4491 2166	*.001* *.056*
PRIMING (P)	F_S = 50.1 F_i = 23.8			5468 2932	*.001* *.001*				F_S = 24.9 F_i = 25.1			8921 2166	*.001* *.001*
TL x TG.NF	F_S = 12.7 F_i = 3.3			5816 2932	*.001* *.071*				F_S = 2.3 F_i = 1.8			5439 2166	*.142* *.180*
TL x P	F_S = 5.1 F_i = 1.1			8197 2932	*.032* *.303*				F_S = 3.2 F_i = 4.8			9203 2166	*.082* *.030*
TG.NF x P	F_S = 1.7 F_i < 1			2811	*.197*				F_S = 1.9 F_i = 1.1			6704 2166	*.182* *.314*
TL x TG.NF x P	F_S = 2.7 F_i = 1.7			5706 2932	*.109* *.188*				F_s < 1 F_i < 1				

Table 9.13. Bilingual Priming Study. *ANOVA results for LOW FREQUENCY ITEMS for ENGLISH and SPANISH SPEAKERS, according to NF of TARGETS (for subject and item data). Significant results are highlighted.*

The variable NF of Targets reproduced the same pattern of results for LF as for the full data, i.e. the differences between NF leader targets and NF

[34] LF English items were responded to in an average of 533 ms; whereas LF Spanish items were responded to in 585 ms.

nonleader targets were significant in the All-Speakers analysis (subject and item data, in all three tables), in the by-Native-Language analysis (significant for Spanish speakers), and in the Target Language analysis (significant for Spanish items). Although the pattern of results was the same, the facilitatory effects of NF of Targets were greater for LF data than for the full data. In particular, LF NF nonleader targets were recognised 16 ms faster than LF NF leader targets[35] (this difference was 10 ms in the full data). Spanish speakers recognised LF NF nonleader targets 22 ms faster than leader targets[36] (this difference was 15 ms in the full data). Spanish LF NF nonleader targets were accessed 34 ms faster than leader targets[37] (this difference was 16 ms in the full data). Figure 9.3 shows a comparison between results in the full data and results in the LF data, in connection with the NF of Targets variable. Longer, deeper lines for Spanish LF data, relative to full data, shows greater sensitivity to facilitatory effects of NF of Targets.

As regards the effect of Priming Condition for LF items, Priming was significant in the All-Speakers analysis (subject and item data) and also in the two separate groups of speakers. On average, LF translated targets were recognised 44 ms faster than LF targets primed by unrelated primes[38]. This priming effect was virtually identical to that observed with the full data (43 ms). Very similar differences were also observed when analysing the data by Native Language: English speakers showed priming effects of 46 ms for LF translated

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[35] Average RT for LF NF leader targets was 567 ms, and 551 ms for nonleader targets.

[36] Spanish speakers took an average of 571 ms to respond to LF NF leader targets and an average of 549 ms to respond to nonleader targets.

[37] For Spanish LF items, NF leader targets took an average of 602 ms to be responded to, whereas nonleader targets took an average of 568 ms.

[38] Average response time for LF translated targets was 581 ms. For the unrelated targets, average response time was 537 ms.

targets, and Spanish speakers showed a priming effects of 42 ms (compare this with 41 and 42 ms, respectively, in the full data). This shows that LF items were not more sensitive to priming that the full data.

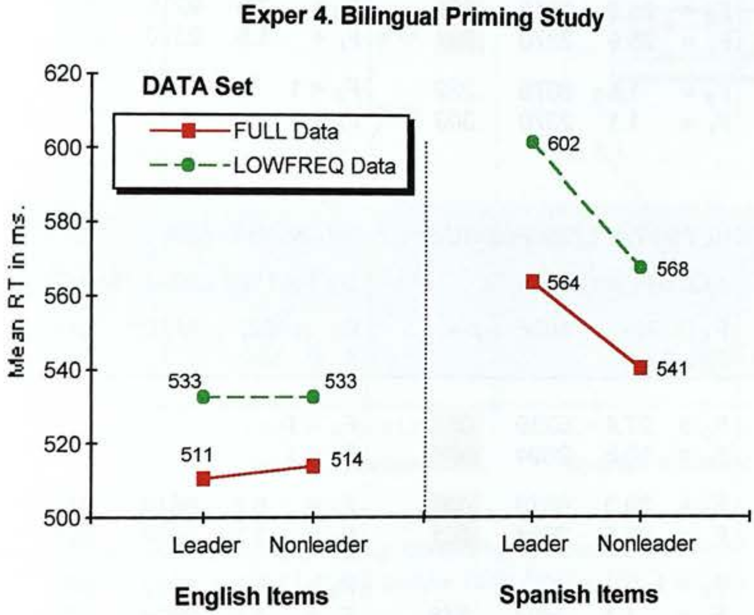

Figure 9.3. Bilingual Priming Study. *Profile comparing results for the FULL DATA and results for LOW FREQUENCY ITEMS, according to NF of TARGETS (Leader, Nonleader).*

As regards the strength priming of effects in relation to language direction, i.e. the interaction of Priming by Target Language and by Native Language, the pattern revealed was similar to that observed in the full data: significantly larger effects of priming in the L1→L2 direction than in the L2→L1 direction. In particular, for English speakers, the L1→L2 priming effect for LF items was 64 ms, and the L2→L1 effect was 29 ms. For Spanish speakers, L1→L2 priming was 57 ms, and L2→L1 priming was 26 ms.

RESULTS FOR LOW FREQUENCY: ENGLISH ITEMS								
EFFECTS	ALL SPEAKERS				BY NATIVE LANGUAGE[39]			
	F_S (1, 62) F_i(1, 116)		MSE	$p <$	F_S (1, 62) F_i (1, 116)		MSE	$p <$
NF OF TARGET (TG.NF)	$F_S < 1$ $F_i < 1$				$F_S =$ $F_i < 1$	3.4	5277	.067
PRIMING (P)	$F_S =$ $F_i =$	25.2 26.9	9215 2370	.001 .001	$F_S =$ $F_i =$	2.8 1.5	9215 2370	.097 .227
TG.NF x P	$F_S =$ $F_i =$	1.5 1.1	6676 2370	.232 .303	$F_S < 1$ $F_i < 1$			

RESULTS FOR LOW FREQUENCY: SPANISH ITEMS								
EFFECTS	ALL SPEAKERS				BY NATIVE LANGUAGE[40]			
	F_S (1, 62) F_i(1, 144)		MSE	$p <$	F_S (1, 62) F_i (1, 144)		MSE	$p <$
NF OF TARGET (TG.NF)	$F_S =$ $F_i =$	27.1 10.8	5239 2694	.001 .001	$F_S < 1$ $F_i < 1$			
PRIMING (P)	$F_S =$ $F_i =$	39.3 22.5	6679 2694	.001 .001	$F_S =$ $F_i =$	6.8 3.9	6679 2694	.011 .048
TG.NF x P	$F_S < 1$ $F_i =$	1.1	2694	.318	$F_S =$ $F_i =$	3.7 1.8	5017 2694	.057 .177

Table 9.14. Bilingual Priming Study. *ANOVA results for LOW FREQUENCY ENGLISH and SPANISH EXPERIMENTAL ITEMS, according to NF of TARGETS (for subject and item data). Significant results are highlighted.*

Comparing these results with the results of the full data, the differences between translated and unrelated targets are larger for LF items. This larger

[39] The ANOVAs on LF items by Target Language yielded significant differences between the two groups of speakers, as expected. For English items, the between-subjects factor of Native Language was reliable both in the subject and item data [F_S (1, 62) = 16.9, MSE = 44836, $p < .001$; F_i (1, 116) = 48.6, MSE = 2370, $p < .001$].

[40] For the Spanish items, the effect of the between-subjects factor of Native Language was also significant in the by-subjects and the by-items analyses [F_S (1, 62) = 9.4, MSE = 75421, $p < .003$; F_i (1, 144) = 65.1, MSE = 2694, $p < .001$].

advantage of L1 priming effect over L2 can be observed in Figure 9.4, where longer and deeper lines, representing LF data, indicate a larger priming effect.

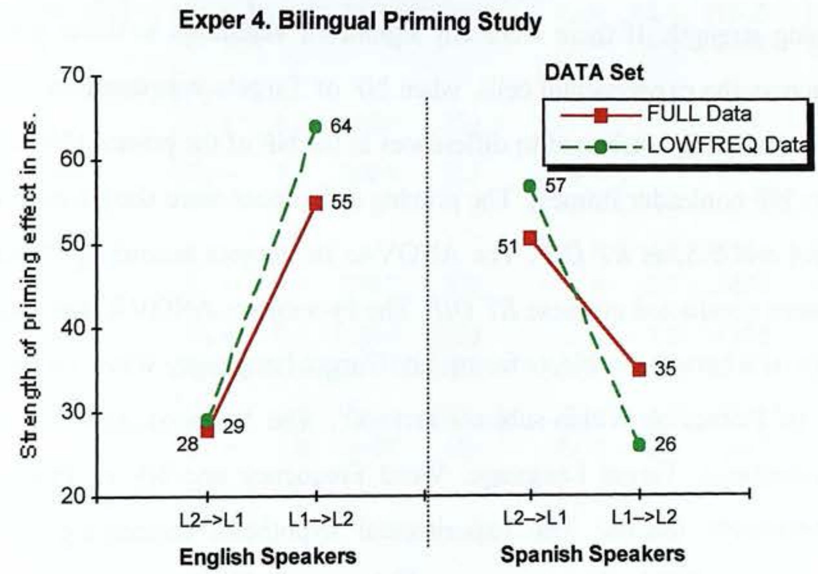

Figure 9.4. Bilingual Priming Study. *Profile comparing strength of PRIMING EFFECT for the FULL DATA and for LOW FREQUENCY ITEMS.*

The conclusion of this section is that not only did LF data reproduce the patterns observed of the full data, LF items were noticeably more sensitive to the effects of NF of Targets and the effects of Priming. This finding has practical implications for experimental research, which will be considered in the last chapter of this thesis.

9.4.2. RESPONSE LATENCIES ACCORDING TO NF OF PRIMES

9.4.2.1. NF OF PRIMES IN FULL DATA

The statistical analysis, at the level of the targets according to NF of Primes, was performed to examine potential differences in strength of priming effects, due to NF in the primes. Accordingly, the differences between both levels of the Priming Condition (unrelated, translation) were calculated for all the experimental conditions. The 'unrelated' condition established the baseline of RT for the targets. The 'translation' RT relative to this baseline established the priming strength. If there were any significant variations in those priming effects across the experimental cells, when NF of Targets was controlled, they could be confidently attributed to differences in the NF of the primes (NF leader Primes *vs* NF nonleader Primes). The priming differences were shown earlier, in Tables 9.4 and 9.5, as *RT DIF*. The ANOVAs for targets according to NF of Primes were conducted on these *RT DIF*. The by-subjects ANOVA used Native Language as a between-subjects factor, and Target Language, Word Frequency and NF of Primes as within-subjects factors[41]. The by-items ANOVA used Native Language, Target Language, Word Frequency and NF of Primes as between-subjects factors. The experimental hypothesis concerning NF of Primes was that NF leader primes would be more effective primes than NF nonleader primes; and within the former, L1→L2 would be more effective than L2→L1.

Results of the ANOVAs are presented in the next three tables. Table 9.12 lists results of the by-All-Subjects analysis and results by Native Language. Table 9.13 offers details of ANOVA for English and Spanish speakers independently. Table 9.14 presents details of analysis by Target Language. Figure 9.5 shows the results in graph form.

[41] Note that after calculating the difference between the 'unrelated' and the 'translation' Priming Conditions, this Prime-NF Dif is now equivalent to crossing Prime-NF and Priming Condition.

EFFECTS	OVERALL RESULTS OF NF OF PRIMES — ALL SPEAKERS			BY NATIVE LANGUAGE[42]		
	F_S (1, 62) F_i(1, 296)	MSE	$p <$	F_S (1, 62) F_i (1, 296)	MSE	$p <$
LANGUAGE (TL)	$F_S < 1$ $F_i < 1$			F_S = 10.4 F_i = 8.5	11615 2497	*.002* *.004*
WORD FREQ (WF)	$F_S < 1$ F_i = 1.3	 2497	 *.254*	$F_S < 1$ $F_i < 1$		
NF OF PRIME (PRM.NF)	F_S = 1.3 $F_i < 1$	6036	*.257*	$F_S < 1$ $F_i < 1$		
TL x WF	$F_S < 1$ F_i = 1.1	 2497	 *.302*	F_S = 3.6 F_i = 2.7	9384 2497	*.063* *.100*
TL x PRM.NF	F_S = 6.4 F_i = 5.4	11308 2497	*.014* *.020*	F_S = 1.8 F_i = 2.1	11308 2497	*.190* *.145*
WF x PRM.NF	F_S = 4.6 F_i = 1.8	5244 2497	*.036* *.182*	F_S = 7.8 F_i = 2.4	5244 2497	*.007* *.125*
TL x WF x PRM.NF	$F_S < 1$ $F_i < 1$			$F_S < 1$ $F_i < 1$		

NOTE. First column: Effects of TL = Target Language, WF = Word Frequency, PRM.NF = Neighbourhood Frequency of Primes. Second column: Results for All Speakers (Overall). Third column: Results by Native Language.

Table 9.12. Bilingual Priming Study. *ANOVA results for ALL SPEAKERS, according to NF of PRIMES (for subject and item data). Significant results are highlighted.*

Target Language yielded significant effects in the by-Native-Language analysis (subject and item data, Table 9.12; English and Spanish speakers in Table 9.13). These significant results mirrored the effect, already mentioned, of the L1→L2 priming advantage over L2→L1 priming. The details of this advantage were discussed earlier in section 9.4.1.1. Word Frequency did not

[42] ANOVA results for the between-subjects factor of Native Language was not significant [$F_s < 1$; $F_i < 1$].

show any reliable effect on priming data, nor did the interaction between Word Frequency and Target Language.

RESULTS OF NF OF PRIMES BY NATIVE LANGUAGE								
EFFECTS	**ENGLISH SPEAKERS**				**SPANISH SPEAKERS**			
	F_S (1, 31) F_i(1, 148)		MSE	*p* <	F_S (1, 31) F_i (1, 148)		MSE	*p* <
LANGUAGE (TL)	F_S =	8.7	10892	*.006*	F_S =	2.7	12339	*.109*
	F_i =	2.7	3127	*.101*	F_i =	6.9	1867	*.009*
WORD FREQ (WF)	F_S < 1				F_S < 1			
	F_i =	1.4	3127	*.246*	F_i < 1			
NF OF PRIME (PRM.NF)	F_S < 1				F_S =	1.7	7003	*.203*
	F_i < 1				F_i < 1			
TL x WF	F_S =	1.1	8330	*.292*	F_S =	2.5	10438	*.123*
	F_i < 1				F_i =	4.8	1867	*.030*
TL x PRM.NF	F_S =	6.2	13616	*.018*	F_S < 1			
	F_i =	5.7	3127	*.018*	F_i < 1			
WF x PRM.NF	F_S =	11.7	5440	*.002*	F_S < 1			
	F_i =	3.3	3127	*.071*	F_i < 1			
TL x WF x PRM.NF	F_S < 1				F_S < 1			
	F_i < 1				F_i < 1			

Table 9.13. Bilingual Priming Study. *ANOVA results for ENGLISH and SPANISH SPEAKERS, according to NF of PRIMES (for subject and item data). Significant results are highlighted.*

RESULTS OF NF OF PRIMES BY TARGET LANGUAGE: ENGLISH ITEMS						
EFFECTS	**ALL SPEAKERS**			**BY NATIVE LANGUAGE**[43]		
	F_S (1, 62) F_i(1, 132)	MSE	$p <$	F_S (1, 62) F_i (1, 132)	MSE	$p <$
WORD FREQ (WF)	$F_S < 1$			$F_S < 1$		
	F_i = 1.9	2590	*.170*	$F_i < 1$		
NF OF PRIME (PRM.NF)	F_S = 7.1	9169	*.010*	$F_S < 1$		
	F_i = 3.1	2590	*.079*	$F_i < 1$		
WF x PRM.NF	F_S = 1.1	4535	*.316*	F_S = 2.9	4535	*.091*
	$F_i < 1$			$F_i < 1$		

RESULTS OF NF OF PRIMES BY TARGET LANGUAGE: SPANISH ITEMS						
EFFECTS	**ALL SPEAKERS**			**BY NATIVE LANGUAGE**[44]		
	F_S (1, 62) F_i(1, 164)	MSE	$p <$	F_S (1, 62) F_i (1, 164)	MSE	$p <$
WORD FREQ (WF)	$F_S < 1$			F_S = 2.8	12960	*.096*
	$F_i < 1$			F_i = 3.6	2423	*.061*
NF OF PRIME (PRM.NF)	F_S = 2.1	8175	*.162*	F_S = 2.6	8175	*.112*
	F_i = 2.3	2423	*.134*	F_i = 2.7	2423	*.105*
WF x PRM.NF	F_S = 2.9	7824	*.092*	F_S = 3.7	7824	*.059*
	F_i = 2.7	2423	*.104*	F_i = 3.4	2423	*.066*

Table 9.14. Bilingual Priming Study. *ANOVA results for ENGLISH and SPANISH EXPERIMENTAL ITEMS, according to NF of PRIMES (for subject and item data). Significant results are highlighted.*

The main effect of NF of Primes was not significant. However, NF of Primes interacted with Target Language and also with Word Frequency. A reliable and robust effect of interaction between NF of Primes and Target

43 For English items, the between-subjects factor of Native Language was reliable in the subject data but not in the item data [F_S (1, 62) = 4.2, MSE = 15546, $p < .044$; F_i (1, 132) = 2.9, MSE = 2590, $p < .086$].

44 For the Spanish items, the effect of Native Language was significant in the by-subjects and the by-items analyses [F_S (1, 62) = 5.1, MSE = 10862, $p < .028$; F_i (1, 164) = 6.2, MSE = 2423, $p < .014$].

Language was obtained in the by-All-Speakers analysis (subject and item data, Table 9.12). This interaction showed that, for English items, NF nonleader primes achieved stronger priming effects, whereas for Spanish items, NF leader primes achieved the stronger priming effects. More specifically, the strength of priming effects in English items was 28 ms for NF leader primes and 51 ms for NF nonleader primes. For Spanish items, strength of priming was 51 ms for NF leader primes and 39 ms for NF nonleader primes. The interaction pattern is shown in Figure 9.5.

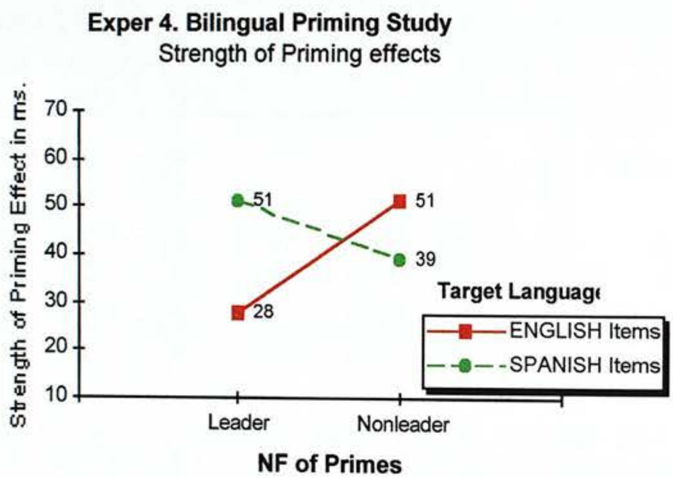

Figure 9.5. Bilingual Priming Study. *Profile of results for STRENGTH OF PRIMING EFFECTS, according to NF of PRIMES (Leader, Nonleader).*

In the by-Native-Language ANOVA, the interaction of NF of Primes with Target Language was highly significant for English speakers (subject and items data, Table 9.13). The interaction in this group of speakers mirrored the pattern of that of the All speakers group: with English primes, NF nonleader primes primed more effectively than NF leader primes; and the reverse was the case with the Spanish primes. In particular, the priming strength for these categories of primes for English speakers were as follows: English NF leader primes showed a priming strength of 15 ms, versus 42 ms of the NF nonleader primes;

but, conversely, Spanish NF leader primes showed a priming strength of 68 ms, with 43 ms for the NF nonleader primes. These patterns meant that effects of NF of Primes were facilitatory in English and inhibitory in Spanish. The data for English speakers is shown in Figure 9.6. NF of Primes was not significant in any way with Spanish speakers.

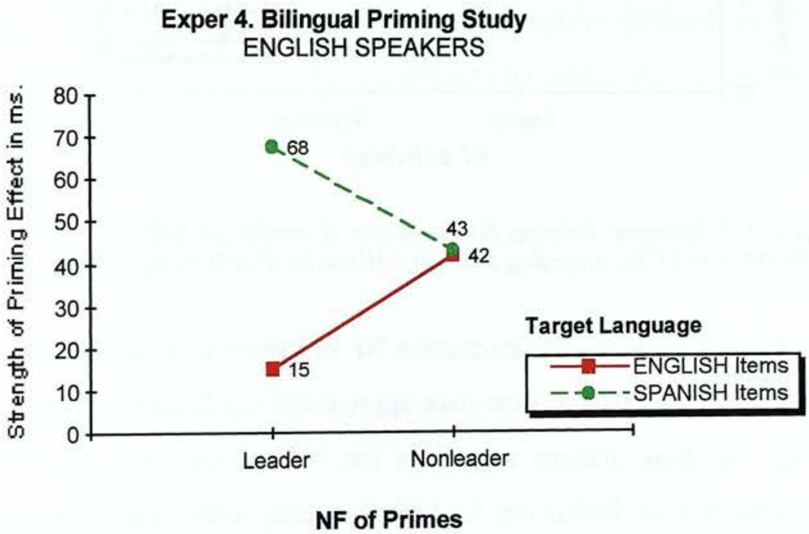

Figure 9.6. Bilingual Priming Study. *Profile of results for STRENGTH OF PRIMING EFFECTS, according to NF of PRIMES (Leader, Nonleader) for English speakers.*

The interaction between NF of Primes and Word frequency was significant in the All-Speakers analysis (subject data, Table 9.12) and in the ANOVA of English Speakers (subject data, Table 9.13). In the All-Speakers ANOVA, NF of Primes effects were facilitatory for high frequency words and inhibitory for low frequency words. For high frequency words, NF nonleader primes showed more powerful priming effects (48 ms) than NF leader primes (33 ms). For low frequency words, this pattern was reversed: the priming effects of NF of Primes leaders were 46 ms, whereas those for nonleaders were 41 ms. The pattern is shown in Figure 9.7.

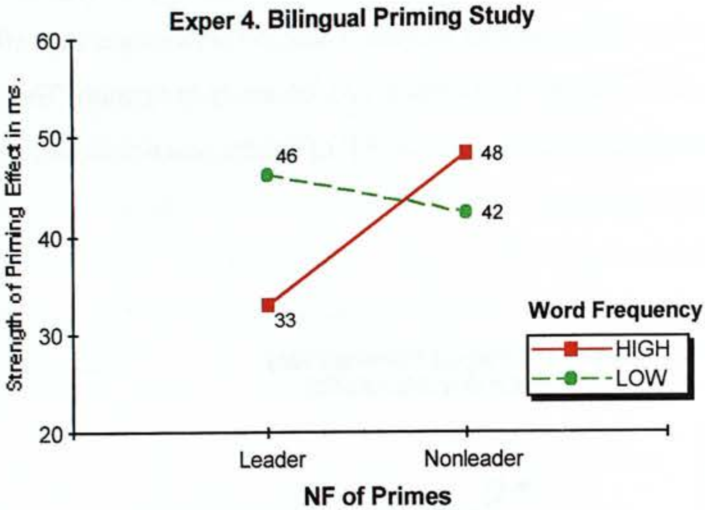

Figure 9.7. Bilingual Priming Study. *Profile of results for STRENGTH OF PRIMING EFFECTS, according to NF of PRIMES by WORD FREQUENCY.*

For English speakers, the interaction NF of Primes with Word Frequency was significant (subject data, item data approached significance; Table 9.13), reproducing the same pattern as that in the All-Speakers analysis, i.e. NF nonleader primes were facilitatory for high frequency words and inhibitory for low frequency words[45].

Finally, the ANOVA on experimental items by Target Language yielded significant differences between the two groups of speakers. Spanish targets (L1→L2, for English speakers) were more sensitive to priming differences than English targets (L1→L2, for Spanish speakers). This could be taken as an indication that the English speakers were less competent in their L2 (Spanish targets) than the Spanish speakers were in their L2 (English targets).

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[45] For English speakers, average strength of priming effects from high frequency primes was as follows: from NF leader primes, it was 26 ms, and from NF nonleader primes, 49 ms. From low frequency primes, NF leader primes gave a priming strength of 57 ms, and NF nonleader primes a strength of 36 ms.

9.4.2.2. NF OF PRIMES IN LOW FREQUENCY DATA

In this section, low frequency (LF) items are explored as an independent data set and compared with results obtained in the full data set. LF ANOVA results are shown in Table 9.15, Table 9.16 and Table 9.17.

Target Language returned significant results in the by-Native-Language analysis (subject and item data, Table 9.15; English speakers and Spanish speakers, Table 9.16). English and Spanish speakers differed significantly, showing the expected L1→L2 priming strength advantage already mentioned in the two previous sections[46].

[46] In the LF data, English speakers showed a priming strength of 28 ms in L2→L1 priming direction, and 64 ms in L1→L2 direction. Spanish speakers showed a priming strength of 56 ms in the L1→L2 direction, and 26 ms in the L2→L1 direction.

RESULTS FOR LOW FREQUENCY ITEMS							
EFFECTS	ALL SPEAKERS			BY NATIVE LANGUAGE[47]			
	F_S (1, 62) F_i(1, 130)	MSE	*p* <	F_S (1, 62) F_i (1, 130)		MSE	*p* <
LANGUAGE (TL)	F_S< 1 F_i < 1			F_S = F_i =	8.1 6.9	17399 3612	*.006* *.009*
NF OF PRIME (PRM.NF)	F_S < 1 F_i < 1			F_S = F_i =	4.8 1.4	7385 3612	*.032* *.226*
TL x PRM.NF	F_S = 3.7 F_i = 3.1	14598 3612	*.059* *.083*	F_S = F_i =	1.1 1.6	14598 3612	*.298* *.201*

NOTE. First column: Effects of TL = Target Language, PRM.NF = Neighbourhood Frequency of Primes. Second column: Results for All Speakers (Overall). Third column: Results by Native Language.

Table 9.15. Bilingual Priming Study. *ANOVA results for LOW FREQUENCY ITEMS for ALL SPEAKERS, according NF of PRIMES (for subject and item data). Significant results are highlighted.*

RESULTS FOR LOW FREQUENCY ITEMS BY NATIVE LANGUAGE								
EFFECTS	ENGLISH SPEAKERS				SPANISH SPEAKERS			
	F_S (1, 31) F_i (1, 65)		MSE	*p* <	F_S (1, 31) F_i (1, 65)		MSE	*p* <
LANGUAGE (TL)	F_S = F_i =	5.1 1.4	16394 4526	*.032* *.243*	F_S = F_i =	3.2 7.7	18405 2698	*.082* *.007*
NF OF PRIME (PRM.NF)	F_S = F_i =	3.9 1.2	7087 4526	*.057* *.280*	F_S = F_i < 1	1.3	7684	*.261*
TL x PRM.NF	F_S = F_i =	3.7 3.7	17319 4526	*.063* *.060*	F_S < 1 F_i < 1			

Table 9.16. Bilingual Priming Study. *ANOVA results for LOW FREQUENCY ITEMS for ENGLISH and SPANISH SPEAKERS, according to NF of PRIMES (for subject and item data). Significant results are highlighted.*

[47] ANOVA results for the between-subjects factor of Native Language were not statistically significant [F_s < 1; F_i < 1].

EFFECTS	RESULTS FOR LOW FREQUENCY: ENGLISH ITEMS					
	ALL SPEAKERS			BY NATIVE LANGUAGE[48]		
	F_S (1, 62) F_i (1, 58)	MSE	$p <$	F_S (1, 62) F_i (1, 58)	MSE	$p <$
NF OF PRIME	F_S = 2.2 F_i < 1	7709	*.140*	F_S < 1 F_i < 1		

EFFECTS	RESULTS FOR LOW FREQUENCY: SPANISH ITEMS					
	ALL SPEAKERS			BY NATIVE LANGUAGE[49]		
	F_S (1, 62) F_i (1, 72)	MSE	$p <$	F_S (1, 62) F_i (1, 72)	MSE	$p <$
NF OF PRIME	F_S = 2.7 F_i = 3.1	14274 3631	*.103* *.086*	F_S = 3.5 F_i = 3.7	14274 3631	*.067* *.058*

Table 9.17. Bilingual Priming Study. *ANOVA results for LOW FREQUENCY ENGLISH and SPANISH EXPERIMENTAL ITEMS, according to NF of PRIMES (for subject and item data).*

The effect of NF of Primes on LF data was only significant in the by-Native-Language analysis (subject data, Table 9.15), to the effect that English speakers showed significantly larger priming effects with NF leader primes (57 ms) than with NF nonleader primes (36 ms). Spanish speakers, on the other hand, showed larger priming effects with NF nonleader primes (48 ms) than with NF leaders primes (35 ms). Thus, for the English speakers, the pattern of results observed in the LF data was different from the pattern observed with the full data, whereas the pattern was the same in both data sets for the Spanish speakers (as shown in Figure 9.8).

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[48] The ANOVA on experimental items by Target Language yielded significant differences between the two groups of speakers, as expected. For LF English items, the between-subjects factor of Native Language was not statistically different [F_S (1, 62) = 2.8, MSE = 18430, $p < .097$; F_i (1, 58) = 1.9, MSE = 3588, $p < .168$].

[49] For LF Spanish items, the effect of Native Language was significant in the by-subjects and the by-items analyses [F_S (1, 62) = 6.8, MSE = 13357, $p < .011$; F_i (1, 72) = 5.9, MSE = 3631, $p < .018$].

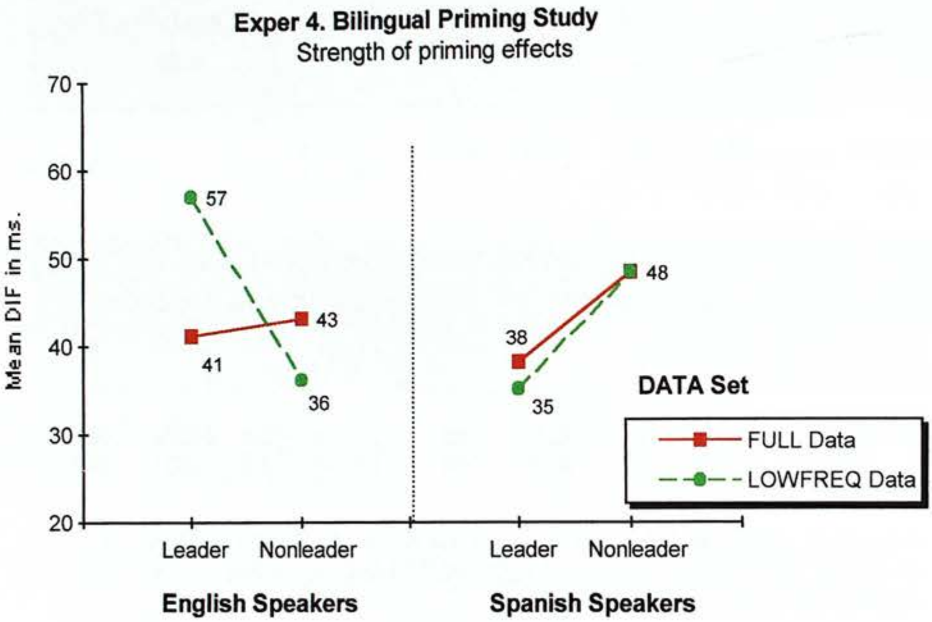

Figure 9.8. Bilingual Priming Study. *Profile comparing STRENGTH of priming of primes according to NF of PRIMES, for the FULL DATA and for LOW FREQUENCY ITEMS for both groups of speakers.*

Now that all the results of Experiment 4 have been analysed, the experimental hypotheses can be examined, to see which have been confirmed.

1. Hypothesis 1 stated that 'NF nonleader targets are recognised more slowly than NF leader targets (inhibitory effects of NF)'. This hypothesis was not confirmed in the study. In fact the reverse was the case: targets with higher frequency neighbours were processed faster than targets with no higher frequency neighbours, i.e. the effects of NF were facilitatory.

2. Hypothesis 2 stated that 'NF nonleader primes are less effective primes than NF leader primes'. This hypothesis could not be confirmed, as no significant differences were observed for this variable.

3. Hypothesis 3 stated that 'there are cross-language priming effects in both languages'. This hypothesis was confirmed, as highly significant differences were obtained between RT to translated targets and RT to unrelated targets, for both English and Spanish.

4. Hypothesis 4 stated that 'L1→L2 priming effects are stronger than L2→L1 priming effects'. This hypothesis was also confirmed with the results of the experiment: the L1→L2 priming advantage was significant over L2→L1.

5. Hypothesis 5 stated that 'the inhibitory effects of NF nonleader targets are stronger for L2 NF nonleader targets (L1→L2 condition)'. This hypothesis was not confirmed, as effects of NF of Targets were found to be facilitatory, not inhibitory.

6. Hypothesis 6 stated that 'the reduced effectiveness of NF nonleader primes will be greatest for L2 NF nonleader primes (L2→L1 priming condition)' This hypothesis was only confirmed for the group of English speakers. Spanish speakers did not show this pattern of results.

9.5. DISCUSSION

The purpose of this bilingual experiment was twofold: First, it examined interlanguage priming effects. Second, it investigated the influence that higher frequency neighbours exerted on the recognition of targets which had been primed by translation equivalents. The results can be summarised as follows:

1. There were highly significant priming effects in both language directions. The strength of the priming was considerably larger in the L1→L2 direction for both groups of speakers.

2. Having higher frequency neighbours facilitated in the recognition of targets. This was an unexpected outcome. Even more surprising was the finding that Spanish speakers and Spanish items were particularly sensitive to these facilitatory effects of NF of Targets.

3. The main effect of the NF of the primes did not affect the recognition of targets. However, this variable interacted with Target Language. With English targets, larger priming effects were evident when they were primed by Spanish NF nonleaders than when primed by Spanish NF leaders. But with Spanish targets, the reverse was the case: there were larger priming effects when the targets were primed by English NF leaders than when primed by English NF nonleaders.

4. In relation to the full data, low frequency items exhibited greater sensitivity to the effects studied in the experiment.

Experiment 4 clearly showed that, in these bilingual speakers of English and Spanish, the lexical processing of one language (target) was influenced by processing in their other language (non-target). This happened even though subjects were specifically instructed to ignore items in the non-target language. The experiment used translation equivalents in a LDT. Despite the presence of translation equivalents, the task at hand ('Is this a real word in English?') did not require the simultaneous activation of the two lexicons. This study has thus, replicated previous findings, as many researchers have demonstrated that lexical processing in bilinguals is influenced by the non-target language (Beauvillain & Grainger , 1987; Bijeljac-Babic *et al.*, 1997; De Groot *et al.*, 2000; Dijkstra *et al.*, 2000; Grainger & Dijkstra, 1992; Van Heuven *et al.*, 1998). In their experiments, these authors used interlingual homographs and orthographically related cross-linguistic primes and targets. Their results have provided data in favour of the hypothesis that lexical access in bilinguals is non-selective. So, the current study provides firm evidence in support of the view that bilingual speakers do activate their both languages, even in the presence of a compelling language bias.

This study also yielded very robust cross-language priming effects, which fully supported the predictions of the Revised Hierarchical Model (Kroll & Stewart, 1994). This model predicts asymmetrical interlinguistic priming effects, similar to the asymmetry predicted for translation. As a result of their bias towards conceptual links, L1 words are more likely to activate their respective meanings than L2 words. In addition, L1 words are functionally of higher frequency than their translation equivalents (Kroll & De Groot, 1997) and therefore they are recognised faster than L2 words. For these reasons, L1 words are more likely than L2 words to be more effective primes. This is exactly what was found in this study for both groups of speakers: L1→L2 priming effects were larger than L2→L1 effects. Similar results have been found by previous studies (Altarriba, 1992; Golland *et al.*, 1997; Jiang & Forster, 2001; Keatly *et al.*, 1994; Tzelgov & Eben-Ezra, 1992).

The evidence about cross-linguistic priming effects in L2→L1 direction is less conclusive. On the one hand, some researchers have found L2→L1 priming effects, although these are generally smaller than L1→L2 (Altarriba, 1992; Chen & Ng, 1989; Frenck & Pynte, 1987; Keatly *et al.*, 1994; Schwanenflugel & Rey, 1986; Tzelgov & Eben-Ezra, 1992). On the other hand, other researchers have failed to obtain any L2→L1 priming effects (Sánchez-Casas *et al.*, 1992; Grainger & Frenck-Mestre, 1998) or have found them only under very specific conditions (De Groot and Nas, 1991, only found L2→L1 priming effects when the translation equivalents were cognates). This study, however, returned very robust L2→L1 priming effects, although the effects were smaller than the L1→L2 priming effects. These conclusions, though, must carry a note of caution, as the experiment used the standard priming paradigm, with perfectly visible primes. Some authors (Forster & Jiang, 2001; Kroll & De

Groot, 1997; Neely, 1991) have expressed reservations about priming effects obtained at long SOAs[50], which includes clearly visible primes. These authors have pointed out that, under those circumstances there is a greater risk of the priming effects being due to participants' expectations and strategies, as they become more familiar with the task.

Experiment 4 did not convey the expected results about the effects of neighbourhood frequency in relation to targets and primes. The experimental hypotheses for the effects of NF were made on the basis of the predictions of the Bilingual Interactive Activation (BIA) Model (Grainger & Dijkstra, 1992; Grainger, 1993; Dijkstra & Van Heuven, 1998) and the Interactive Activation Model (McClelland & Rumelhart, 1981). In particular, these models predict a strong inhibitory effect in the recognition of words with higher frequency neighbours, as a result of lateral inhibition coming from other word nodes enjoying higher resting activation levels (because of their higher word frequency). Previous experimental data has provided ample support for the predicted inhibitory effects of NF (Carreiras *et al.*, 1997; Grainger, 1990; Grainger *et al.*, 1989; Grainger *et al.*, 1992; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Huntsman & Lima, 1996; Paap & Johansen, 1994; Perea & Pollatsek, 1998; and Zagar & Mathey, 2000). The results obtained in the present experiment clearly conflict with those of previous research (including experiments in this thesis): not only did these results fail to show the expected inhibitory effects of NF, they showed precisely the opposite, the effects were facilitatory. Particularly puzzling were the results for the Spanish items, which were most sensitive to the facilitatory effects of NF. Experiments 2 and 3 of this thesis had distinctly yielded inhibitory results for Spanish words with higher

[50] The SOA is the 'stimulus onset asynchrony', i.e. the time lag between the presentation of the primes and the presentation of the target.

frequency neighbours. Finally, the NF of the primes did not show any reliable effects on the recognition of the targets, either in the case of L1 primes or L2 primes.

The results of Experiment 4 reveal that the presence of a cross-linguistic prime, in the form of a translation equivalent, undoubtedly introduces new elements in the recognition of targets, which alter the inhibitory effect of higher frequency neighbours. As this experiment is new in the area of bilingual neighbourhood effects, further research is needed to determine more precisely what aspects of cross-linguistic priming cause higher frequency neighbours to be less competitive with the target. The last chapter of this thesis discusses the general findings of the research presented in this dissertation and proposes new directions for future research.

Chapter 10
General Discussion and Conclusions

10.1. SUMMARY OF GENERAL RESULTS

Within the field of visual word recognition, the study of orthographic neighbourhood effects (neighbourhood size and neighbourhood frequency) has taken a prominent stand in the last few years. A considerable amount of research has been conducted in English, whereas comparatively little work has been carried out in other languages (e.g. Spanish). In addition, not much research involving bilinguals has been done in connection with neighbourhood effects, as this is an area of enquiry that has only started to developed relatively recently. There is just a handful of studies which involve English and either French or Dutch, but no bilingual studies have yet been published on neighbourhood effects concerning Spanish. The work reported in this doctoral thesis is, therefore, a contribution in this direction. Moreover, this research had a double objective:

- First, to study whether orthographic neighbourhood effects are language specific and, if so, to explore factors that may contribute to that specificity.

- Second, to investigate whether neighbourhood effects observed in monolingual lexical processing are also observed in the lexical processing of bilingual speakers.

Four lexical decision experiments were designed to pursue these objectives, with reference to English and Spanish. The first two studies were monolingual and they involved monolingual speakers of English and Spanish. The other two studies were bilingual and they involved bilingual speakers of these two languages.

The experiments yielded some clear findings:

- Neighbourhood effects are language specific. N is facilitatory of lexical processing in English and has no significant effects in Spanish. Conversely, NF is clearly inhibitory of lexical processing in Spanish, whereas in English its role is not determinant. These effects have been observed with monolingual speakers (Experiments 1 and 2) and with bilingual speakers (Experiment 3).

- In the context of bilingual processing of English and Spanish, NF is a more significant factor than N in the recognition of a visual target. The results of Experiment 3 showed robust overall inhibitory effects of NF for all the experimental items (English and Spanish, high frequency and low frequency) and for both groups of speakers.

- The inhibitory nature of NF turned facilitatory when the stimuli were primed by translation equivalents. The results of Experiment 4 indicated that these effects were particularly strong when Spanish targets were preceded by their English translations.

- Highly significant priming results were obtained for both language directions, although the strength of the priming effect was considerably larger in the L1→L2 direction than in L2→L1 (Experiment 4).

These results have theoretical implications for models of visual word recognition as well as practical implications for experimental research. They are considered in the following sections.

10.2. THEORETICAL IMPLICATIONS

Previous experimental data about neighbourhood effects has apparently yielded contradictory results. On the one hand, many studies have found that the effects of N are facilitatory[1]. On the other hand, there is considerable amount of evidence supporting the inhibitory effects of NF[2]. These results seem contradictory because words that have large neighbourhoods (facilitatory effects) typically have higher frequency neighbours (inhibitory effects). In the light of this 'contradiction', Andrews (1997) suggested that the nature of these two effects might be language specific. She based her hypothesis on the fact that most of the studies offering results for the facilitatory nature of N had been done in English, whereas most of the studies offering results in support of the inhibitory nature of NF had been carried out in languages other than English. These other languages all had in common a more shallow orthography than

[1] Andrews, 1989, 1992; Bozon & Carbonnel, 1996; Carreiras *et al.*, 1997, Experiment 3; Forster & Shen, 1996; Huntsman & Lima, 2002; Johnson & Pugh, 1994; Pollatsek, *et al.*, 1999; Sears, Hino & Lupker, 1995; Sears, Hino & Lupker, 1999a; Sears, Lupker & Hino, 1999b.

[2] Carreiras *et al.*, 1997; Grainger, 1990; Grainger *et al.*, 1989; Grainger *et al.*, 1992; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Huntsman & Lima, 1996; Paap & Johansen, 1994; Perea & Pollatsek, 1998; and Zagar & Mathey, 2000.

English. The findings of this thesis, that neighbourhood effects are language specific, support the idea that the 'neighbourhood paradox' may be more apparent than real (Andrews, 1997; Sears *et al.*, 1995; Mathey, 2001).

The results of these experiments (particularly Experiments 2 and 3) agree with the conclusion that Ziegler and his colleagues (Ziegler & Perry, 1998; Ziegler *et al.*, 2001) have reached, about why N should play such a significant (facilitatory) role in English compared to languages like Spanish, French or German. In English, there is a much higher incidence of body neighbours[3] than in the other languages. These authors conducted experiments investigating the specific contribution of body neighbours towards the facilitatory effects of N in English. They found that not all the neighbours played a facilitatory role, only body neighbours did. They argue that the role of body neighbours is facilitatory because they aid English readers to build the mapping of spelling-to-sound correspondences[4]. The authors consider that the orthographic-to-phonological inconsistencies of the English language grant body neighbours (and hence most orthographic neighbours) a determinant facilitatory effect, as they act as an interface between the domain of orthography and the domain of phonology (Andrews, 1997; Treiman *et al.*, 1995). The help of orthographic redundancy[5] is not needed in languages with shallow orthography, like Spanish, where the highly predictable print-to-sound correspondences pose little need for the readers of these languages to develop specific strategies to establish those correspondences. The results of this thesis fully support this view.

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[3] Orthographic neighbours that share orthographic rime.

[4] This view had already been advanced by Bowey (1990).

[5] Letter sequences that are systematically repeated in a language's orthography.

Depth of orthography is not the only difference between English and Spanish in the orthography / phonology relationship, which may result in a different role for N and NF in each language. In Spanish lexical processing, the syllabic unit plays a crucial role, similar in relevance to the role of N in English. Spanish is a syllable-based language, whereas English syllables are very diffuse units, whose boundaries are much more blurred. A number of recent papers have addressed the role of syllabic units in the study of neighbourhood effects in Spanish and French and have found that 'syllabic neighbours'[6] are activated and play a role during the processes of word recognition (Carreiras *et al.*, 1993; Domínguez *et al.*, 1997; Perea & Carreiras, 1998). This question about the role of competing syllables, in experiments with languages other than English, may be at the root of the inhibitory effects of NF in Spanish. Perea & Carreiras (1998), in a study about syllabic units in Spanish, report inhibitory effects for syllable neighbours. This suggests that the notion of 'lexical similarity', contained in Coltheart *et al.*'s (1977) definition of orthographic neighbour may be more relevant to languages like English than to languages with a shallow orthography, like Spanish (and French). The evidence from the present experiments, namely, that of the inhibitory effects of NF for Spanish and the facilitatory effects of N for English, support the view that lexical competition is present in Spanish and that lexical conspiracy is present in English.

Current models of visual word recognition based on the activation metaphor, like the Interactive Activation (IA) Model (McCelland & Rumelhart, 1981) have problems explaining the facilitatory effects of N, as they anticipate exactly the opposite. According to the model, the connections between the nodes at the same level (letter level or word level) are always inhibitory, because only one letter or one word can be in a particular position at a

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[6] For example the Spanish word *pelo* [hair] relative to *pera* [pear].

particular time. Thus, the model predicts that a word with many neighbours will receive more inhibitory messages than a word with few neighbours. However, Andrews (1997) has suggested that the IA Model can in fact explain the facilitatory effects of N through the mechanism of reverberation. It is a kind of echoing of positive feedback, generated from the activated neighbours to their corresponding letter nodes, which in turn channel more excitatory activation back to the appropriate word nodes. The overall effect, then, is to enhance the recognition of the target. But Andrews' argument does not hold. Lateral inhibition is a central principle in the IA Model (the robust inhibitory effects of NF found in Experiment 3 fully agree with this principle). Thus, to invoke a 'subsidiary' mechanism, like positive feedback, should make for a greater impact on lexical processing than lateral inhibition. This seems difficult to justify without compromising the main pillar of the IA model, that of lexical competition.

As a result, to be able to accommodate the facilitatory effects of N (and more precisely the facilitatory effects of body neighbours) in deep orthographic languages like English, the IA Model would need to incorporate a level of body representations, to capture the special role that these neighbours play in the processing of those languages (Taft, 1991, Ziegler & Perry, 1998). The level of body representation would not be present in the implementation of the model for languages with shallow orthography.

The Bilingual Interactive Activation (BIA) Model (Grainger & Dijkstra, 1992; Dijkstra & Van Heuven, 1998; Van Heuven *et al.*, 1998) differs from its monolingual version in that it has an extra level of representation, with two language nodes (see Figure 5.3 in Chapter 5). In the version of the model with an integrated lexicon for both languages (which is the version favoured by the authors), all the lexical representations in the bilingual memory are encompassed in one single level of word nodes. Each of these nodes is connected to the relevant language node. The authors have conducted research in English and Dutch with supports the integrated, language non-selective, lexicon. There is no doubt that an integrated lexicon for two languages with the same Germanic origin is a very appropriate representation of the bilingual lexicon, as the degree of orthographic similarity between words of those languages is greater. However, when working with two languages as different orthographically as English and Spanish (with English favouring short words and Spanish favouring longer words) the notion of an integrated lexicon within the BIA framework may not be as relevant.

The results of Experiments 2 and 3 demonstrated that the effects of NF in Spanish are inhibitory. These results are both in line with the predictions of the IA Model, as well as with findings from previous experimental research. On the strength of this, it was hypothesised that the targets presented in Experiment 4 would exhibit similar inhibitory effects, i.e. words with higher frequency neighbours would be responded to more slowly than words with no higher frequency neighbours. The hypothesis extended to targets primed by translation equivalents as well as to targets primed by unrelated primes. The hypothesis was not confirmed, however. This specific side of the results of Experiment 4 was surprising, for three reasons. First, the effects of NF were not inhibitory but significantly facilitatory. Second, this facilitation effect was particularly robust in the case of Spanish items (which were the items that had shown largest inhibitory effects of NF in Experiment 3). And third, some of the Spanish targets in Experiment 4 had been used as 'single targets' in Experiment 3 and had conveyed inhibitory results of NF.

It is unclear at this stage why the NF results of Experiment 3 and Experiment 4 should be so different. There is one factor that might have triggered the switch of results, and it is linked to differences in the experimental task. In the former experiment the task was a standard LDT, and in the latter experiment the task was a LDT with semantic (translation) priming. Obviously, more research is needed to discern why the presence of a prime in the other language should reverse the nature of the influence of higher frequency neighbours, from one of competition to one of conspiracy.

At a theoretical level, the notion of 'language node activation' in the BIA Model could provide a key for the reversed pattern. 'Language node activation' is a kind of 'enhanced state of activation' which a language node has when the input is biased towards that language. This 'heightened' language node sends top-down excitatory messages to its corresponding word nodes, and inhibitory messages to all the words of the non-target language. This is what happens when the context indicates which language the next linguistic input is likely to be in (for example, in the language-block presentation of Experiments 3 and 4). It can be argued, that in the context of a LDT with translation priming (a task which undoubtedly encourages activation of both languages), the language node activation has to be particularly prominent for the task to be accomplished satisfactorily. This, in turn, could cause the neighbours of the target word, irrespective of their relative frequency, to behave primarily as 'friends', as opposed to 'enemies' (words of the non-target language). To use Grainger & Dijkstra's (1993) terminology, the words in the target language would be 'patriots' and the words in the non-target language would be 'traitors'. A primary function, then, of the language node proposed by the BIA Model, would be to assign word nodes to the right camp.

Hopefully the previous discussion has shown that the experimental work of this dissertation has provided some meaningful answers to the initial research questions. However, new answers pose new questions. The following section highlights some of the issues that still need to be addressed within the field of orthographic neighbourhood research.

10.3. IMPLICATIONS FOR FUTURE RESEARCH

In the light of the present experimental work, some conclusions can be drawn which can lead to new directions for further research.

The notion of lexical similarity, or N-metric, as defined by Coltheart *et al.*'s (1977), has proved very productive, but some researchers have suggested that the concept of neighbourhood size needs to be more flexible and to incorporate neighbours other than strictly same-number-of-letter neighbours (Forster and Taft, 1994). As has been suggested earlier in this thesis, the concept of orthographic syllabic neighbourhood could be particularly relevant to the Spanish lexicon, perhaps more so than the concept of letter-based neighbourhood. For research of neighbourhood effects in languages of differing orthography depth, this flexibility in the concept of lexical similarity is particularly relevant.

There are considerable differences between English and Spanish at word level, which indicate that a great deal of research needs to be done to fully understand how neighbourhood effects operate in the context of the two lexicons. Table 10.1 offers a preliminary list of aspects in which English and Spanish are different. These sketched differences can serve as pointers for new research. In addition, now that there Spanish psycholinguists have a number of computer databases at their disposal, statistical analyses, similar to those carried out in English by Treiman *et al.* (1995) and Andrews (1997), can be performed to see if these differences can be statistically substantiated.

Furthermore, specific examples for future research, following the work presented in this thesis, are:

- To study neighbourhood effects, using the same targets as those used in Experiments 3 or 4 but under different forms of LDT and priming; for instance, using visible priming as well as masked priming.

- To investigate neighbourhood effects in bilinguals with different levels of proficiency.

- To examine neighbourhood effects, employing word familiarity judgements to select the bilingual items, rather than using straight print frequency.

- To replicate studies similar to those done in French / English and Dutch / English (Grainger & Dijkstra, 1992; Van Heuven *et al.*, 1998). This replication could be done using Spanish and other languages that share a reasonable amount of orthographic overlap, like French, Catalan or Italian.

SPANISH	ENGLISH
• Shallow orthography.	• Deep orthography.
• Syllables: clearly defined boundaries.	• Less clear definition of syllables as perceptual units in reading
• Written accents: *canto* vs *cantó*.	• No written accents
• Different patterns of letter combination: not as many consonant clusters, many restrictions on end of word consonants.	• Letter combination much more versatile. Many more consonant clusters.
• Many more word suffixes: conjugations, number-gender agreements, etc. Greater impact of methodological issue of calculating neighbourhood.	• No conjugation endings, or number-gender agreement, etc. Methodological issue of calculating neighbourhoods.
• No homographs. Very few homophones (*bota* and *vota*).	• Many homographs and homophones (it affects both spoken and written neighbourhoods).
• Considerably more 5-6-7 letter words. Very few 3-letter words	• Considerably more 3-4 letter words (the concept of neighbourhood works better with shorter words).
• Fewer monosyllabic words and more polysyllabic words.	• Many more monosyllabic and bisyllabic words.
• Less dense orthographic neighbourhoods.	• More dense neighbourhoods.
• More univocal relationship between form and meaning of the words: Words are less polysemous.	• Greater degree of polysemy.
• Formality of language expressed mainly through more complex grammar	• Formality of language expressed mainly through choice of vocabulary: with longer words of Latin origin..
• Lesser difference in word frequency between spoken vocabulary and written vocabulary.	• Greater difference in word frequency between spoken and written vocabulary. Issue of 'word familiarity' with certain frequently written words.

Table 10.1. Comparison between Spanish and English. *Some differences at word level.*

10.4. CLOSING REMARKS

The main conclusion from this doctoral thesis is that orthographic neighbourhood effects, in the context of English and Spanish, are language specific. However, the nature of this specificity needs to be fine-tuned with further research, as there are factors, related to the experimental tasks and to the particular characteristics of the two lexicons, that influence the specific role of orthographic neighbours. As this is an area of growing interest in psycholinguistic research, and this study is amongst the first to address the issue, there is no doubt that more work will soon follow.

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