Family and neighbourhood relations in the mental lexicon:
A cross-language perspective

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Family and neighbourhood relations in the mental lexicon:
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Table of Contents

Introduction

Chapter 1

Words are the building blocks of human language. They are the carriers of the meaning of the message we want to convey. We use and encounter thousands of words every day. Estimates indicate that we utter approximately 16,000 words a day (Mehl, Vazire, Ramírez-Esparza, Slatcher, & Pennebaker, 2007). Also, the speed with which we are able to retrieve words from our mind is remarkable. We can utter approximately two to three words per second and are even able to read more than five words within one second (e.g., Levelt, 1989; Bailey & Bailey, 1999). With this speed of using words, it is not surprising that sometimes a word other than the intended word pops up in our mind during reading, speaking, listening, or writing. We most likely all had the experience in which we read a word while actually another was written. In similar vein, we are very fast in generating associated words for a given word.

This flexibility in activating words follows from the way in which words are organised in our mental lexicon, the place in our mind where all these words are stored. Words are not isolated islands in a big ocean. If this were the case, other words would not pop up and interfere in the processing of a given word. Rather, words can be connected to other words through many different types of relationships. For instance, words such as *cat* and *hat* are related because they share part of their orthographic and phonological form. Other words, such as *cat* and *dog*, are related in meaning and activate semantic fields related to animals and pets. Yet other words such as *cat* and *cat fight* share both formal aspects and touch upon similar semantics. The mental lexicon could therefore be considered as a highly interconnected web of words.

Obviously, relationships between words are not restricted to one language only. Words from different languages in the lexicon of a bilingual can be related through the same type of relationships that connect words in the lexicon of a monolingual. For instance, the English word *cat* shares a formal relationship with the Dutch word *zat* 'drunken', a semantic relationship with *hond* 'dog', and both a formal and semantic relationship with the Dutch word *kattenbak* 'cat's box'.

Monolingual and bilingual research on both visual and auditory word processing has shown that, during the reading or listening of words, related words can become activated and influence the processing of these words. This thesis deals with cross-language activation and focusses on two types of cross-language relationships that relate a given word in one language to words from another language: Morphological family members and orthographic neighbours. In what follows, I will first discuss some general issues regarding cross-language activation in bilingual word processing. Next, I will explain the notions of morphological family and orthographic neighbourhood in the monolingual and bilingual mental lexicon and formulate the goals of this dissertation.

Cross-language activation in bilingual word processing

One question that has received a great deal of attention is whether bilinguals can and do activate words from both of their languages when reading in only one language. Research examining cross-linguistic lexical activation has mainly focused on two types of items that share their form in two or more languages: cognates and interlingual homographs. Cognates are words that share both their form and meaning across languages. They can be identical in form (e.g., *horizon* in English and Dutch) or nearly identical (e.g., *cat* and *kat* in English and Dutch, respectively). Interlingual homographs are similar in form but do not share this meaning overlap (e.g., *roof* means 'to steal' in Dutch).

Behavioural studies involving bilingual participants processing cognates and interlingual homographs have observed that these types of words were responded to significantly differently from words that exist in one language only (e.g., Caramazza & Brones, 1979; De Groot & Nas, 1991; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998, Kroll & Stewart, 1994; Lemhöfer et al, 2008; Sanchez-Casas, Davis, & Garcia-Albea, 1992, Schwartz, Kroll, & Diaz, 2007; Voga & Grainger, 2007; Dijkstra, Miwa, Brummelhuis, Sappelli & Baayen, 2010; Von Studnitz & Green, 2002; Font, 2001). More recently, studies using electrophysiological and neuroimaging measures observed differences in brain activity during the processing of cognates and controls (e.g., De Bleser et al., 2003; Midgley, Holcomb, & Grainger, 2011).

While cognates are generally found to facilitate word processing and interlingual homographs more often show an inhibitory effect, the direction and even presence of cognate and homograph effects depend on several factors, such as task demands and stimulus characteristics. For instance, Dijkstra et al. (2010) observed a facilitation effect for cognates relative to control words in language specific lexical decision. In this task, participants must determine whether or not a presented letter string is an existing word in a given language by means of a button press corresponding to a yes- or no-response. However, cognate inhibition was observed in language decision, a task in which a participant must decide whether the presented word belongs to one language or the other (i.e., what is the word's language membership?) by pressing a button corresponding to one of the languages. Moreover, Dijkstra et al. (2010) even showed that the strength of the cognate effect in lexical decision depends on the formal overlap between cognate representations. They observed a stronger facilitation effect for cognates that share complete form overlap (e.g., *film*) relative to non-identical cognates that have nearly complete form overlap (e.g., *cat-kat*). Duyck, Van Assche, Drieghe, and Hartsuiker (2007) obtained a similar facilitation effect for identical cognates relative to non-identical cognates in a sentence context.

Further, whether or not cognate or homograph effects are observed also depends on stimulus list composition. Dijkstra, De Bruijn, Schriefers, and Ten Brinke (2000) observed no difference in response latencies to Dutch-English interlingual homographs and English controls when the stimulus list contained only English control words and English pseudo-words apart from the interlingual homographs. However, when Dutch control words were introduced in the experiment (to be rejected, just like pseudo-words), strong inhibitory effects were obtained for the Dutch-English interlingual homographs. In sum, the specific experimental contexts in which bilinguals process cognates and homographs give rise to different effects.

Cognate and interlingual homograph effects are generally taken as evidence that bilinguals access words in their lexicon in a language-non-selective way. When reading a cognate or homograph, both readings of a cognate or homograph are assumed to be activated in parallel and thus affect the processing of a given target word. However, a point of criticism that has been raised against studies involving cognates or interlingual homographs is that their letter strings are to a large extent language ambiguous, which will obviously lead to the activation of both languages. It is argued that stronger evidence in favour of language non-selective access would come from more indirect co-activation of a non-target language, i.e., by looking at activation that goes beyond the input word itself. In this dissertation, we study two types of cross-language relationships that are not directly visible from the input, namely morphological relatedness and orthographic relatedness across languages. To measure the effect of these relationships on bilingual word processing, we focus on two quantitative measures of morphological and orthographic relatedness: Morphological family size and orthographic neighbourhood size.

Morphological Family Size

A word's morphological family can be defined as the number of complex words that are morphologically related to a given word and in which this word occurs as a constituent (Schreuder & Baayen, 1997). For instance, morphological family members of the English word *home* are presented in Table 1.1.

Table 1.1. Morphological family of the English word *home*.

home
hometown
homemade
homey
foster home
homeless
care home
....

The productivity of words can vary considerably. A word such as *home* has over one hundred of family members, while the morphological family of the word *villa* is restricted to only a few members (e.g., *villa park*, *holiday villa*). It has been observed that the number of morphological relatives of a word can predict response latencies and accuracy scores in behavioural experiments. Schreuder and Baayen (1997) were the first to observe that

Dutch words with a large number of morphological family members were processed faster and more accurately than Dutch words with a smaller morphological family. Since then, effects of family size in monolinguals have been observed for various other alphabetic languages and even for non-alphabetic languages (Schreuder & Baayen, 1997; Bertram, Baayen, & Schreuder, 2000; De Jong, Schreuder, & Baayen, 2000; De Jong, 2002; Kuperman, Schreuder, Bertram, & Baayen, 2009; Baayen, Lieber, & Schreuder, 1997, De Jong, Feldman, Schreuder, Pastizzo, & Baayen, 2002; Juhasz & Berkowitz, 2011; Moscoso del Prado Martín, Bertram, Häikiö, Schreuder, & Baayen, 2004; Kuperman, Bertram, & Baayen, 2008; Moscoso del Prado Martín et al., 2005; Boudelaa & Marslen-Wilson, 2011).

When bilinguals acquire new words from their second language, irrespective of whether they are balanced bilinguals, unbalanced bilinguals, or learners of a second language, they start to develop relationships between these words, just like they do for words in their native language. These relationships can be based on orthographic, phonological, semantic, or morphological similarity. In this way, new words in the mental lexicon of these bilinguals become connected.

As was argued earlier in this Introduction, words from the second language and native language can be connected through the same type of relationships as words belonging to one language only. Words between languages can be morphologically related as well. Because a family member by definition contains the target word to which it is morphologically related, a cross-language family relation is restricted to cognates or interlingual homographs. Examples of the within-language and cross-language morphological family of the English-Dutch interlingual homograph *room* and the English-Dutch cognate *normal* (*normaal* in Dutch) are presented in Table 1.2.

Table 1.2. Morphological family of the English-Dutch interlingual homograph *room* and the English-Dutch cognate *normal*.

English	room	Dutch
roommate		slagroom ('whipped cream')
hotel room		roomsaus ('cream sauce')
roomy		romig ('creamy')
...		...
English	normal	Dutch
normality		normaliter ('normally')
normalization		abnormaal ('not normal')
...		...

Following the theoretical view of language non-selective access to an integrated lexicon, reading a word could result in the activation of related words from another language as long as there is sufficient overlap between the related word and the input word. Going a bit further, it is even possible that when bilinguals process a cognate or homograph in their second language, they might also activate morphological family members from their native language. This is because cognates and interlingual homographs have overlapping representations in the two languages, which might result in a co-activation of both of them. As a consequence, an input item could lead to the activation of morphological family members from the other language depedent on their formal overlap with this other-language representation (e.g., the English cognate *normal* could activate the Dutch family member *abnormaal*).

Until now, research on the effect of activation of cross-language family size has been sparse. Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005) investigated the role of cross-language family size in the recognition of Dutch-English interlingual homographs. Within-language and cross-language family size effects were observed in both English (L2) and Dutch (L1) lexical decision data. The materials of the two lexical decision tasks contained both purely English or Dutch words and Dutch-English interlingual homographs. In both tasks, Dijkstra et al. observed a facilitatory effect of the within-language family size on the recognition of purely English or Dutch words and Dutch-English interlingual homographs. On the other hand, the cross-language family size produced an inhibitory effect on the recognition of interlingual homographs. Finally, Dijkstra et al. investigated whether the family size effect was task-dependent by means of a generalized Dutch-English lexical decision task with the same stimuli. In this task, the participants responded ‘yes’ to both English and Dutch words, and ‘no’ to pseudo-words that did not exist in either language. Interestingly, this experiment revealed facilitatory effects of both morphological families on response latencies in lexical decision.

This study was the first, and to our knowledge only, study that investigated cross-language family size effects in bilinguals. The study leaves open several interesting questions. For instance, is it the absence of semantic overlap between target word and family member that caused the inhibition in English lexical decision (e.g., the English word *room* is not semantically related to the activated family member *slagroom* ‘whipped cream’) or did inhibition occur because the activation of Dutch family members increased the amount of non-target language activation that is linked to a no-response (i.e., more Dutch activation increasing the evidence that the letter string is not an English word)? And does the input word need to have complete formal overlap across languages in order to activate cross-language family members?

To answer these and other questions, this dissertation focuses on cross-language family size effects in cognates. It is not clear how the activation of cross-language family members affects the processing of cognates. In a language-specific task situation, such as English lexical decision, cross-language family size effects could be either facilitatory or inhibitory depending on whether semantic overlap or task-specific processes are more relevant during word processing. Further, cognates are particularly interesting, because the degree of formal overlap between cognate representations can be varied, which allows an investigation of the form aspect of cross-language family size effects. This cannot be properly done with interlingual homographs, as the set of nearly identical interlingual homographs is too restricted.

Because cognate effects can differ as a function of task situation, cross-language family size effects could be influenced by the direction of the cognate effects. To explore the nature of cross-language family size effects in cognates under different circumstances, we considered different research methods in the experimental chapters. Both behavioural and electrophysiological measures were applied. The latter type of measure also has the advantage of allowing a study of when family size effects arise during word processing, which could give an indication of whether the family size effect is a purely semantic effect or whether activation of form plays a role as well.

The following questions about morphological family size effects are addressed for monolingual and bilingual word processing:

1. Can within-language and cross-language morphological family size effects be observed in cognates, and under which experimental conditions do these effects arise? (Chapters 2 and 3)
2. Can activation in the monolingual and bilingual lexicon spread beyond the primary morphological family, to items that are indirectly related to the target word? (Chapter 4)
3. Is the (within-language and cross-language) family size effect a purely semantic effect or does it also have a formal component? (Chapters 2 and 3)
4. Which mechanisms underlie the activation of within-language and cross-language morphological family members? (Chapters 2 to 4)

Orthographic neighbourhood size

The second type of relationship we investigate in this dissertation concerns orthographic neighbourhood, a relationship that is purely based on form overlap. Orthographic neighbours are words that differ from each other in only one letter position (Coltheart, Davelaar, Jonasson, & Besner, 1977). The English word *wool* only differs in one letter position from other English words such *fool*, *wood*, and *tool*. A similar orthographic neighbourhood relationship can exist across languages. For instance, Dutch orthographic neighbours of the English word *wool* are *kool* and *woon*.

Monolingual research has shown that response latencies to words are affected by the number of orthographic neighbours these words have and the frequency of these neighbours (see for an overview, Andrews, 1989; and Ferrand, 2001). The effects of neighbourhood size are observed to be larger when the frequency of the neighbours is controlled for. Moreover, the few studies that investigated cross-language orthographic neighbourhood size effects have shown that word processing can even be affected by the number of cross-language orthographic neighbours (e.g., Grainger & Dijkstra, 1992; Van Heuven, Dijkstra, & Grainger, 1998).

While cross-language neighbourhood size is generally found to have an inhibitory effect, the effect of within-language neighbourhood size on word processing is less clear: Studies on orthographic neighbourhood size have observed both facilitatory and inhibitory effects of within-language neighbourhood size on response latencies in behavioural experiments.

Facilitatory effects are generally explained to reflect increased resonance between word and letter representations for target words with a large number of orthographic neighbours, which facilitates the processing of these target words (e.g., Andrews, 1989). Interactive activation models such as IA and BIA+ (McClelland & Rumelhart, 1981; Dijkstra & Van Heuven, 2002), on the other hand, predict inhibition effects for both within-language and cross-language orthographic neighbours, based on the assumption that, during word processing, activated lexical candidates compete for selection with the target word. To account for the observed facilitatory effects of within-language neighbourhood size within an interactive activation framework, Grainger and Jacobs (1996) formulated multiple read-out criteria that could account for facilitatory effects observed in lexical decision. They argued that lexical decision responses could be based on either activity in an individual word representation or the summed lexical activation of activated word candidates.

Conflicting results concerning the effect of within-language neighbourhood size are considered to be due largely to applying different contrasts in neighbourhood size and using different experimental methods (see Andrews, 1989). Interactive activation models predict no clear difference in response latencies between words with many or few neighbours, but do predict a difference between words with no neighbours and some neighbours (regardless of language membership of the neighbours). However, studies observing facilitatory within-language effects have, the study of Van Heuven et al. (1998) included, generally applied the first contrast. This implies that the predictions of these models could not have been not properly tested with these experimental data. Only the monolingual study of Bowers, Davis, and Hanley (2005) used a contrast between no neighbours and some neighbours in a semantic categorization task. They observed that repeated exposure to a novel neighbour word such as *banara* made it more difficult to semantically categorize familiar words such as *banana*. Interference effects even became larger with more training on the novel words. This result, though observed in a task other than the generally used lexical decision task (semantic categorization), revealed that by applying a different neighbourhood size contrast, different effects of neighbourhood size can be observed.

In this dissertation (Chapter 5), both within-language and cross-language neighbourhood size effects are addressed in a design that contrasts words that have no neighbours in one or both languages of a bilingual ('hermit words') with words that have neighbours in one or both of its languages in a standard lexical decision task. This approach allows us to compare our findings to the findings of Bowers et al. (2005) that were obtained with a similar contrast in neighbourhood size but with a different experimental task, and to replicate Van Heuven et al.'s (1998) bilingual findings with a different contrast for lexical decision with Dutch-English. We aim to answer the following questions:

1. Are both within-language and cross-language orthographic neighbours activated in a purely monolingual setting?
2. Is the direction of within-language and cross-language family size effects dependent on the contrast in neighbourhood size that is applied (no neighbours versus some neighbours relative to few versus many neighbours)?
3. Which mechanisms underlie activation of (within-language and cross-language) orthographic neighbours?

In sum, this thesis deals with types of cross-language relationships that are not directly visible in the input. This approach serves two theoretical purposes. First, observing cross-language effects through relationships that are not directly visible in the input provides strong evidence for language non-selective access to an integrated lexicon. Second, both the measure of morphological family size and that of orthographic neighbourhood size are quantifications of the interconnectedness between a given word and other words within the lexicon. Observing effects in different experimental paradigms will give some insight into the conditions under which morphological and orthographic relations are activated and into the mechanisms underlying the activation of morphologically and orthographically related words. This is relevant for existing and future models of bilingual and monolingual word processing that aim to unravel the structure of the mental lexicon of monolingual and bilingual language users.

Outline of the dissertation

In this dissertation, four experimental chapters are presented that address the questions specified in the previous section. In Chapters 2 to 4, the nature and role of morphological family size in cognate processing are explored. More specifically, Chapter 2 investigates whether and under which conditions cross-language family size effects are observed in a set of three behavioural experiments. Task specific requirements of these three experiments (English lexical decision, Dutch-English language decision, and English progressive demasking) may lead to different processing mechanisms to be used, and to different family size effects. Then, in an ERP study in Chapter 3, we investigate whether the ERP signal is sensitive to the morphological productivity of words in monolingual and bilingual processing. In addition, the time course of the morphological family size is inspected to clarify the nature of the family size effect. In Chapter 4, we address the question of how far activation can spread within the bilingual lexicon. Within-language family size effects of the primary and secondary morphological family are tested behaviourally in lexical decision with both monolinguals and bilinguals. Finally, in Chapter 5, within-language and cross-language orthographic neighbourhood size effects are investigated. All chapters have been submitted or are in preparation to be submitted as journal articles. They can be read as independent chapters, but because of their format as separate articles, some overlap may exist between the different chapters in terms of introduction and method sections.

Finally, in Chapter 6, I will present a summary of the main findings of this dissertation and discuss their consequences for existing models of bilingual word processing. Moreover, I make a first attempt to specify the structure of a new interactive activation model based on the original BIA+ model that is able to account for the observed morphological family size and orthographic neighbourhood size effects.

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Cross-language morphological family size effects in cognate processing: Task-dependency and form-similarity

Chapter 2

This chapter is based on: Mulder, K., Dijkstra, T., Schreuder, R., & Baayen, R.H. (in preparation). Morphological family size effects in bilinguals: Evidence from identical and non-identical cognates.

Abstract

The present bilingual study considered cross-language morphological family size effects in English lexical decision and Dutch-English language decision. The English lexical decision data showed a facilitatory effect of Dutch family size on the processing of English-Dutch cognates relative to English control words. No interaction of Dutch family size with cognate type was observed, showing that the degree of form overlap between cognate representations does not influence the direction and size of the family size effect in a language-specific context. However, in Dutch-English language decision, in which a bilingual context is created, Dutch and English family size effects were inhibitory and interacted with cognate type. This sensitivity of the family size effect to the degree of formal overlap between cognate representations led us to perform a re-analysis of available English progressive demasking data of Dijkstra, Miwa, Brummelhuis, Sapelli, and Baayen (2010). Interestingly, Dutch family size was found to inhibit cognate processing, while there was no effect of English family size on either cognates or English control words. We conclude that cross-language family size effects are sensitive to the bilingual or monolingual task context in which lexical items occur and depend on both semantic and formal aspects of word processing. We discuss various mechanisms that can explain the observed family size effects in a spreading activation framework.

Introduction

In our mental lexicon, words can be linked to other words through various relationships, such as orthographic, semantic, or morphological similarity. For instance, the word *ship* is related to complex words such as *shipwreck* and *steamship* in terms of the part of their morphology they share with this word. Obviously, such relations between words in the lexicon are not restricted to words from one language only. Dutch complex words such as *basisschool* 'primary school' or *schooltas* 'school bag' bear a similar morphological relation to the English word *school*.

Monolingual studies have found that the number of morphologically related complex words in which a given target word occurs as a constituent, defined as the word's morphological family size (Schreuder & Baayen, 1997), affects target word processing. In this paper, we address the role of morphological family size in bilingual word processing. More specifically, we investigate whether cross-language family size affects the processing of cognates, a special type of items that allow for cross-language activation. Further, we will address the question of whether cross-language family size effects in cognates vary according to task differences and formal characteristics of cognates. In what follows, we will first discuss the nature of family size effects in monolingual word processing before discussing possible implications for bilingual word processing.

In monolingual studies, words with larger morphological families are generally found to be processed faster and more accurately than words with smaller morphological families. Facilitatory effects are observed in lexical decision studies for several languages with a concatenative morphology (e.g., for Dutch: Schreuder & Baayen, 1997; Bertram, Baayen, & Schreuder, 2000, De Jong, Schreuder, & Baayen, 2000; De Jong, 2002; Kuperman, Schreuder, Bertram, & Baayen, 2009; for English: Baayen, Lieber, & Schreuder, 1997, De Jong, Feldman, Schreuder, Pastizzo, & Baayen, 2002; Juhasz & Berkowitz, 2011; for (non-Germanic) Finnish: Moscoso del Prado Martín, Bertram, Häikiö, Schreuder, & Baayen, 2004; Kuperman, Bertram, & Baayen, 2008). Moreover, facilitatory effects are also observed for languages with an alphabetic writing system and a non-concatenative morphology (for Hebrew: Moscoso del Prado Martín et al., 2005; for Arabic: Boudelaa & Marslen-Wilson, 2011). Finally, written Chinese is non-alphabetic and non-concatenative but shows effects similar to the family size effect in terms of the productivity of semantic radicals (Feldman & Siok, 1997).

Schreuder and Baayen (1997) explained facilitatory family size effects by means of global lexical activation along the lines of the multiple read-out model of Grainger and Jacobs (1996): Words that co-activate many other words (lemmas[1]) give rise to more global lexical activation supporting a positive lexicality decision. De Jong, Schreuder, and Baayen (2003) simulated this mechanism in a computational model of monolingual morphological processing (the Morphological Family Resonance Model; MFRM). They showed that read-out of global activation may not be necessary if activation is allowed to resonate between forms, lemmas, and meanings. In their model, associated lemmas (family members) of a target word are activated via the semantic representation of that target word. When a semantic representation of a target word is linked to many associated lemmas, a large amount of activation is spread back and forth between this semantic representation and the associated lemmas, gradually increasing the shared semantic activation and the activation level of the target lemma. Such resonance within the morphological family will thus speed up the rate at which the activation of the target lemma increases, speeding up word recognition. Figure 2.1 presents a schematic representation of the resonance of activation between family members and the semantic representation of the target word.

[1] Lemmas are abstract word units. In Schreuder and Baayen's (1995) model of morphological processing, lemma nodes links form information at the access level with higher-order semantic and syntactic information. See also Taft (2011), who discussed an interactive activation framework incorporating a lemma level that captures lexical information.

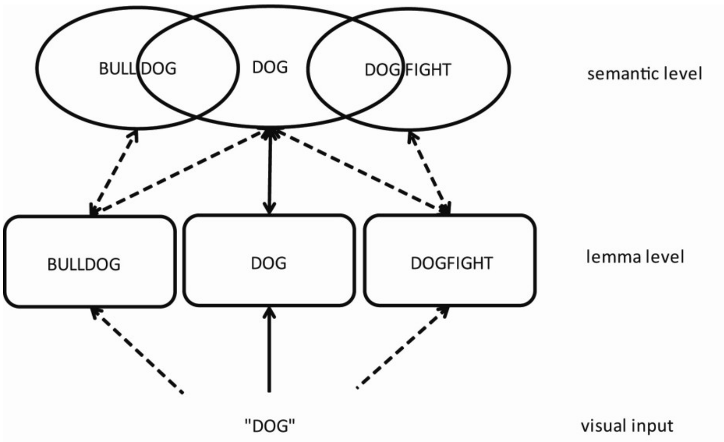

Figure 2.1. Resonance of activation between morphological family members and the semantic representation of the target.

Though morphological family members are connected to a target word via both orthographic and semantic links, family size effects are generally assumed to be semantically driven. Early evidence for the semantic character of the family size effect was obtained by Schreuder and Baayen (1997) and Bertram et al. (2000), who observed that correlations between family size and reaction times increased when semantically opaque family members were excluded from the family size count (e.g., *honeymoon* is morphologically but not semantically related to *honey*; exclusion of opaque family members such as *honeymoon* from the family size count of *honey* increased the correlation of family size with RT).

In line with these findings, De Jong et al. (2000) observed that the family size effect appeared for both regular and irregular past participles (e.g., *roei-geroeid*, 'row-rowed' vs. *v**e**cht-gev**o**chten*, 'fight-fought', even though the irregular past participle does not share the exact form with its mono-morphemic stem and other family members. This was put forward as evidence that the family size effect is not a mere form effect. Again, inclusion of a morphologically related but not semantically related form such as *vocht* (meaning 'moisture') in the family size count of *vecht* decreased the correlation between RTs and family size.

Moscoso del Prado Martín et al. (2005) reported an additional semantic characteristic of the family size effect in Hebrew. The root *B-G-R* only occurs in words related to maturing (e.g., *mBuGaR* 'an adult' or *hitBaGeR* 'to mature'), whereas the root *X-SH-B* appears in two semantic fields, one related to thinking, and one related to arithmetics and calculations. The activated semantic fields of morphological roots that were related in meaning to a Hebrew word had a different effect on response latencies than unrelated activated semantic fields. In a Hebrew visual lexical decision task, Moscoso et al. not only observed the expected facilitation effect of family members that were related in meaning, but they also observed an inhibition of RTs when the number of family members that were not semantically related increased. In sum, these studies show that the family size effect is at least partially semantic in nature. Moreover, the different effects for semantically related and unrelated family members observed by Moscoso et al. (2005) give rise to the hypothesis that semantic convergence between target word and family member determines the direction of the family size effect.

Until now, only few studies have addressed family size effects in bilingual word processing. Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005) investigated the role of family size in the recognition of Dutch-English interlingual homographs. Interlingual homographs are words that share their form but not their meaning in two or more languages. For instance, the English-Dutch homograph *room* means 'cream' in Dutch. As a consequence of being an existing word in two languages, reading an interlingual homograph could activate morphological family members of these words in both languages.

Within-language and cross-language family size effects were observed in both English (L2) and Dutch (L1) lexical decision data. The materials of the two lexical decision tasks contained both purely English or Dutch words and Dutch-English interlingual homographs. In both tasks, Dijkstra et al. observed a facilitatory effect of the within-language family size on the recognition of purely English or Dutch words and Dutch-English interlingual homographs. On the other hand, the cross-language family size produced an inhibitory effect on the recognition of interlingual homographs. Thus, in the case of English lexical decision, activation of English family members such as *roommate* facilitated the lexical decision to the English word *room*, while Dutch family members such as *slagroom* ('whipped cream') slowed it down. The observed family size effects were independent of the relative frequency of the two readings of the homographs. Finally, Dijkstra et al. investigated whether the family size effect was task-dependent by means of a generalized Dutch-English lexical decision task with the same stimuli. In this task, the participants responded 'yes' to both English and Dutch words, and 'no' to pseudo-words that were pseudo-words in both languages. Interestingly, this experiment revealed facilitatory effects of both morphological families on response latencies in lexical decision.

This study on interlingual homographs was the first to show that the morphological family of both languages is activated during bilingual word processing. The direction of the observed family size effects in this study is in line with the hypothesis that a semantic relationship rather than a form relationship determines the direction of the family size effect. Important to note is that non-target language family members of interlingual homographs are never semantically related to the homographs' representation in the other language (e.g., the Dutch word *roomsaus* is not semantically related to the English representation of the homograph *room*). While this semantic incongruence would strictly always lead to inhibitory effects in interlingual homographs, both English and Dutch family size effects were observed to be facilitatory in the generalized lexical decision task. This gives rise to the proposal that mechanisms other than semantic convergence might codetermine the direction of the family size effect.

In the present study, we focus on family size effects for a different type of item that can activate cross-language language family members, namely cognates. Cognates are words that share both their form and meaning in two or more languages (e.g., *film* in English and Dutch). They can be either identical (e.g., *film* in English and Dutch) or non-identical in form (e.g., *admiral* and *admira**a**l*, in English and Dutch, respectively). To our knowledge, this is the first study that addresses cross-language family size effects in cognates. Therefore, a main aim of this study is observing cross-language family size effects for these types of items in a standard English lexical decision task with Dutch-English cognates (Experiment 1).

Family size effects in cognates are particularly interesting, because, unlike interlingual homographs, cognates activate roughly the same semantics for both languages (see Figure 2.2).

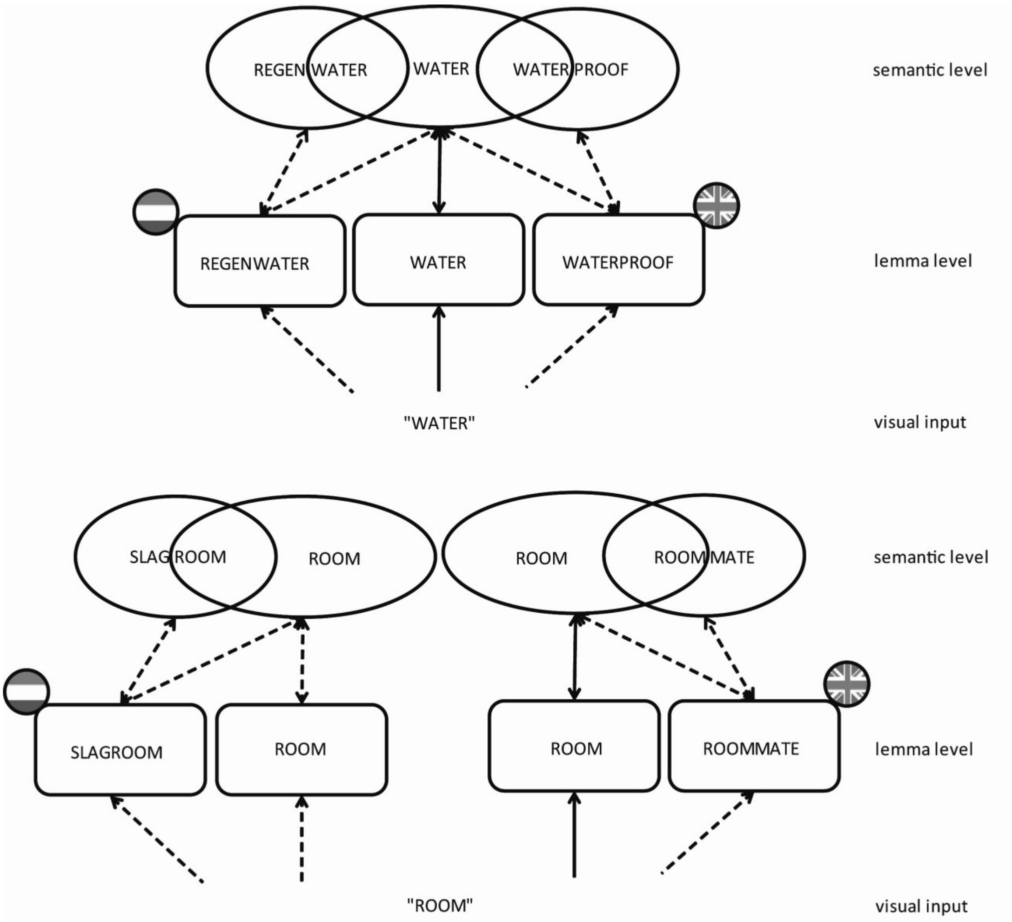

Figure 2.2. Schematic illustration of the activation of family members of the English-Dutch interlingual homograph *room* and the English-Dutch cognate *water* in an English task context.

The direction of the cross-language family size effect in cognates is less predictable in comparison to interlingual homographs, because it may reveal additional sensitivity to formal aspects of word processing. If semantic convergence exclusively determines the direction of cross-language family size effects, facilitatory effects are expected across different tasks for cognates. However, if the direction of the cross-language family size effect is sensitive to other factors that affect word processing, then different outcomes may be expected in different experimental paradigms and for cognates differing in the amount of formal overlap in two languages.

This issue was investigated in a Dutch-English language decision task (Experiment 2). In this task, participants have to decide as quickly and accurately as possible whether a presented letter string is a Dutch word or an English word. In the case of a cognate, a response conflict is expected to arise because of the formal overlap between cognate representations (e.g., the words *tent* and *admiral* (in Dutch 'admiraal') could activate both a Dutch and English response). As a consequence, this response competition between two readings of a cognate should result in a cognate inhibition effect (cf. Dijkstra, Miwa, Brummelhuis, Sapelli, & Baayen, 2010).

The question is whether the family size effect is sensitive to this induced response competition. Importantly, because activated family members overlap semantically with the cognate to which they are linked, facilitatory effects could still arise. Alternatively, because the activated family members could increase the activation of the specific cognate representation to which they are linked, target and non-target language family members could also strengthen the response competition between the two representations of a cognate. This would then result in inhibitory effects of both the target and non-target language family.

In this situation, in which two languages have to be distinguished, cross-language family size effects may be sensitive to the degree of formal overlap between cognate representations. Note that an effect of formal stimulus characteristics cannot be tested with interlingual homographs, because these items nearly always have complete formal overlap between two languages. However, cognates are extremely suitable to test this assumption, because the degree of formal overlap between representations can be varied.

Importantly, any difference between family size effects for cognates with complete formal overlap (i.e., identical cognates; *tent*) and cognates with nearly complete formal overlap (i.e., non-identical cognates; *admiral* - *admiraal*) can help to clarify the mechanism underlying the family size effect. If the cross-language family size effect is not sensitive to the degree of orthographic similarity between cognate representations, family size effects should behave in the same way for identical and non-identical cognates.

However, if the direction of the family size effect in cognates depends to a certain extent on the formal overlap between cognate representations, then different predictions may be formulated for identical cognates and for non-identical cognates in task situations in which this orthographic information is relevant for responding correctly. In an English-Dutch language decision task, English-Dutch identical cognates (e.g., *water*) might induce more response competition between an English and a Dutch response than English-Dutch non-identical cognates (e.g.*, thief*), because they contain less language-specific orthographic information and both responses are correct. Activated Dutch and English family members of an identical cognate (e.g., *regenwater*, 'rain water', and *waterproof,* respectively) would strengthen this competition, because part of their orthographic representation is also language-ambiguous (i.e., *regen**water**)*, while for non-identical cognates this would be less the case (cf. *thief – tasjes**dief**).* Thus, a large family size could increase the cognate inhibition effect for identical cognates relative to non-identical cognates.

Given the results of the lexical decision and language decision experiments, we devote the last part of this paper to a re-analysis of available progressive demasking data with Dutch-English bilinguals of Dijkstra et al. (2010). This task is known to tap into early stages of word processing and is sensitive to formal aspects of word processing (cf. Grainger & Jacobs, 1996). We argue that if family size effects are observed in this paradigm, this would provide a strong case for sensitivity of the cross-language family size effects to formal aspects of processing.

Experiment 1 – English Lexical Decision

Method

Participants. Twenty-nine native speakers of Dutch, mainly students of the University of Nijmegen (mean age 23.8 years, SD = 5.49) took part in this experiment. All participants had English as their second language, having learnt English at school from around the age of 11. All had normal or corrected–to-normal vision. Participants were paid or received course credits for participating in the experiment.

Materials. The stimulus set consisted of 400 items, half of which were English words and half were pseudo-words. All word items were selected from the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Only word items with an English lemma frequency of at least one per million in the CELEX database and a length between three and eight letters were selected. All word items were mono-morphemic words. For each item, the English family size values and the English lemma frequencies per million were extracted from the CELEX lexical database and logarithmically transformed.

The experimental items were 90 Dutch-English cognates. Forty of these items were identical in form in Dutch and English (identical cognates; e.g., *horizon-horizon*), while the other fifty items were nearly identical in orthography in both languages (non-identical cognates; e.g., *admiral-admiraal*). The non-identical cognates were always presented in their English form. The degree of orthographical overlap was calculated by the Levenshtein distance measure (Levenshtein, 1966). For each cognate item, the Dutch family size values and the Dutch lemma frequencies per million were extracted from the CELEX lexical database and logarithmically transformed. Half of the identical and half of the non-identical cognates had a high family size in Dutch, while the other half of these cognates had a low Dutch family size. The sets of identical and non-identical cognates with a high Dutch family size were matched on English Frequency, English Family Size[2], and Length (in letters) to the identical and non-identical cognates with low Dutch family size. Moreover, the non-identical cognates with high and low family size were matched on Levenshtein Distance.

The experiment further included 90 English control words that were matched to the set of cognates on English Frequency, English Family Size and Length, and twenty English filler words that were matched on Length to the cognates and controls. Finally, 200 pseudo-words were added that were matched to the set of 200 word items on Length. Table 2.1 presents the characteristics of the cognate and control items.

[2] Recently, Mulder, Dijkstra, Schreuder, & Baayen (under revision; Chapter 4) investigated English primary and secondary family size effects in English visual lexical decision with Dutch(L1)-English(L2) bilinguals. Their stimulus materials included both Dutch-English cognates and purely English items. No effects of Dutch primary and secondary family size effects were observed on the set of cognates. The authors argued that this occurred because the English family size was varied and, consequently, took away part of the effect. However, they hypothesized that cross-language family size effects might be observed in a design in which the family size of the target language is controlled for. This design is adopted in the present study.

Table 2.1. Item characteristics of the experimental items used in Experiment 1.

	Identical cognates		Non-identical cognates		English controls
	High Family Size	Low Family Size	High Family Size	Low Family Size	
Length	4.6	5.1	4.92	5.08	4.99
Levenshtein Distance	0	0	1.48	1.28	-
Log English Frequency	3.53	3.62	3.51	3.14	3.44
Log English Family Size	2.22	1.77	1.82	1.86	1.82
Log Dutch Frequency	3.45	2.99	3.33	2.90	-
Log Dutch Family Size	**3.49**	**0.92**	**3.65**	**1.19**	-

Procedure. Participants performed an English visual lexical decision task. In this task, participants decide whether or not the visually presented stimulus is an existing English word by pressing a button corresponding to either the answer 'yes' or 'no'. The task was developed and carried out in *Presentation* version 13.0 (Neurobehavioural Systems, www.nbs.com) and was run on a HP Compaq Intel Core 2 computer with 1.58 GHz memory and a refresh rate of 120 Hertz. The participants were seated at a table at a 60 cm distance from the computer screen. The visual stimuli were presented in white capital letters (24 points) in font Arial in the middle of the screen on a dark grey background. Participants were tested individually in a soundproof room.

Participants first read the English instructions, which informed them that they would be presented with word strings and which asked them to push the 'yes' button if the letter string they saw was an existing English word and to push the 'no' button if it was not. They were asked to react as accurately and quickly as possible.

Each trial started with the presentation of a black fixation point '+', which was displayed in the middle of the screen for 700 ms. After 300 ms the target stimulus was presented. It remained on the screen until the participant responded or until the timeout at 1500 ms. The visual target stimulus disappeared when the participant pressed a button, or when the time limit of 1500 ms was reached, and a new trial was started after an empty black screen of 500 ms.

The experiment was divided in two parts of equal length. The first part was preceded by 20 practice trials. After the practice trials, the participant could ask questions before continuing with the experimental trials. The two parts each contained 200 experimental trials. Each part began with three dummy trials to avoid lack of attention during the beginning of the two parts. The end of the first part was indicated by a pause screen. The experiment lasted for approximately 16 minutes.

After completing the lexical decision task, participants performed the X-LEX (Meara & Milton, 2003). This task was used to obtain a general indication of their proficiency in English in terms of vocabulary knowledge. Based on their scores (all scores >3200), all participants could be qualified as highly or intermediately proficient in English. Finally, participants were asked to fill out a language background questionnaire. The total session lasted approximately 30 minutes.

Results

Data cleaning was first carried out based on the error rate for participants and word items. Participants with an error rate of more than 15% on the word items were removed from the data set (participant accuracy mean ranged from 66%-99%), which resulted in the exclusion of the data from five participants.

Three word items (*lung, alley,* and *toad*) that elicited errors in more than 25% of the trials were removed from the data set. After removal of these items, we were left with 4243 data points on the word items. RTs from incorrect responses or null responses were removed from the remaining data set (4.18% of the data points). This resulted in a data set with 4058 data points. Inspection of the distribution of the response latencies revealed non-normality. A comparison of a log transform and an inverse transform (RT=-1000/RT) revealed that the inverse transform was most successful in solving this non-normality.

Response latencies were analysed with a linear mixed effects model with subject and item as crossed random effects (see, e.g., Baayen, 2008; Baayen, Davidson, & Bates, 2008). We considered the following predictors: One lexical variable that is known to affect response latencies is target word frequency. Recent research shows that *SUBTLWF* (logarithmical transformation of English Subtitle frequency per million) is a better predictor of response latencies than the logarithmically transformed English CELEX frequencies per million (see Brysbaert & New, 2009). In the remainder of this experiment, we will use the term *English Frequency* to refer to the logarithmical transformation of *SUBTLWF* as a predictor of target word frequency. Moreover, because bilinguals are expected to be sensitive to non-target language word frequency, we considered the logarithmically transformed CELEX values per million for Dutch lemma frequency (*Dutch Frequency).*

Further, the logarithmically transformed CELEX values for English family size (*English Family Size)* and Dutch family size (*Dutch Family Size*) were included as predictors. The English family size values were collinear with the values of the logarithmically transformed values of *English Frequency* and *Dutch Family Size*. To remove collinearity, we regressed *English Family Size* on *English Frequency* and *Dutch Family Size* and used the resulting residuals as new predictors of English family size uncontaminated by English frequency. Similarly, *Dutch Family Size* was regressed on *Dutch Frequency* and *English Family Size*.

Besides these predictors for target and non-target language family size and frequency, other predictors were considered that could affect lexical decision latencies. In order to test whether cognate items were processed differently from non-cognate items, we included a factor *Cognate* with the levels 'cognate' and 'non-cognate'. Moreover, the predictor *Word type*, containing three levels ('identical cognate', non-identical-cognate', and 'non-cognate control'), was included to account for the degree of form overlap between English and Dutch, with controls having zero overlap, non-identical cognates having intermediate overlap, and identical cognates having maximal overlap. Furthermore, to be able to account for the possibility that family size effects are dependent on a "complete-or-not complete" distinction in formal overlap, the factor *Identical Cognate* (with the levels Identical cognates and Other items (the latter including non-identical cognates and non-cognate controls)) was considered.

Further, *OLD* (the mean distance (in number of steps) from a word to the 20 closest Levenshtein neighbours in the lexicon; OLD-20; see Balota et al., 2007, and Yarkoni, Balota, & Yap, 2008) was included as a predictor to account for effects of similarity between English words. Finally, we included *Trial* (the rank of the item in the experimental list) as predictor to account for learning effects during the experiment.

We performed a stepwise variable selection procedure in which non-significant predictors were removed to obtain the most parsimonious model. Next, potentially harmful outliers (defined as data points with standardized residuals exceeding 2.5 standard deviation units) were removed from the data set. We then fitted a new model with the same significant predictors to this trimmed data set.

The final model incorporated three parameters for the random-effects structure of the data: a standard deviation for the random intercepts for subject (SD = .21) and item (SD = .08), as well as a standard deviation for the by-subject random slope for *Trial* (SD = .05). The standard deviation for residual error was .29. The model contained four numerical predictors (*English Frequency, Dutch Frequency*, *Dutch Family Size*, and *OLD)*, one factorial predictor (*Identical Cognate*) and one two-way interaction (*Dutch Family Size:OLD*). The relevant statistics and corresponding coefficients of the final model are reported in Table 2.2. The significant partial effects of the final model are visualized in Figure 2.3. In both Table 2.2 and Figure 2.3 (panel c), the two levels of *Identical Cognate* are specified as *True* and *False*: the former corresponding to the set of identical cognates, and the latter to the set of non-identical cognates and non-cognate controls.

Table 2.2. Coefficients of the main effects and interaction effects of the final model, together with the estimate and standard error in English lexical decision (Experiment 1).

	Estimate	Std. Error	t-value	p-value
Intercept	-1.454	0.084	-17.279	0.000
English Frequency	-0.123	0.017	-7.409	0.000
Dutch Frequency	0.022	0.010	2.149	0.002
Dutch Family Size	-0.073	0.039	-1.857	0.048
OLD	-0.029	0.018	-1.629	0.087
Identical Cognate *True*	-0.078	0.021	-3.715	0.000
Dutch Family Size:OLD	0.043	0.019	2.202	0.019

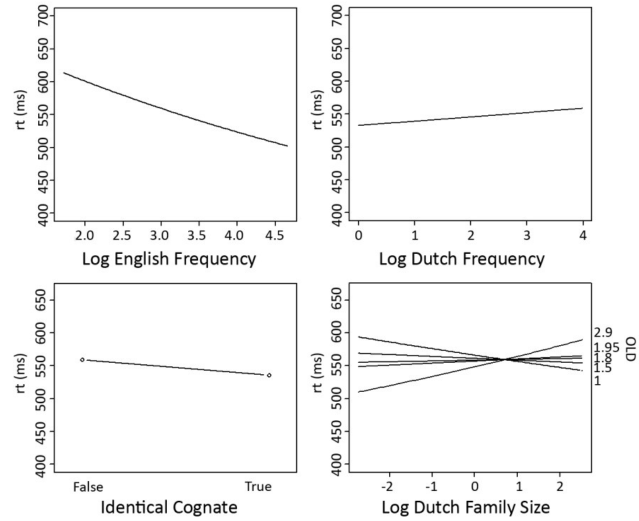

Figure 2.3. Partial effects of the significant predictors on response latencies in English lexical decision (Experiment 1).

The analyses showed a facilitatory effect on response latencies for *English Frequency*, while (non-target language) *Dutch Frequency* had an inhibitory effect. Moreover, the final model revealed a processing advantage for identical cognates in comparison to non-identical cognates and non-cognate controls. While models including either the predictors *Cognate* or *Word Type* also produced significant facilitation effects for cognates in comparison to non-cognate controls, with the latter predictor indicating the largest facilitation effects for identical cognates, Identical *Cognate* turned out to be a better predictor than either *Cognate* or *Word Type*, suggesting that it is maximal formal overlap with Dutch words that is most helpful in order to make an L2 lexical decision.

Words with a high *Dutch Family Size* were processed significantly faster than words with a low *Dutch Family Size*. The significant interaction between *Dutch Family Size* and *OLD* shows that response latencies were slower when a word has a large *Dutch Family Size* and fewer close orthographic neighbours. However, when a word has more close orthographic neighbours, a large *Dutch Family Size* is beneficial to word processing. No significant interaction between *Dutch Family Size* and either *Cognate Type* or *Identical Cognate* was observed.

Discussion

As predicted, in the English lexical decision task of Experiment 1, Dutch-English bilinguals were sensitive to the frequency of the English target words, higher frequency words leading to faster responses than lower frequency words. The effect of *English Family Size* of the target words was not significant. This is not surprising, because this factor was controlled for in order to allow non-target language (Dutch) family size effects to arise.

Importantly, statistical analyses revealed a significant effect of *Identical Cognate*. This predictor turned out to be a better predictor than both *Cognate* and *Word Type*. Response latencies for identical cognates were faster than response latencies for non-identical cognates and controls. This result supports the distinction between identical cognates and non-identical cognates. This dissociation between the two cognate types is in line with the findings of Dijkstra et al. (2010), who observed a gradual decrease in response latencies with an increase in similarity for non-identical cognates and a steep decline in response latencies going from non-identical to identical cognates.

Dutch Family Size interacted significantly with *OLD*, a measure of orthographic neighbourhood density. The interaction revealed a processing disadvantage for words with a high Dutch family size and more distant English orthographic neighbours. Thus, making a lexical decision on an English word is easier when a word has a high Dutch family size and is orthographically closer to English neighbours.

Interestingly, no significant interaction between *Dutch Family Size* and *Identical Cognate* was observed. A lack of a difference in the direction of the effect or the effect size for identical and non-identical cognates would follow if the family size effect is exclusively semantically driven. This is in line with the study by De Jong et al. (2000), who observed no difference in family size effects in lexical decision for both past participles that did and did not have complete formal overlap with their target (e.g., roei – ge**roei**d, 'row' – 'rowed'; vecht – *ge**vocht**en*, 'fight' – 'fought'). Therefore, though a morphological relationship links a target word to its family members, it seems that the effect of the activation of these family members itself is not dependent on the degree of formal overlap they share with the target word. However, while this may be true for a situation in which words are processed (by either monolinguals or bilinguals) in a monolingual task context, formal overlap might affect the family size effect when bilinguals process words in a bilingual task context. This could especially be the case in a task, that requires bilinguals to judge the language membership of presented words, and in which co-activated non-target language words activate conflicting language membership information.

This issue is investigated in Experiment 2, in which we carried out a Dutch-English language decision task with Dutch-English bilinguals. In this task, participants are presented with words existing in one or both target languages, and have to decide whether or not the presented word is English or Dutch. There are no pseudo-words in this task. The purpose of using this task was to investigate whether the cross-language family size effect changes when response competition between cognate representations is experimentally induced.

In language decision, the two readings of a cognate are linked to a different response. For instance, in Dutch-English language decision, the English reading *work* of the cognate *work* is linked to an English response, while the Dutch reading *werk* is linked to a Dutch response. Making a language decision on a cognate should therefore result in response competition between the representations of a cognate and slow down target word processing. The task dependency of processing form similar words was earlier observed for both interlingual homographs (Dijkstra, 2005; Dijkstra, Timmermans, & Schriefers, 2000; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998) and cognates (Font, 2001; Dijkstra et al., 2010) showing a change in the directionality of the effects in (generalized) lexical decision and language decision. Moreover, Dijkstra et al. (2010) observed a discontinuous strong increase in response latencies in language decision going from nearly-identical to identical cognates, mirroring the cognate effects found in lexical decision.

As was hypothesized in the Introduction, the activation of morphological family members of a cognate in language decision may affect target word processing in two ways. First, given that morphological family members of a cognate share part of their semantics with the cognate, activation of both within-language and cross-language family members could lead to facilitation for cognates with a high family size. This will then reduce the cognate inhibition effect.

Alternatively, activated morphological families may inhibit word processing given that they are linked to cognate representations that are in response conflict. Because family members are assumed to strengthen the activation of the target word to which they are linked, cognates with a high family size could then strengthen response competition and increase the cognate inhibition effect. Moreover, if language-specific information is necessary in order to resolve a response conflict, then family size effects might be sensitive to the degree of form overlap between cognate representations. If this is the case, stronger inhibitory effects of the family size of both languages are expected in identical cognates compared to non-identical cognates, because they activate less language-specific information.

Experiment 2 – Dutch-English Language Decision

Method

Participants. Forty-five students of the University of Nijmegen (mean age 20.4 years, SD = 1.92) took part in this experiment. They were all native speakers of Dutch, having English as their second language. They were first exposed to English at school, approximately from the age of 11. They were paid or received course credits for participating in the experiment.

Materials. The stimulus set consisted of 168 items, of which half were Dutch and half were English words. The experimental items were 72 Dutch-English noun cognates and 96 control items. The cognate set consisted of 24 form-identical cognates and 48 cognates that were not identical in form.

The 48 non-identical cognates were either presented in Dutch or English orthography. A participant was presented with only half of the non-identical cognates in their Dutch form and the other half in their English form. Consequently, the combined data from two participants, each presented with half of the non-identical cognates in one of the two languages, formed a complete dataset containing all the 48 items that were non-identical in both their English and Dutch form. Within each version, the two sets of 24 non-identical cognates were matched to each other on English Family Size and Dutch Family Size, English Frequency and Dutch Frequency (see Experiment 1 for a definition), Length (in letters), log English Bigram Frequency and log Dutch Bigram Frequency. Furthermore, the two sets of 24 language specific non-identical cognates of version 1 were matched on Length and their language specific bigram frequency with the non-identical cognates from the same language in version 2. Finally, the identical cognates were matched on Length, English Frequency, and English Family Size to the set of 48 non-identical cognate items, but could not be matched on Dutch Family Size and Dutch Frequency. The identical cognates have a lower mean Dutch Frequency and are less productive in terms of morphological family members than Dutch non-identical cognates.

The English and Dutch non-identical cognates in each version and the identical cognates were each matched on English Family Size and Dutch Family Size, English Frequency and Dutch Frequency, Length, log English Bigram Frequency and log Dutch Bigram Frequency to 24 English and 24 Dutch non-cognate controls items, respectively. These control items only had a noun-reading. Table 2.3 presents the characteristics of the cognate and non-cognate stimuli.

The experiment consisted of two item blocks. The presentation order of the items within each item block was randomized individually with the restriction that no more than three cognates or controls followed each other directly.

Table 2.3. Item characteristics of the experimental items used in Experiment 2.

Stimulus	Length	Log English frequency	Log English family size	Log Dutch frequency	Log Dutch family size
Identical cognates	5.1	3.21	1.93	2.98	1.96
Dutch controls	4.9	-	-	3.03	2.43
English controls	4.7	3.40	1.74	-	-
English non-identical cognates	4.9	3.56	2.03	3.66	3.07
Dutch non-identical cognates	5.2	3.56	2.03	3.66	3.07
English controls	5.0	3.65	1.78	-	-
Dutch controls	5.1	-	-	3.51	2.97

Procedure. Participants performed an English language decision task. In this task, participants have to decide whether the visually presented stimulus is an existing English or Dutch word by pressing a button corresponding to either the answer 'yes' or 'no'.

The task was developed and carried out in *Presentation* version 13 (Neurobehavioural Systems, www.nbs.com) on a HP Compaq Intel Core 2 computer with 1.58 GHz memory and a refresh rate of 120 Hertz. Participants were tested individually in a sound proof room. They were seated at a table at a 60 cm distance from the computer screen. The visual stimuli were presented in white capital letters (24 points) in font Arial in the middle of the screen on a dark grey background.

Participants first read the English instructions. These informed them that they would be presented with word strings, and asked them to push the 'left' button if the letter string they saw was an existing English word and the 'right' button if the letter string was a Dutch word. They were asked to react as accurately and quickly as possible.

Each trial started with the presentation of a black fixation point '+', which was displayed in the middle of the screen for 700 ms. After 300 ms the target stimulus was presented. It remained on the screen until the participant responded or until a maximum of 1500 ms passed by. The experiment was divided in two parts of equal length. The first part was preceded by 20 practice trials. After the practice trials, the participant could ask questions before continuing with the test trials. The two parts each contained 84 experimental trials, and each started with three dummy trials.

After completing the language decision task, participants performed the X-LEX (Meara & Milton, 2003). This task was used to obtain a general indication of their proficiency in English in terms of vocabulary knowledge. All participants obtained a score of 3200 or higher (group mean 4190), which qualified them as intermediately or highly proficient in English. Finally, participants were asked to fill out a language background questionnaire. The experimental session lasted approximately 18 minutes.

Results

The data were first screened for high error rates of participants and items. The participant accuracy mean ranged between 90.3% and 100%. Due to the small proportion of errors, data of no participants had to be excluded. However, four participants were excluded based on their slow mean RTs (more than 2 SD from group RT mean) on the task relative to the mean RTs of the other participants.

Items that had more than 20% of errors were removed from the data set. These included two cognate items (*priest* and *thee*) and one control item (*poem*). Note that responses to identical cognates, which have an identical form in English and Dutch, could never result in errors, because both an English or a Dutch response is appropriate. Incorrect items and null responses were removed from the remaining data set. This resulted in a dataset of 6473 data points. Inspection of the distribution of the response latencies revealed non-normality, with outliers in both tails. An inverse transform (RT=-1000/RT) was most successful in attenuating this non-normality.

Like in Experiment 1, the data were analysed with a linear mixed effects model. We considered the same predictors as in Experiment 1. *Response Language* and *Previous Language* (in both cases, Dutch or English) were added as variables. Moreover, we added the predictor *Total Family Size* (the sum of the Dutch and English family sizes) to account for possible increased response conflict due to large amount of global activation in the lexicon produced by the family members. The same procedure as in Experiment 1 was applied to obtain the final model.

Both *Dutch Family* Size and *English Family Size* were considered in one model. Both predictors had an inhibitory effect on response latencies when both were included in the same model or when included a separate model with only one family size measure. Moreover, *Total Family Size* had an inhibitory effect. An ANOVA revealed that the model with *Total Family Size* was slightly better in explaining the variance (as reflected by lower AIC values). Therefore, *Total Family Size* was included in the model in favour of *English Family Size* and *Dutch Family Size*. Further, the predictor *Dutch Frequency* produced an insignificant coefficient and was removed from the model. Finally, both *Word Type*, *Identical Cognate* and *Cognate* were considered. The model with *Identical Cognate* resulted in the best fit of the data.

The final model incorporated two coefficients for the random-effects structure of the data: a standard deviation for the random intercept for item (SD = .07) and subject (SD = .14), as well as a standard deviation for the by-subject random slope for *Trial* (SD = .06). The standard deviation for residual error was .35. The model contained three numerical predictors (*English Frequency*, *Total Family Size* and *OLD*) and three factorial predictors (*Identical Cognate, Response Language*, and *Previous Language*), and four interactions (*Identical Cognate: Total Family Size*, *Identical Cognate: English Frequency*, *Total Family Size: Response Language*, and *Identical Cognate: Previous Language*). The relevant statistics and corresponding coefficients of the final model are reported in Table 2.4. The significant effects of the final model are visualized in Figure 2.4. In both Table 2.4 and Figure 2.4 (panels e and g), *Identical Cognate* has two levels: *True* and *False*: the former corresponding to the set of identical cognates, and the latter to the set of non-identical cognates and non-cognate controls.

Table 2.4. Coefficients of the main effects and interaction effects of the final model, together with the estimate and standard error in English-Dutch language decision (Experiment 2).

	Estimate	Std. Error	t-value	p-value
Intercept	-1.932	0.122	-15.808	0.000
English Frequency	-0.085	0.032	-2.659	0.008
Total Family Size	0.151	0.032	4.697	0.000
Identical Cognate*False*	0.109	0.130	0.839	0.369
Response Language*Dutch*	0.411	0.085	4.855	0.000
OLD	0.069	0.028	2.511	0.014
Previous Language*Dutch*	-0.031	0.024	-1.311	0.181
Identical Cognate*False*:Total Family Size	-0.165	0.038	-4.327	0.000
Identical Cognate*False*:English Frequency	0.068	0.043	1.592	0.094
Total Family Size:Response Language*Dutch*	-0.120	0.032	-3.800	0.000
Identical Cognate:Previous Language*Dutch*	0.088	0.034	2.615	0.001

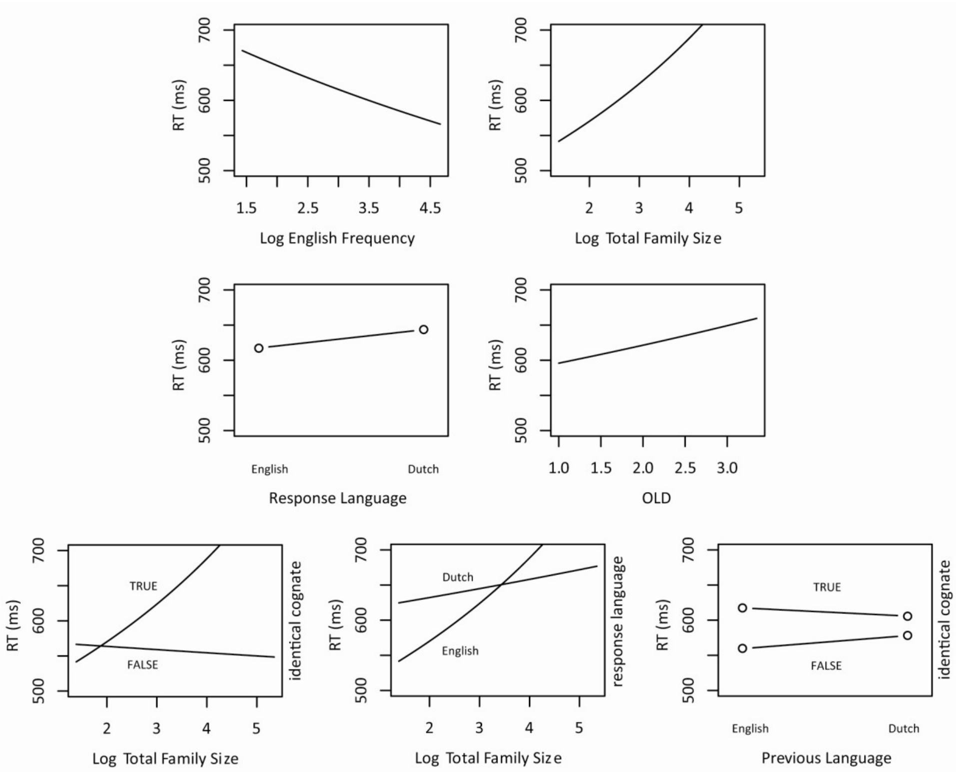

Figure 2.4. Partial effects of the significant predictors on response latencies in English-Dutch language decision (Experiment 2).

A significant facilitatory main effect of *English Frequency* was observed. Further, *Total Family Size* had an inhibitory effect on word processing. Further, *OLD* had an overall inhibitory effect, showing that the more distant in terms of orthographic similarity orthographic neighbours are, the harder it is to make a language decision.

The main effect of *Response Language* revealed slower response latencies when Dutch was chosen as response language (including responses to Dutch identical cognates and Dutch control words). Moreover, we observed an interaction between *Total Family Size* and *Response Language* demonstrating faster RTs for words with a high combined family size when the response language was Dutch.

There was no significant main effect of *Identical Cognate* when multiple interactions were included in the model. *Identical Cognate* interacted significantly with *Total Family Size* and revealed more inhibition with an increasing number of Dutch and English family members for identical cognates than for the other stimuli. Finally, *Identical Cognate* interacted with *Previous Language* showing faster response latencies for non-identical cognates and controls compared to identical cognates when the response language was English.

The possibility of a response strategy was considered in a model predicting the response language (English or Dutch) on identical cognates only. The same predictors that were considered in the analysis of the complete data set were included. Again, all non-significant predictors were removed.

The final model incorporated two coefficients for the random-effects structure of the data: a standard deviation for the random intercept for item (SD = .09) and subject (SD = .16), as well as a standard deviation for the by-subject random slope for *Trial* (SD = .06). The standard deviation for residual error was .42. The model contained two numerical predictors (*Dutch Frequency* and *Dutch Family Size*) and one interaction (*Dutch Family Size: Dutch Frequency*). The relevant statistics and corresponding coefficients of the final model are reported in Table 2.5. The significant interaction of the final model is visualized in Figure 2.5.

Table 2.5. Coefficients of the model predicting the choice for response language in identical cognates in Dutch-English language decision (Experiment 2).

	Estimate	Std. Error	t-value	p-value
Intercept	0.956	0.103	9.270	0.000
Dutch Frequency	0.249	0.043	4.840	0.000
Dutch Family Size	0.249	0.061	4.094	0.000
Dutch Family Size: Dutch Frequency	-0.068	0.018	-3.709	0.000

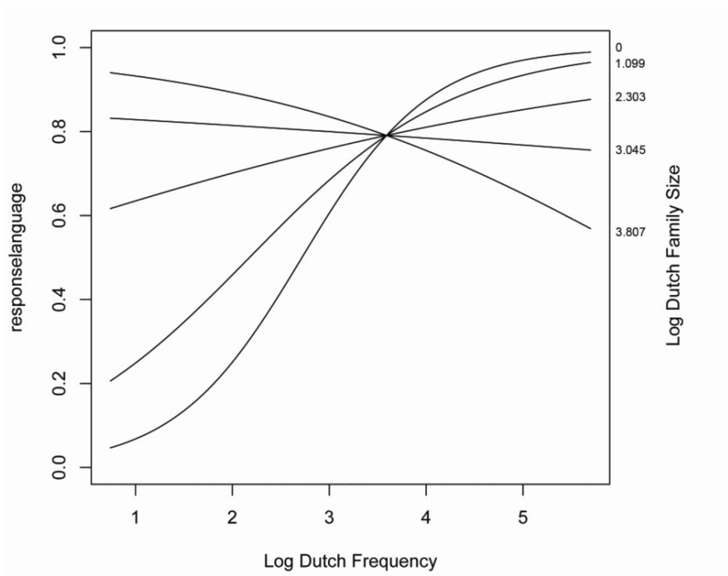

Figure 2.5. Significant interaction between Dutch Family Size and Dutch Frequency as a predictor of the choice for response language (0 = English, 1 = Dutch) on identical cognates.

Dutch Family Size interacted significantly with *Dutch Frequency*, revealing that a high *Dutch Frequency* led to more Dutch responses when the *Dutch Family Size* was low (and vice versa). When both the *Dutch Family Size* and *Dutch Frequency* were low, more English responses were given.

Discussion

The aim of Experiment 2 was to tap into the task dependency of the family size effect for cognates. In this experiment, we applied a language decision task in which participants had to decide if a visually presented word was either English or Dutch. Given that in this task participants clearly have to distinguish the two readings of a word, response conflicts are expected to arise upon seeing a cognate and these conflicts should result in a cognate inhibition effect. We hypothesized that activation of both target and non-target language family members should strengthen the activation of both representations and add to the response competition in cognates.

There was a clear dissociation between identical cognates and non-identical cognates in terms of response latencies. Identical cognates were processed more slowly than non-identical cognates and controls, though the main effect of *Identical Cognate* disappeared when multiple interactions with *Identical Cognate* were considered in the model. The inhibitory effect can be explained as follows. For identical cognates, which have a similar form in both Dutch and English, there is no language specific orthographic cue that will resolve the language decision, and both language responses will be appropriate. This will induce response competition for identical cognates. The response competition is attenuated in non-identical cognates, because these items contain orthographic cues that resolve the language ambiguity, resulting in no significant inhibition for these types of cognates compared to language specific controls.

The family size effects of both languages were found to be both inhibitory (in the final model, both family sizes are combined into one count *Total Family Size*, which resulted in an even larger coefficient for family size). This argues against the hypothesis that cross-language family size effects are entirely driven by the semantic overlap between family members and target word. This would logically always lead to facilitatory effects in cognates. Rather, the inhibitory family size effects observed for both languages show that family size effects are sensitive to task context. Activated family members were found to increase the induced response competition between cognate representations (i.e., the more a word points to both languages, the more difficult it is to make a choice between a Dutch and an English response).

Interestingly, the observed dissociation between identical cognates and non-identical cognates is also reflected in the strength of the combined family size effect. *Total Family Size* interacted with *Identical Cognate*, showing large inhibition for identical cognates but not for non-identical cognates and controls. This shows that activation of Dutch and English morphological family members added to the competition in identical cognates, increasing the inhibitory effect for these words.

Surprisingly, although participants were more fluent in Dutch than in English, they were slower when they chose Dutch as a response language (for both items that either require a Dutch response or items that may receive a Dutch response). Moreover, participants were slower on non-identical cognates and controls compared to identical cognates when they were preceded by a Dutch item. This could point to a response strategy in which English is set as a default response (cf. the language decision experiment in Dijkstra et al., 2010). Finally, *Total Family Size* moderated the Dutch responses: A Dutch response for words with a high combined family size resulted in faster response latencies.

The possibility of a response strategy was considered in a model predicting the choice for a given response in English or Dutch on identical cognates only. The choice pattern for identical cognates could be predicted from *Dutch Family Size* and *Dutch Frequency*. Identical cognates that were highly frequent in Dutch elicited more Dutch responses than less frequent identical cognates. Similarly, identical cognates that had a high productivity in terms of Dutch family members more often elicited a Dutch response than identical cognates with a smaller number of Dutch family members. However, when both the Dutch frequency and family size were either very low or very high, participants more often pressed the English response button. Thus, relating this to the observed pattern in the response latencies, it seems that our bilingual participants were adopting a response strategy in which English was the default response language, which was hindered by the strong Dutch activation.

In sum, the results of the language decision experiment reveal that the direction of the family size effect is not exclusively dependent on semantic convergence between target and family members, but is also sensitive to task-induced processes such as response competition between cognate representations.

The finding that the size of the family size effect was sensitive to the degree of form overlap in cognates in language decision raises an interesting point. The observed interaction in language decision suggests that at least part of the cross-language family size effect is orthographic in nature. Generally, form effects are found to occur at early stages of word processing. The paradigm of progressive demasking is considered to be able to pick up early form effects (Grainger & Jacobs, 1996). Schreuder and Baayen (1997) investigated possible early effects of family size in a Dutch progressive demasking task with Dutch monolinguals. No effects of family size were observed, which led them to conclude that family size does not influence early stages of word processing.

However, Schreuder and Baayen tested the effects of family size in a study with an orthogonal design. The associated analysis of variance may have had insufficient power to observe family size effects. With the statistical technique of regression, such as is applied in linear mixed effect models, family size effects are easier to pick up. Therefore, to test whether within-language and cross-language family size effects are sensitive to formal aspects of word processing, we re-analysed available English progressive demasking data by Dijkstra et al. (2010) with the regression technique.

Dijkstra et al. investigated the effects of orthographic, phonological, and semantic overlap between cognate readings in a series of experiments, among which progressive demasking. Importantly, similar to our study, the participants in their study were Dutch-English bilinguals and their stimuli contained Dutch-English identical and non-identical cognates, as well as English controls. This re-analysis allows us not only to see whether and under which circumstances within-language and cross-language family size effects are present in progressive demasking, but also to make a direct comparison with the experiments reported in the present paper. If family size effects are observed in our re-analysis, this has consequences for the common interpretation of the family size effect as an exclusively late semantic, post-lexical effect (cf. Schreuder & Baayen, 1997).

Re-analysis of English progressive demasking data by Dijkstra et al. (2010)

Data cleaning was conducted following Dijkstra et al. (2010, pp. 296). Response latencies were analysed with a linear mixed effects model with subject and item as crossed random effects. We included the following predictors that were also considered by Dijkstra et al.: *English Frequency, Dutch Frequency*, *Orthographic Similarity*, *Phonological Similarity*, and *Semantic Similarity*[3]. Further, we included the residualized values of *English Family Size* and *Dutch Family Size* (regressed on family size of the other language and frequency of the same language), and *Trial* (see Experiment 1). As was done by Dijkstra et al., response latencies were logarithmically transformed to solve non-normality of the distribution. We adopted the same procedure of regression analysis as was done in Experiments 1 and 2. The set of cognates and English controls were analysed separately

[3] The similarity scores used in Dijkstra et al. were based on a 7 point rating scale, with a score closer to 7 indicating larger similarity between word pairs.

(see the Appendix for a list of the stimuli). In what follows, we present the final models for both types of stimuli.

We first analysed the set of English control words. The final model incorporated three parameters for the random-effects structure of the data: a standard deviation for the random intercepts for subject (SD = .16) and item (SD = .07), as well as a standard deviation for the by-subject random slope for *Trial* (SD = .03). The standard deviation for residual error was .16. The final model contained three numerical predictors (*English Frequency, Semantic Similarity*, and *Trial)*, and no interactions. The coefficient of the predictor *English Family Size* was non-significant and was removed from the model. The relevant statistics and corresponding coefficients of the final model are reported in Table 2.6. The significant effects of the final model are visualized in Figure 2.6. As can be seen in panel a of Figure 2.6., a higher *English Frequency* led to faster responses. Panel b shows that increasing cross-language *Semantic Similarity* significantly speeded up responses. Finally, the significant effect of *Trial*, displayed in panel c, shows that subjects responded more quickly as they progressed through the experiment.

Table 2.6. Coefficients of the main effects and interaction effects of the final model on the control stimuli, together with the estimate and standard error in English progressive demasking.

	Estimate	Std. Error	t-value	p-value
Intercept	8.031	0.180	44.69	0.000
English Frequency	-0.026	0.005	-5.63	0.000
Semantic Similarity	-0.077	0.026	-2.98	0.003
Trial	-0.041	0.006	-6.76	0.000

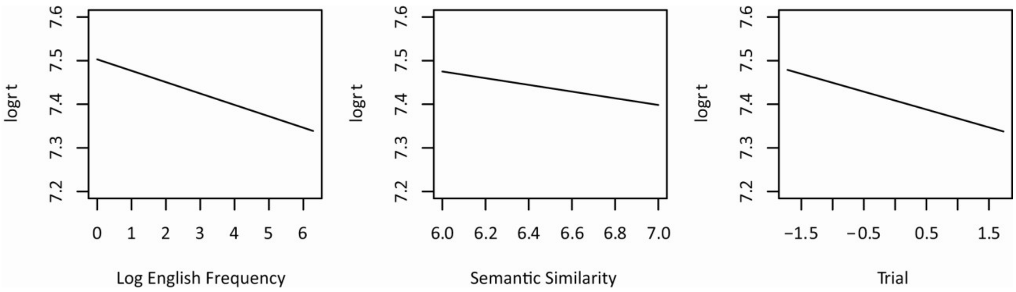

Figure 2.6. Partial effects of the significant predictors of response latencies to English controls in progressive demasking.

Importantly, no effects of *English Family Size* were observed. This supports the findings of Schreuder and Baayen (1997), who found no effects of Dutch family size for Dutch words with Dutch monolinguals in progressive demasking.

The final model for the identical and non-identical cognates incorporated three parameters for the random-effects structure of the data: a standard deviation for the random intercepts for subject (SD = .17) and item (SD = .06), as well as a standard deviation for the by-subject random slope for *Trial* (SD = .02). The standard deviation for residual error was .16. The model contained four numerical predictors (*Dutch Frequency*, *Semantic Similarity*, *Dutch Family Size*, and *Trial)*, three two-way interactions (*Dutch Frequency:Semantic Similarity, Dutch Frequency:Dutch Family Size,* and *Semantic Similarity:Dutch Family Size*), and one three-way interaction (*Dutch Frequency:Semantic Similarity:Dutch Family Size)*. The coefficients for *English Frequency*, *English Family Size*, *Orthographic Similarity*, and *Phonological Similarity* were not significant and removed from the model. The relevant statistics and corresponding coefficients of the final model are reported in Table 2.7. Figure 2.7 displays the significant main effect of *Trial* and significant two-way interactions of the final model.

Table 2.7. Coefficients of the main effects and interaction effects of the final model on the cognate stimuli, together with the estimate and standard error in English progressive demasking.

	Estimate	Std. Error	t-value	p-value
Intercept	9.914	0.560	17.847	0.000
Dutch Frequency	-0.650	0.166	-3.881	0.000
Semantic Similarity	-0.355	0.080	-4.428	0.000
Dutch Family Size	2.416	0.706	3.420	0.000
Trial	-0.045	0.005	-8.714	0.000
Dutch Frequency: Semantic Similarity	0.091	0.024	3.810	0.000
Dutch Frequency: Dutch Family Size	-0.720	0.207	-3.473	0.000
Semantic Similarity: Dutch Family Size	-0.347	0.102	-3.408	0.000
Dutch Frequency: Semantic Similarity: Dutch Family Size	0.103	0.030	3.485	0.000

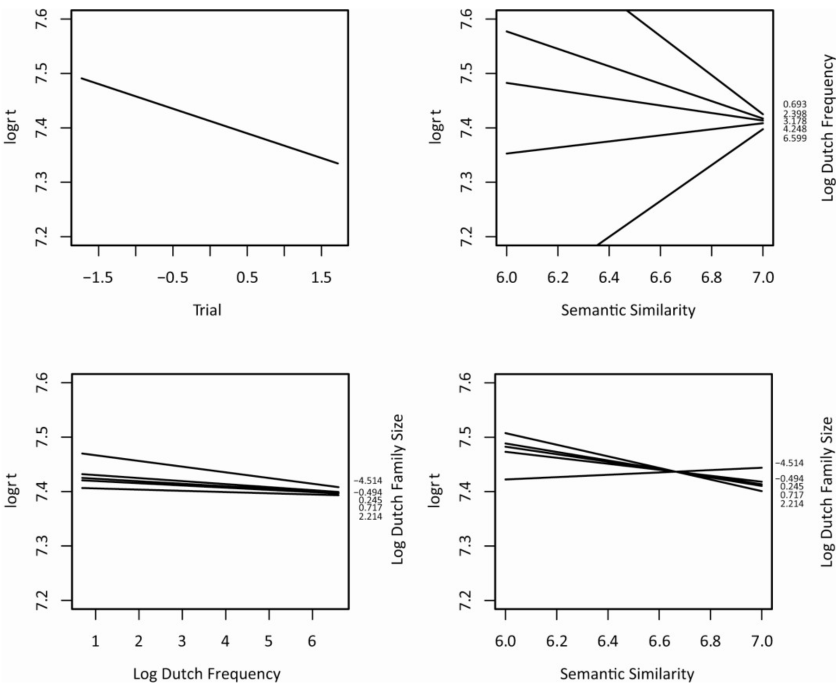

Figure 2.7. The main effect of Trial and the significant two-way interactions of the final model predicting response latencies to Dutch-English cognates in progressive demasking.

Interestingly, *English Frequency* did not affect response latencies to cognates, while *Dutch Frequency* did have a facilitatory effect. Given that Dutch is the dominant language of the participants, the presented orthographic code of a cognate may have a stronger representation in this language than in their second language English. As a consequence, the contribution of English frequency is reduced. The activation of the dominant language was beneficial for the recognition of demasked cognates. Besides a facilitatory effect of *Dutch Frequency*, we observed faster response latencies when the *Semantic Similarity* between cognate representations was higher. Finally, the interaction between *Dutch Frequency* and *Semantic Similarity* (see panel b of Figure 2.7) shows that the facilitatory effect of *Dutch Frequency* is large when the semantic overlap is small.

Surprisingly, in the analysis of the cognate set, *Dutch Family Size* was found to have a significant inhibitory main effect. *Dutch Family Size* also interacted significantly with

Dutch Frequency (see panel c), showing that response latencies are faster when both the *Dutch Frequency* and *Dutch Family Size* are high. Finally, response latencies were faster when the *Semantic Similarity* and *Dutch Family Size* are high, but not when the *Semantic Similarity* is low and the *Dutch Family Size* is high (see panel d).

In sum, we argue that Dutch family members are activated because the cognate representation to which they are linked has a stronger representation in the dominant language than in the second language. The weaker representation for English words in the lexicon of the bilinguals may be the reason for the absence of a family size effect in the English control words.

General discussion

Until now, few studies have explored family size effects in bilingual word processing. The present study was the first to investigate cross-language family size effects on the processing of identical and non-identical cognates. By looking at family size in cognates, we aimed at answering the following questions: First, can we observe cross-language family size effects for cognates? And second: Is the cross-language family size effect driven exclusively by semantic convergence between target and family member or is it also sensitive to other, more task-dependent processes, such as response competition between cognate representations? In the latter case, language-specific orthographic cues of stimuli, such as the degree of orthographic overlap between cognate representations might affect response latencies to cognates.

The first question was addressed in an English lexical decision task (Experiment 1) with Dutch-English bilinguals. Importantly, to be able to observe cross-language family size effects for cognates, we controlled for within-language (English) family size and varied the cross-language (Dutch) family size of these cognates. A cognate facilitation effect was observed for both identical and non-identical cognates relative to English control words, with the largest effects for identical cognates. Dutch family size was observed to have a facilitatory effect on cognate processing. Importantly, this experiment showed that cross-language family size effects can be observed in cognates. Further, no interaction between Dutch family size and cognate type was found, indicating that the strength and the direction of the cross-language family size effect did not significantly change as a function of the degree of form overlap in the cognate items.

The second question was investigated in a Dutch-English language decision (Experiment 2) with the same type of bilinguals as was used in Experiment 1. In this task, response competition between Dutch and English cognate representations was experimentally induced, which resulted in an inhibitory cognate effect for identical cognates but not for non-identical cognates, relative to language-specific control words. English family size had an inhibitory effect on response latencies to both cognates and purely English words. With respect to Dutch family size effects, similar inhibitory effects were observed for cognates and purely Dutch items. Moreover, the inhibitory effects of Dutch and English family size in cognates were stronger when they were combined into one family size count (*Total Family Size*). These results demonstrate that the direction of the within-language and cross-language family size effects is not just driven by semantic overlap in the morphological family, but is sensitive to other processes that play a role in the task at hand, such as response competition.

Interestingly, the combined family size effect was also found to depend on cognate type: A large combined morphological family induced more inhibition in identical cognates than in non-identical cognates. Thus, in language decision, the degree of orthographic overlap between activated cognate representations affected the amount of response competition between activated cognate representations. Apparently, the family size effect has a form component that turns out to affect processing when cognate representations have to be distinguished based on their form. Note, however, that there can still be resonance of activation between semantics and orthography, and that it is possible that the family size effect is still semantically driven. In other words, though the family size effect is dependent on formal characteristics of the stimuli, the activation of family members does not necessarily proceed in a bottom-up manner via orthography, but could also be the result of resonance between the semantic representation of the target and associated words.

The observed interaction between family size and cognate type led us to question whether cross-language family size effects could occur in other tasks in which orthographic information is relevant for appropriately completing the task, but in which there is no induced response competition between representations belonging to different languages. We hypothesized that if the cross-language family size effect is indeed partly a form effect, significant effects could also arise in a task that tap on early stages of word processing, such as progressive demasking.

Available English progressive demasking data of Dutch-English bilinguals of Dijkstra et al. (2010) were re-analysed for both within-language and cross-language family size effects. Similar to our study, the materials included both identical and non-identical cognates and purely English controls. The analyses showed no effects of English family size on both the English controls and cognates. However, Dutch family size was found to have a significant effect on the processing of cognates. In the cognate set, Dutch family size interacted with Dutch frequency and semantic similarity, showing facilitation for cognates with a high Dutch family size when either the Dutch frequency or the semantic similarity was high. This suggests that for these bilinguals the Dutch reading of a cognate has a stronger representation than the English reading. As a consequence, only Dutch effects will show up.

Remarkably, in this paradigm no main effect of orthographic similarity and no interaction between family size and orthographic similarity were observed. This leads us to conclude that family size effects in cognates are only dependent on the degree of form overlap between cognate representations when these representations need to be distinguished based on their language membership in order to answer appropriately. This was not necessary in language-specific lexical decision and language-specific progressive demasking, but was extremely relevant in language decision.

How do these results with respect to family size effects in cognates relate to the findings of earlier, predominantly monolingual, studies that found evidence for the assumption that the family size effect is a purely semantic effect? Our findings suggest that the family size effect is not exclusively a semantic effect, and is sensitive to other aspects of word processing, such as response competition and formal characteristics of the stimuli. It is important to note that most of the above-mentioned earlier studies used the lexical decision task as experimental paradigm. In this task, the amount of formal overlap between stimulus word and family members might be less relevant during lexical processing, and the positive decision to a word is speeded because of resonance between semantics and orthography (e.g., De Jong, 2000). In addition, applying an orthogonal design (cf. Schreuder & Baayen, 1997) instead of a regression design might cause that smaller effects of formal nature are not picked up.

When two languages do not necessarily have to be contrasted, where orthographic language-specific information is less relevant for distinguishing activated cognate representations, semantic convergence seems to determine the direction of the family size effect. In the bilingual domain, support for this claim comes from facilitatory family size effects observed for target words in either the native or second language in language-specific lexical decision or generalized lexical decision with bilinguals (e.g., Dijkstra et al., 2005; Mulder, Dijkstra, Schreuder, & Baayen, under revision).

In tasks where two languages must be contrasted and where orthographic language-specific information is relevant for distinguishing activated cognate representations, semantic convergence between target and family members does not lead to facilitatory effects of family size. Activated family members strengthen the activation of the cognate representation to which they are linked. In language decision, these cognate representations are in response conflict, and the activation of family members strengthen this competition. As a result, family size effects are inhibitory in nature. Especially in identical cognates, a large family size in one of the two languages is not beneficial for word processing: The activation of a large number of family members that contain language-ambiguous orthographic information (e.g., the activation of *water* in the English family member ***water**fall* and Dutch family member *drink**water*** for the target cognate *water*) increases the response conflict between competing cognate representations. This results in more inhibition for identical cognates with a large family size in one the two languages relative to non-identical cognates (that contain more language-specific information to resolve the response conflict) with a large family size.

The finding that, in English progressive demasking, Dutch family size had a significant effect on response latencies indicates that the family size effect is partially a form effect. It can only come about by an activation of Dutch family members on the basis of the English input word, followed by selection problems, due to orthographic overlap. Interestingly, the finding that only the Dutch and not the English family size affected response latencies in English progressive demasking shows that the Dutch-English bilinguals were less familiar with the English word forms. However, we cannot fully exclude that semantics were also activated during word processing in progressive demasking (see also Hauk, Davis, Ford, Pülvermüller, & Marslen-Wilson, 2006, who observed early semantic effects in an ERP study).

Our findings have consequences not only for models explaining morphological effects but also for models of bilingual word processing. According to the Morphological Family Resonance Model (MFRM, De Jong et al., 2003), family members are activated through the activated semantic representation of the target to which they are linked, and family size effects occur because of the resonance of activation between the activated family members and the semantic representation. One may argue that this resonance mechanism via an initial semantic route is not available during early stages of word processing, and may not account for the observed family size effects in progressive demasking.

However, given the long time period during which a word gradually emerges from its mask in progressive demasking, it is, in fact, quite likely that semantic representations might have become activated. This is in line with findings from cross-modal priming experiments of Marslen-Wilson, Brown, and Zwitserlood (1989) that show a multiple activation of semantic codes during early stages of word processes. In their experiments, subjects were presented with spoken words such as *kapitein* ('captain') which shared a large initial overlap with *kapitaal* ('capital'). At the same time, visual probes were displayed to which participants had to make a lexical decision. The probes were associatively related to either *kapitein* (e.g., boot, 'ship') or *kapitaal* (e.g., *geld*, 'money'), and the probes were presented either at a point at which the input could not yet distinguish between *kapitein* and *kapitaal* (e.g., during the [t] of *kapitein)* or at the end of the word. When they were presented in the middle of the spoken word, both associative probes were facilitated, relative to an associatively unrelated condition. However, when the probes were presented at the end of the word, it was only the probe word that was related to the presented word that was facilitated (e.g., *boot* in the case of *kapitein*). Thus, partial information from the word form can activate its semantic representation.

As De Jong et al. (2000) postulate, out of the degraded input, and over time, multiple lexical candidates could become activated and activate their semantic representations. As a consequence, the morphological family members of these candidates could become activated. However, they argue that family size effects were masked and could not be picked up. In a perceptual identification task, which De Jong argues to be a more sensitive task to pick up early family size effects, a family size effect arises (see De Jong, 2002). Rather than arguing that the family size effect has a formal component, the observed effect is explained in terms of semantic processing that follows the presentation of the stimulus.

However, we argue that family members are not necessarily activated via a semantic route. It is quite likely that family members can (also) be activated via a formal route, e.g., by *water* activating *water fall* etcetera. Inhibitory family size effects may then arise in tasks that exclusively tap into formal aspects of processing due to lexical competition via lateral inhibition. In these early stages of word processing, resonance between activated family members and the semantic representation of the target word to which they are linked would still be under development.

The data presented in this paper support an account proposing a dual route of activation for family members depending on the task at hand. In tasks that tap into early stages of word processing, family members are activated via the orthographic representation of the target. In that case, resonance of activation between the semantic representation of the target and the target's morphological family members is not fully at work. At later stages in word processing, family members can also be activated via the semantic route that has been put forward by De Jong et al (2003). The explanation of family size effects presented above thus proposes an extension of the MFRM model of De Jong et al. (2003) in terms of adding an orthographic route to activate family members. Importantly, resonance of activation between the semantic level and lemma level can still occur via this route, and in many task situations, the semantic route may be the dominant route.

Our data are also in line with language non-selective access accounts of bilingual word processing, such as has been put forward by bilingual interactive activation models, for example the BIA+ model (Dijkstra & Van Heuven, 2002). We have shown that cross-language family members can become co-activated in a language-specific context. Though it allows co-activation of orthographically or phonologically related lexical items, the BIA+ model has no specific account for resonance between family members and the target to which they are linked. Integrating the MFRM model of De Jong (2003) within the BIA+ model could result in a model that allows activation of family members via an orthographic route and a semantic route, and allows resonance between semantic and orthographic representations. This is displayed in Figure 2.8[4].

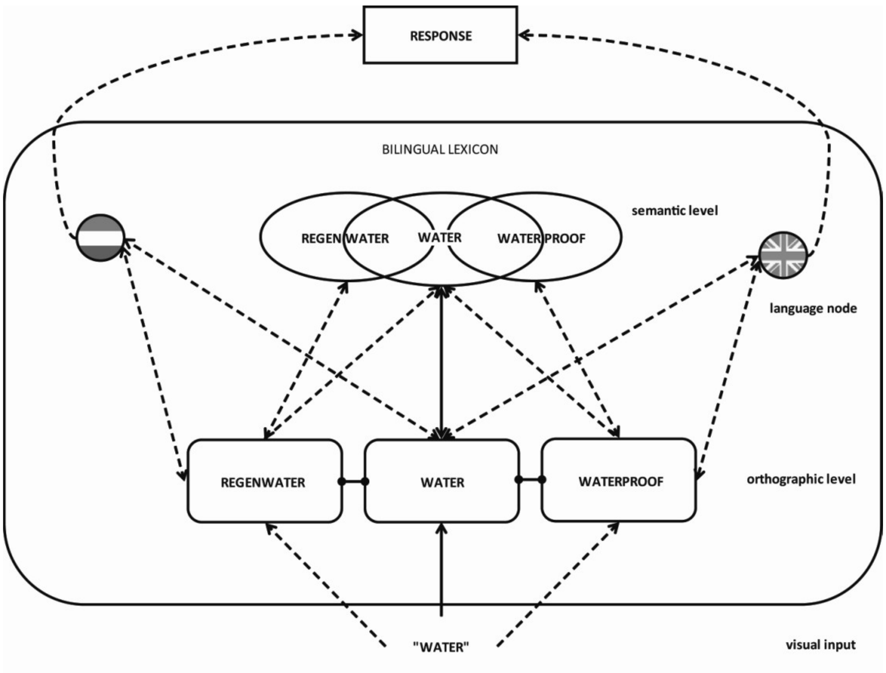

Figure 2.8. Schematic representation of activation of family members within a bilingual interactive activation model based on BIA+. The activation of the morphological family of a target word can affect the processing of a target word *positively* when (a) family members are activated via a semantic route, or (b) family members are activated via an orthographic route but there is resonance of activation between semantics and orthography, and *negatively* when (a) activated family members map onto a different response or (b) family members are activated via an orthographic route and resonance of activation between semantics and orthography is still under development.

[4] Note that, in contrast to De Jong et al. (2003), and Schreuder & Baayen (1995), the BIA+ model does not specify a level for lemmas and morphemes, but contains an orthographic level.

However, a further extension is required to account for all our bilingual data. In a task situation in which two languages need to be distinguished, such as language decision, activation of language membership information determines the role of the activated family size. Similar to what happens in a language-specific context such as in English lexical decision, the presented target word will activate its morphological family members via the semantic route. Moreover, it will also activate the language membership information of the activated family members. In language decision, a response conflict arises when activated representations from two languages overlap in form (e.g., cognates or interlingual homographs) and are linked to a different response. The response competition is more directly dependent on language membership information than on semantic convergence between target and family members. Inhibitory effects of family size of both languages can be explained by summed language membership activation that increases the response conflict. The effect of summed language membership activation on response competition is less strong when the orthographic overlap between the target word and family members is reduced (i.e., there is less activation sent to the inappropriate language membership node). Thus, in an interactive activation account, family size effects can be explained via three mechanisms: facilitation through semantic activation, and inhibition though lexical competition or summed language membership activation.

In sum, we observed effects of cross-language family size for cognates in three paradigms: English L2 lexical decision, Dutch-English language decision, and English L2 progressive demasking. The results of our study indicate that semantic convergence between family members and target word is a major driving mechanism when orthographic information is not relevant for making the correct response. However, in a situation in which language-specific orthographic information is more relevant, such as language decision and progressive demasking, activation of cross-language family members can be inhibitory. Finally, the effect is sensitive to the degree of form overlap in cognates when the cognate representations need to be distinguished. All in all, this study has shown that the effect of morphological family size is sensitive to different types of processing in different task settings.

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Appendix

<u>Items used in Experiment 1</u>

Identical cognates with high family size: toilet, radio, norm, lamp, winter, nest, tent, team, club, machine, piano, wolf, haven, god, park, museum, motor, tram, code, storm

Identical cognates with low family size: tempo, echo, goal, opera, villa, chaos, shirt, factor, cake, talent, mild, effect, fruit, fort, status, horizon, camera, basis, crisis, drama

Non-identical cognates with high family size: card, ball, gold, crown, grass, soup, powder, theatre, apple, river, lamb, lung, bible, rose, wheel, shoe, silver, canal, terrain, photo, straw, thief, bath, salary, tower

Non-identical cognates with low family size: pear, idiot, melon, pill, swan, brain, minute, panic, news, fist, idol, tomato, symbol, magnet, paper, ideal, sock, admiral, ocean, pilot, myth, pleasure, fork, cord, fountain

English controls: bullet, fever, lake, wood, bird, cloud, faith, silk, wing, mirror, cave, donkey, duke, engine, pigeon, throat, evil, witch, evil, frog, noise, horse, widow, guard, kidney, fame, harm, prison, muscle, mercy, bike, wizard, cereal, tail, debt, source, arrow, skill, fire, skirt, snake, damage, truth, knife, grief, speech, crime, flower, aim, plain, alley, chore, spine, freight, piece, queen, turtle, autumn, toad, cup, army, glue, salt, thumb, lion, thirst, stomach, pencil, button, eagle, beach, hole, carrot, bucket, dirt, cellar, bull, acid, crowd, mill, sugar, tale, pillow, degree, anger, uncle, cheese, potato, poet, peace, jail

Items used in Experiment 2

Identical cognates: alcohol, baron, camera, chaos, ego, flora, globe, god, horizon, hotel, lip, minister, moment, norm, opera, oven, psalm, shirt, sultan, tent, toilet, truck, villa, volume

Non-identical cognates in English orthography: admiral, advice, altar, athlete, bible, camel, canal, friend, honey, jewel, melon, method, pill, tea, thief, tomato, tongue, year*,* beard, castle, choir, devil, grass, hat, hearth, hero, king, maid, minute, night, owl, person, priest, rice, sand, sea, son, thorn, violin, wine, coffee, ear, planet, prince, cigar, flesh, sword, soup

Non-identical cognates in Dutch orthography: admiraal, advies, altaar, atleet, baard, bijbel, dief, doorn, duivel, gras, haard, held, hoed, honing, jaar, juweel, kameel, kanaal, kasteel, koffie, koning, koor, meid, meloen, methode, minuut, nacht, oor, persoon, pil, planeet, priester, prins, rijst, sigaar, soep, thee, tomaat, tong, uil, viool, vlees, vriend, wijn, zand, zee, zoon, zwaard

English controls: gun, window, eagle, faith, guilt, skill, carrot, lad, silk, muscle, torch, animal, arrow, cattle, tale, donkey, duke, engine, pigeon, throat, peace, road, trash, horse, frog, dusk, bird, grape, sale, fun, herb, poem, woman, youth, dirt, peach, bullet, cheese, statue, alley, funeral, candle, lake, vein, mud, habit, noise, witch

Dutch controls: dak, pruik, geest, genade, konijn, koorts, ober, laars, lente, macht, moeras, mouw, plicht, poort, varken, jurk, keuken, huid, vijver, angst, riem, zonde, vleugel, stier, struik, schade, herfst, gips, muur, pech, ochtend, maagd, kuiken, tapijt, kroeg, gevel, grot, keizer, stad, oord, pauw, stank, egel, hals, trui, nier, lichaam, bijl

Items used in Experiment 3

Cognates: advice, alarm, anchor, ball, baker, bamboo, banana, bath, beard, book, breast, breeze, bride, card, cellar, chance, chaos, choir, circle, circus, clock, code, coffee, colour, cool, cord, core, cork, crisis, crown, deaf, death, debate, degree, detail, devil, doctor, domain, drama, east, echo, fatal, fist, flood, foot, fruit, glass, gold, grave, green, grey, guide, guitar, hard, head, heaven, hell, honey, hope, hotel, hour, hunger, idea, idiot, jewel, jury, king, kiss, lamb, lamp, leader, length, light, lion, logic, love, luck, mask, mass, melon, menu, metal, mild, mill, milk, model, moment, month, moon, mouse, myth, needle, nest, nose, oath, oven, pain, palace, pearl, pill, plan, plant, point, price, prince, pure, rain, rich, rhythm, ring, saddle, salt, school, screen, seed, ship, shoe, short, snow, soap, sock, soup, south, sport, stone, storm, street, strong, sugar, summer, sword, tender, tennis, thick, thief, thin, thirst, thorn, throne, thumb, tomato, tongue, tooth, total, tower, train, type, unit, valley, warmth, water, wheel, wild, wind, winter, wound, year, youth

English controls: acid, alley, angle, angry, animal, army, arrow, autumn, beach, bird, body, bottle, branch, bright, bucket, bull, bullet, burden, cage, candy, carrot, case, cattle, cause, cave, chain, chair, cheese, cherry, choice, church, coat, coin, crazy, crime, crowd, danger, debt, demand, design, desk, dirt, donkey, doubt, duck, duke, dull, duty, eagle, ease, empty, enemy, engine, error, face, faith, farmer, fast, fate, favour, fear, fever, fire, garden, gate, girl, glue, granny, guilt, heavy, herb, hole, horse, huge, itch, joke, judge, juice, knife, knight, large, lazy, limit, loss, mail, member, mercy, mind, mirror, money, monkey, movie, muscle, napkin, noise, office, orphan, paint, pants, peace, piece, pigeon, pillow, plate, pocket, poem, poet, port, power, proof, rabbit, rail, regret, rent, rifle, road, rumor, screw, shape, shop, sign, silk, silly, skirt, sleeve, small, smooth, soft, song, spark, spoon, story, sure, swamp, tale, target, tenant, thigh, throat, tire, trace, treaty, tree, ugly, uncle, virgin, voice, vote, voyage, wall, watch, wave, wife, window, wing, witch, woman

Neurophysiological correlates of morphological family size effects

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Chapter 3

This chapter is based on: Mulder, K., Schreuder, R., & Dijkstra, T. (in press). Morphological family size in L1 and L2 processing: An electrophysiological study. *Language and Cognitive Processes*.

Abstract

The present study examined morphological family size effects in first (L1) and second (L2) language processing. Items with a high or low Dutch (L1) family size were contrasted in four experiments involving Dutch-English bilinguals. In two experiments, reaction times (RTs) were collected in English (L2) and Dutch (L1) lexical decision tasks; in two other experiments, an L1 and L2 go/no-go lexical decision task were performed while Event-Related Potentials (ERPs) were recorded. Two questions were addressed. First, is the ERP signal sensitive to the morphological productivity of words? Second, does non-target language activation in L2 processing spread beyond the item itself, to the morphological family of the activated non-target word? The two behavioural experiments both showed a facilitatory effect of Dutch family size, indicating that the morphological family in the L1 is activated regardless of language context. In the two ERP experiments, family size effects were found to modulate the N400 component. Less negative waveforms were observed for words with a high L1 family size compared to words with a low L1 family size in the N400 time window, in both the L1 and L2 task. In addition, these family size effects persisted in later time windows. The data are discussed in light of the Morphological Family Resonance Model (MFRM) of morphological processing (De Jong, Schreuder, and Baayen, 2003) and the BIA+ model (Dijkstra & Van Heuven, 2002).

Introduction

Words are productive entities. They can occur in many complex words. For instance, the word *time* occurs in derivations and compounds such as *timeless*, *timetable,* and *tea time*. The number of morphologically related complex words that can be derived from a target word is referred to as a word's morphological family size. It is assumed that upon reading a word, many of its morphological family members become activated, because these family members are linked to the activated semantic representation of the target word (Schreuder & Baayen, 1997). Thus, when processing a word, its semantic representation is activated, and activation is then spread to other items that are linked to this semantic representation. This implies that, upon presentation of a word like *time*, over a hundred family members will be activated, leading to a large amount of global lexical activation.

Grainger and Jacobs (1996) have argued that, in lexical decision, global lexical activation in the lexicon caused by active non-target word candidates can feed the positive response to a target word, resulting in a shorter response latency for this target. In line with this idea, increased lexical activation due to the activation of a large number of morphological family members has been shown to speed up target word processing. Monolingual studies in a variety of languages have observed that words with larger morphological families are processed faster and more accurately than words with a smaller number of morphological derivatives (Bertram, Baayen, & Schreuder, 2000; De Jong, Schreuder, & Baayen, 2000; De Jong, 2002; Kuperman, Schreuder, Bertram, & Baayen, 2009; Lüdeling & De Jong, 2002; Baayen, Lieber, & Schreuder, 1997; De Jong, Feldman, Schreuder, Pastizzo, & Baayen, 2002; Juhasz & Berkowitz, 2011; Moscoso del Prado Martín, Bertram, Häikiö, Schreuder, & Baayen, 2004; Kuperman, Bertram, & Baayen, 2008; Moscoso del Prado Martín et al., 2005).

In the present study, we want to deepen our knowledge of the effects of morphological family size in several ways. Our first aim is to extend the finding of a family size effect in L1 processing from behavioural to electrophysiological data. Our second aim is to demonstrate cross-language family size effects in L2 processing in both behavioural and electrophysiological data. We will set the stage for a discussion of our experiments by considering a theoretical account and several empirical studies of morphological family size effects in monolinguals and bilinguals.

To account for family size effects, De Jong, Schreuder, and Baayen (2003) have proposed the Morphological Family Resonance Model (MFRM). The model explains the facilitatory effect of family size in terms of resonance between lemmas and the semantic (and syntactic) representations to which these lemmas are linked (see Figure 3.1). When a semantic representation of a target word is linked to many lemmas (its morphological family members), these activated lemmas will spread back a large amount of activation. Over time, this will increase both the activation of the target's semantic representation and the target lemma. In other words, resonance within the morphological family will speed up the activation rate of the target lemma, thus speeding up word processing.

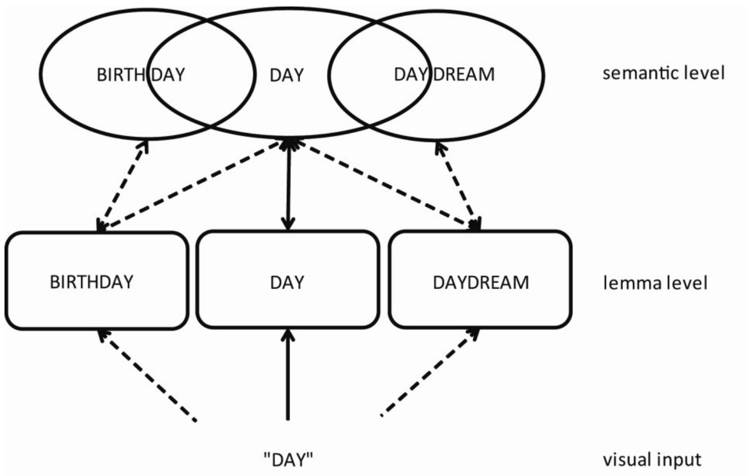

Figure 3.1. Schematic representation of the activation of morphological family members and the resonance between representations at the lemma and semantic levels.

Research indicates that the effect of family size on target word processing is semantically driven. Schreuder and Baayen (1997) and Bertram et al. (2000) showed that the correlation between response latencies and family size decreased when family members were included in the family size count that were morphologically but not semantically related (for instance *honeymoon* is a semantically unrelated family member of *honey*). Furthermore, the family size effect has been observed for past participles that do not share the vowel with their stem (e.g., *zwem – gezwommen* 'swim-swum' *vs. roei-geroeid* 'row-rowed'; De Jong et al., 2000). These studies showed that activation of semantic information underlies the activation of a word's family members and, consequently, that the family size effect is not a form effect only. These findings concerning the semantic character of the family size effect suggest that family size effects play a role at stages of word processing after word identification has taken place.

However, in a magneto-encephalographic (MEG) study, Pylkkänen, Feintuch, Hopkins, and Marantz (2004) observed that family size modulated the MEG response component M350, speeding up M350 latencies. The M350 component is considered to be an early subcomponent of the N400, an EEG component that is sensitive to both lexical and post-lexical stimulus factors (see Pylkkänen & Marantz, 2003). The M350 has been found to be sensitive to factors affecting early stages of lexical processing prior to word selection/identification, such as lexical frequency. The authors argue that their finding that family size modulates this MEG component, therefore, does not appear to be consistent with the assumption that family size affects processing post-lexically (cf. Schreuder & Baayen, 1997).

Recently, studies on bilingual word processing have shown that the morphological family size of words of both languages of a bilingual influence word processing when reading in only one of those two languages. Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005) investigated family size effects on the processing of Dutch-English interlingual homographs in both English and Dutch lexical decision tasks. In both tasks, facilitatory effects were observed for the family size of the target language, while the family size effect of the non-target language was inhibitory.

More recently, Mulder, Dijkstra, Schreuder, and Baayen (in preparation) investigated family size effects in cognate processing. More specifically, they addressed the questions of whether the cross-language family size effect might be task-dependent and sensitive to the degree of orthographic overlap in cognates. They observed target and non-target language family size effects on cognate processing in both Dutch-English language decision and English lexical decision. In language decision, the bilingual participant must press one button as quickly as possible if a presented word belongs to one language and another button if it belongs to the other language. Because cognates overlap in their orthographic form, both of their readings will be activated, resulting in response competition when the language of the cognate must be determined. Reading cognates did indeed result in slower responses than reading non-cognates. More importantly, cognates with a larger family size in English or in Dutch were processed slower than cognates with a smaller family size in these languages, suggesting that the morphological families of each of the two languages became activated and contributed to the cross-linguistic response competition. The effects became larger when the Dutch and English family size were summed in one combined family size measure. Moreover, the inhibitory effect of combined family size was larger for identical cognates than for non-identical cognates, most likely because these items induce maximal response competition.

When a similar reasoning is applied to lexical decision, a larger morphological family of the non-target language should result in faster response times (because of a larger global activation or more resonance in the lexicon). Mulder et al. observed significant facilitatory effects of the family size of the non-target language (Dutch) on the processing of cognates. Moreover, in lexical decision, the cross-language family size effect was not sensitive to the degree of form overlap between English and Dutch cognate readings. Importantly, cross-language family size effects were observed when the family size of the target language was controlled for. However, when the family size of both languages was varied, as was done by Mulder, Dijkstra, Schreuder, and Baayen (under revision), only the effect of target language family size remained. Because both effects worked in the same direction (resulting in facilitation), in the regression analysis the effect of English family size probably took away part of the effect of Dutch family size. The authors therefore argued that non-target language family size effects are more likely to be found in a paradigm in which the family size of the target language is kept constant. In the present study, in which we will look at cross-language family size effects in English lexical decision, this design is adopted. In sum, previous studies suggest that the morphology family of the non-target language is activated during cognate processing. The studies thus indicate that word representations in our lexicon, both within and across the languages we know, are highly interconnected in terms of their morphological relationships.

As indicated above, a major aim of this study is to examine cross-language morphological family size effects in L2 processing. We will measure both RTs and ERPs. To our knowledge, family size effects have not been measured before by means of ERPs. Such electrophysiological measures might be more sensitive to possible effects of family size (and other word characteristics like cognate status, see Midgley, Holcomb, & Grainger, 2011) than behavioural measures, because they provide a direct, online measure of brain activity. Moreover, ERP measures will allow us to track the resonance of activation between target and family members as it develops over time. Assuming that the family size effect is at least partially a semantic effect, we expect it to influence ERP components that are sensitive to semantic aspects of word processing.

One ERP component that is sensitive to semantic aspects of word processing is the N400 (e.g., Kutas & Hillyard, 1980). The N400 is a negative-going component peaking around 400 ms after stimulus onset, and is characterized by a large distribution over posterior electrode sites (Kutas & Van Petten, 1994). The amplitude of the N400 is assumed to reflect how easily a word can be semantically integrated into the current context, whether the context is a single word, a sentence, or a discourse (Kutas & Federmeier, 2000, p.464; also see Van Berkum, Hagoort, & Brown, 1999).

In line with this view, monolingual and bilingual studies involving semantic priming have observed less negative amplitudes in the N400 time window for words that were preceded by a semantically related prime relative to a semantically unrelated prime (Kutas & Hillyard, 1989; Kerkhofs, Dijkstra, Chwilla, & De Bruijn, 2006). In addition, bilingual ERP studies involving cognates have found less negative-going N400 waves for cognates relative to non-cognates (Midgley et al., 2011; Yudes, Macizo & Bajo, 2010). These findings may reflect the easier processing of targets given more semantic information (from the prime or the co-activated cognate representation, see Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010).

Interestingly, in an ERP study on orthographic neighbourhood size effects, Holcomb, Grainger and O'Rourke (2002) observed that words with many orthographic neighbours (i.e., words that differ from a given target word in one letter position, such as *cat* and *car*; see Coltheart, Davelaar, Jonasson, & Besner, 1997) elicited a larger (i.e., more negative-going) N400 compared to words with few orthographic neighbours. Holcomb et al. argued that this N400 effect of orthographic neighbourhood size reflected overall semantic activation. In line with these findings, Müller, Duñabeitia, and Carreiras (2010) observed the same pattern for words with a large orthographic neighbourhood size. Even more interestingly, they observed the same pattern for words with a large number of semantic associates (for example, the word *giraffe* could activate associates such as *zoo* or *animal*). Thus, activation of more semantic representations due to the activation of orthographically or semantically related items resulted in larger N400 amplitudes. Note that in the case of both orthographic neighbours and semantic associates, semantic representations are activated that are not convergent with that of the target word.

If we now consider the effects of differences in morphological family size on the ERP signal, two possibilities arise. In addition to activating their own semantic representations, words with a high family size activate the semantic representations of a large number of morphologically related family members. This should result in more semantic activation compared to words with a low morphological family size. In analogy to ERP evidence of the above mentioned studies on orthographic and associative neighbourhood density, more negative N400 amplitudes are expected to arise for words with a high family size compared to words with a low family size due to this increased semantic activation.

On the other hand, given the large semantic overlap between the target word and the activated morphological family members, the direction of the N400 effect of family size could differ. Morphological family members contain the target (e.g., *household* contains *house*), and consequently, strengthen the activation of the target word by means of co-activation. In analogy to ERP studies involving cognates (which also have converging semantics), *less* negative N400 amplitudes are expected to arise for words with a high family size compared to words with a low family size.

In this sense, investigating morphological family size effects is particularly interesting due to the different nature of the semantic overlap between target word and family members compared to orthographic neighbours and semantic associates. The direction of the N400 effect of family size could reveal a potential sensitivity of this component to semantic aspects of single word processing (orthography mapping on diverging or converging semantic representations).

Before considering L1 morphological family size effects in L2 processing, we first investigate L1 family size effects in L1 processing in two experiments. Dutch words with high and low Dutch family size are tested behaviourally in a Dutch lexical decision task (Experiment 1) and in an ERP study incorporating the same materials in a Dutch go/no-go lexical decision task (Experiment 2). The goal of this ERP study is to investigate whether the ERP signal is sensitive to differences in family size between words.

Next, we focus on L1 family size effects in L2 processing in two subsequent experiments. Our intention is to show that activation of the non-target language in L2 processing is not restricted to the non-target language lemma itself, but is passed on to non-target language family members of the target word. Cross-language family size effects are investigated by manipulating the Dutch (L1) family size of Dutch-English cognates while controlling for English (L2) family size and word frequency. Again, the materials are tested both behaviourally in an English lexical decision task (Experiment 3) and electro-physiologically in an English go/no-go task while ERPs are recorded (Experiment 4).

Morphological family size effects in L1 processing

Experiment 1: Behavioural data

Method

Participants. Twenty-six right-handed native speakers of Dutch with good knowledge of English (mean age = 21.7 years, SD = 2.66) were paid or received course credits to take part in this experiment.

Stimuli. The experimental stimuli were 80 Dutch words, extracted from the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). Only word items with a lemma frequency of at least one per million in the CELEX database and a length from four to six letters were selected. All items were mono-morphemic non-cognate words. For each item, the Dutch morphological family size values were calculated and logarithmically transformed. Half of the items had a high Dutch morphological family size (above 30, mean 37.7) and the other half had a low Dutch family size (below 10, mean 5.6). The difference between the mean numbers of Dutch family members in both sets was statistically significant. This contrast in family size was based on the contrast used in Experiments 3 and 4 that distinguished cognates with high and low family size, to allow for a comparison between family size effects in L1 and L2 processing. Moreover, this contrast in family size is comparable (i.e., differing in less than one log unit) to the contrast used by Schreuder and Baayen (1997) and De Jong et al. (2000). Both sets of words were matched on Dutch lemma frequency and on the number of Dutch orthographic neighbours. Table 3.1 presents the characteristics of the experimental items.

Finally, 80 pseudo-words were included that resembled Dutch words with respect to their orthography and phonology. They were created by replacing one or more letters of existing Dutch words. The pseudo-words were matched to the experimental stimuli on length (in letters). The presentation order of the items was randomised for each participant individually and had the restriction that no more than three words or pseudo-words could follow each other directly.

Table 3.1. Item characteristics of the experimental items used in the L1 lexical decision data (Experiment 1 and 2).

	Length	Log Dutch frequency	Log Dutch neighbours	Log Dutch family size
High family size	4.8	3.35	1.84	3.63
Low family size	4.65	3.31	1.87	1.73

Procedure. Participants performed a Dutch lexical decision task. In this task, participants have to decide whether or not the word they are presented with is an existing Dutch word or not by pressing a button corresponding to the answer ‘yes’ or ‘no’.

The visual stimuli were presented in white capital letters (24 points) in font Courier New in the middle of the screen on a dark grey background. Participants were seated at a table at a 60 cm distance from the computer screen. The maximum height and width of the stimuli were such that no saccades were necessary to be able to read the stimuli.

Each trial began with the onset of a fixation cross which remained on the screen for 500 ms and was followed by 300 ms of blank screen. A target word then appeared on the screen for 1500 ms. The next trial began after 700 ms of blank screen with the fixation cross. The experiment started with an instruction screen in Dutch followed by a short practice session to assure good performance during the experiment. The items were presented in two blocks of each 80 stimuli (requiring approximately four minutes) with one pause in between. The length of the pause was determined by the participant.

Results

Data cleaning was first carried out based on the error rate for participants and word items. All participants had an error rate of 15% or less on the word items (mean accuracy 96%, range 88-100%). Therefore, no participant data were removed. The mean accuracy for the word items was 96% (range 50-100%). One item from the low family size condition that elicited errors in more than 15% of the trials (*grap*) was removed from the data set. Furthermore, two items from the high family size condition (*fonds*, *rente*) that elicited very slow mean RTs (more than 2 SD above item mean) were removed from the data set. RTs from incorrect responses or null responses were removed from the remaining data set (3.25 % of the remaining data points). Finally, outlier RTs that were 2.5 SD above or below the subject and item mean (4.07 %) were removed. This resulted in a data set with 1858 data points.

A repeated measures analysis of variance (ANOVA) was conducted on the RT and accuracy data with *Family Size* (high versus low) as a within-subject factor. In the RT data, a main effect of *Family Size* was observed in the by-participant analysis [$F1(1,25) = 6.87$, MSE = 141.79, $p < .05$; $F2\,(1,75) = 2.07$, MSE = 953.84, $p = .15$], revealing slower RTs for words with a low family size compared to words with a high family size. The accuracy data also revealed a main effect of *Family Size* in the by-participant analysis [$F1(1,25) = 5.505$, MSE = 0.001, $p < .05$; $F2\,(1,75) =$, MSE = 0.002, $p = .10$], showing higher accuracy scores for words with a high family size. Mean response latencies and accuracy scores are presented in Table 3.2.

Table 3.2. Mean response latencies and accuracy scores and their standard deviations between parentheses for words with high and low family size in the L1 lexical decision data (Experiment 1).

	RT (SD)	Accuracy (SD)
High family size	505 (54.36)	.98 (.04)
Low family size	514 (50.45)	.96 (.04)

Discussion

The RT data of Experiment 1 are consistent with earlier behavioural findings on morphological family size effects in monolingual word processing: Words with larger morphological families were responded to faster and more accurately than words with smaller morphological families. The effect of *Family Size* was significant in the by-participant analyses and showed a trend in the by-item analyses. Although we used a contrast in family size that was comparable to the contrast used by Schreuder and Baayen (1997), the effect is smaller than the effect reported by Schreuder and Baayen. This can be explained by the considerably faster mean RTs to word items in the present study (505 ms for words with high family size, and 514 ms for words with low family size) relative to those in Schreuder and Baayen's study (553 and 594 ms for words with high and low family size, respectively). The effect in our data is more comparable to that observed by De Jong et al. (2000), whose response latencies corresponded in size to the latencies reported in our experiment (502 and 521 ms, respectively), and who reported a 19 ms advantage for nouns with high family size compared to nouns with a low family size.

This suggests that the size of the family size effect is a function of response speed, and becomes larger when RTs get longer, just like semantic effects in semantic priming studies tend to be larger for slow responses (Flores d'Arcais, Schreuder, & Glazenborg, 1985)[5]. Alternatively, the magnitude of the effect might also depend on the frequency of the items.

[5] A correlation analysis on the monolingual data did not reveal a significant relationship between the mean response latencies on the task as a whole and the difference in latencies between the high and low family size conditions. This is not surprising given that the differences between the family size conditions per participant are rather small. Interestingly, we did observe a significant correlation for our relatively slower L2 participants in Experiment 3 ($r = -.44$, $p = .03$, one-tailed), showing that the slower cognates are responded to, the larger the facilitating Family Size effect is. This supports the assumption that effect of Family Size varies as a function of response speed.

The finding that words with a large number of family members are responded to faster than words with a smaller family size can be accounted for in two ways. First, the activation of many family members produces a large amount of global lexical activation that can facilitate a positive decision (cf. Grainger & Jacobs, 1996). This would imply that family members are activated pre-lexically and influence word processing before word identification has been completed. Alternatively, the faster response could be due to the increased amount of semantic information that is available through the activation of family members. Facilitatory effects of family size could then be considered as a late lexical or post-lexical effect arising via the mechanism of resonance (De Jong et al., 2003). Because lexical decision has a response component, these accounts cannot be disentangled.

In Experiment 2, the same materials were tested in an ERP study using a Dutch go/no-go lexical decision task. This task requires no response to words, which makes it possible to disentangle the two accounts. If the ERP signal is sensitive to the morphological productivity of words in the lexicon, family size effects are especially expected to arise within the N400 time window, since the N400 is associated with lexical-semantic integration. The effect should arise even when no response is required. Given that more semantic information becomes available with the activation of a large number of morphological family members, more negative amplitudes in the N400 time window could be expected for words with larger morphological families compared to words with smaller families (cf. Müller et al., 2010). However, if the ERP signal is sensitive to the semantic convergence between target word and activated family members, this could result in less negative N400 amplitudes for words with larger morphological families.

Experiment 2: ERP data

Method

Participants. Fifteen native speakers of Dutch with good knowledge of English participated in the ERP experiment (mean age = 24.7 years, SD =2.25). All were right-handed and had normal or normal-to-corrected visual acuity and no history of neurological disorders.

Stimuli. The experimental stimuli were identical to those used in the lexical decision task.

Procedure. Participants performed a Dutch go/no-go lexical decision task. This task is similar to the lexical decision task of Experiment 1 in that participants have to decide whether or not the visually presented stimulus is an existing Dutch word or not. However, in this task, a button press was only required for Dutch pseudo-words (randomly appearing in 50% of the trials). This procedure had several advantages. First, it reduced the risk of recording ERPs contaminated by motor artefacts due to button presses. Second, it allowed us to observe any family size effects that occur at later stages of word processing (from 600 ms onwards), which would presumably not have been possible if we had included a response component in the task.

The trial presentation procedure was identical to that of the lexical decision task. Presentation of all visual stimuli and digitising of the EEG was synchronised with the vertical retrace interval (60 Hz refresh rate) of the stimulus PCs video card to ensure precise time marking of the ERP data.

EEG recording. Participants were seated in a comfortable chair in a sound proof room and were fitted an elastic cap (ActiCap 32, Brain products GmbH) equipped with 32 tin electrodes. The electrodes were placed at locations from the standard International 10-20 system. Four electrodes were used to monitor for eye-related artefacts (blinks and vertical or horizontal eye-movement): one below, above, and next to the left eye, and one next to the right eye. All electrodes were referenced to an electrode placed over the left mastoid. A final electrode was placed over the right mastoid. The signal was re-referenced to the average to the left and right mastoids before analysis. The 32 channels of electrophysiological data were amplified using a Brain Amp amplifier system (Brain Products, GmbH) with cutoffs set at 0.016 and 100 Hz. The output of the amplifier was continuously digitized with a sampling rate of 1,000 Hz throughout the experiment.

ERP data analysis– The data of the channels were re-referenced to the right mastoid. A low cut-off filter of 0.53 Hz and high cutoff filter of 30 Hz was applied. Data points containing eye-blinks and button presses were removed from the data set (21.5% of the experimental trials). Data of two participants containing artefacts in more than 30 per cent of the experimental trials were removed from the dataset. All target items were base-lined to the average of activity in the 100 ms before target onset.

Mean amplitudes were calculated for Dutch target words with a high and a low family size in three latencies windows: 100-300 ms to capture early activity prior to the N400, 300-500 ms to capture the N400 itself, and 500-800 to capture later activity. Repeated measures analyses of variance (ANOVA) were conducted with *Family Size* (high versus low), *Site* and *Hemisphere* (left vs. right) as within-subject factors. The Geisser and Greenhouse correction was applied to all repeated measures with more than one degree of freedom.

To analyse these factors, we adopted the approach from Holcomb and Grainger (2006), dividing the head up in one midline column and six lateral columns along the anteroposterior axis of the head (see Figure 3.2). The midline analysis included the factors *Family Size* and *Site*, containing five levels (Fcz, Fz, Pz, Cz, and Oz). The lateral analysis involved, besides *Family Size*, the anterior/posterior electrode *Site* factor with three (column 1: FC1/FC2 vs. C3/C4 vs. CP1/CP2), or four levels (column 2: F3/F4 vs. FC5/FC6 vs. CP5/CP6 vs. P3/P4; column 3: FP1/FP2 vs. T7/T8 vs. P7/P8 vs. O1/O2) and the factor *Hemisphere*. The electrodes at the midline and columns 1, 2, and 3 were identical to those used by Holcomb and Grainger, except for the two frontal electrodes F7 and F8 from column 3, which were used to detect eye artefacts.

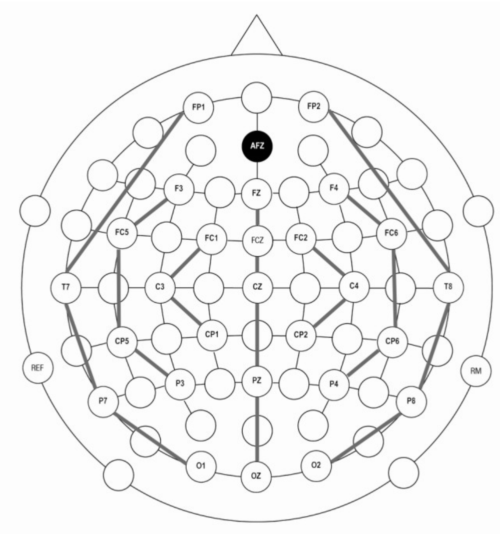

Figure 3.2. Electrode montage and four regions (midline, c1,c2, and c3) used for the analysis of the electrophysiological data.

Results

Error rate. Trials in which participants either pressed the response button when they were presented with a word, or did not press when they encountered a pseudo-word were counted as errors. The mean percentages of errors on the overall task and on the target words in specific were 1.97% and 1.63%, respectively.

Event-related potentials. Grand-average waveforms at the midline sites for items with high and low family size, time-locked to the onset of the stimulus, are presented in Figure 3.3. Visual inspection of Figure 3.3 suggests a difference between the two conditions in both the 300-500 ms time windows and the 500-800 ms time windows: more negative going waveforms for items with a low family size in the former windows and less positive going waveforms in the latter compared to items with a high family size. Moreover, there seems to be an early difference in the 100-300 ms time window. Figure 3.4 displays the topographic maps obtained by interpolation from 27 sites used for analyses in the 100-300 ms, 300-500 ms, and 500-800 ms time windows.

100-300 ms time window

The ANOVAs with *Family Size* and *Site* as within-subject factors on the midline column, and with the additional factor *Hemisphere* in the three lateral columns revealed no significant main effects of *Family Size* and no interaction with *Site*. A significant interaction between *Family Size* and *Hemisphere* was obtained in Column 2 [$F(1,12) = 9.34$, MSE = 5.38, $p < .05$], showing higher positive amplitudes for words with a high family size compared to words with a low family size in the left hemisphere only. Follow-up *t*-tests show that the effect of *Family Size* is significant in the left hemisphere [$t(1,51) = -2.87$, MSE = .23, $p < .01$], but not in the right hemisphere [$t < 1$].

Additional analyses on time windows of 50 ms (see Table 3.3) revealed no significant main effects of *Family Size*, and no interactions with *Site*. However, there was a significant interaction between *Family Size* and *Hemisphere* between 150 and 200 ms in the two most lateral columns: Column 2 and Column 3, and between 250 and 300 ms in Column 2. Moreover, this interaction effect was marginally significant between 200 and 250 ms in Column 2. Follow-up *t*-tests on these columns all show more positive-going waveforms for words with a high family size compared to words with a low family size in the left hemisphere only.

300-500 ms time window

The ANOVA on the midline column revealed a main effect of *Family Size* [$F(1,12) = 5.58$, MSE = 3.16, $p < .05$]. The analyses on the lateral columns revealed a main effect of *Family Size* in Column 1[$F(1,12) = 4.91$, MSE = 7.56, $p < .05$], and Column 2 [$F(1,12) = 5.91$, MSE = 3.98, $p < .05$] but not in the most lateral Column 3. The direction of the effect is similar in the four columns: Less negative waves for words with a high family size compared to words with a low family size. No significant interactions of *Family Size* with *Site* or *Hemisphere* were found.

Additional analyses on time windows of 50 ms (see Table 3.3) show that the main effect of *Family Size* was significant in the 350-400 ms time window for both the midline and Columns 1 and 2, and marginally significant for Column 3. Further, a significant main effect of *Family Size* was observed in the time window of 450-500 ms in the lateral Column 2, and a marginally significant effect in Column 1. In this latter time window, a positivity arose that continued in the 500-800 time window. The main effect of *Family Size* was reflected in more positive amplitudes for words with a high family size compared to words with a low family size. Moreover, there was a marginally significant interaction between *Family Size* and *Hemisphere* in Column 2 for this time window, showing more positive amplitudes for words with a high family size compared to words with a low family size in the left hemisphere. Follow-up *t*-tests show that this effect of *Family Size* was not present in right hemisphere.

500-800 ms time window

The ANOVA revealed a marginally significant effect of *Family Size* for the midline [$F(1,12) = 4.54$, MSE = 4.64, $p = .05$] and for Column 1 [$F(1,12) = 3.91$, MSE = 8.99, $p = .07$], showing more positive amplitudes for words with a high family size compared to words with a low family size. No interactions between *Family Size* and *Site* or *Hemisphere* were observed.

Further analyses on the main effect of *Family Size* and interactions with *Site* or *Hemisphere* in time windows of 50 ms (see Table 3.3) revealed significant main effects of *Family Size* between 500 and 550 ms for both the midline column and Columns 1 and 2, and a marginally significant effect in Column 3. Further, the main effect of *Family Size* was significant between 550 and 600 ms on the midline, and marginally significant in Column 3. After 600 ms, the main effect was reduced to a more central distribution with significant effects between 600 and 650 ms at the midline and Column 1. Finally, a significant interaction between *Family Size* and *Hemisphere* was observed between 700 and 750 ms in the most lateral columns and a marginally significant interaction was observed in Column 1, all showing higher positive amplitudes for words with high family size in the left hemisphere only. Follow-up *t*-tests revealed that words with a higher family size elicit more positive amplitudes in the left hemisphere only in Column 1, and less negative amplitudes in the left hemisphere only in Columns 2 and 3.

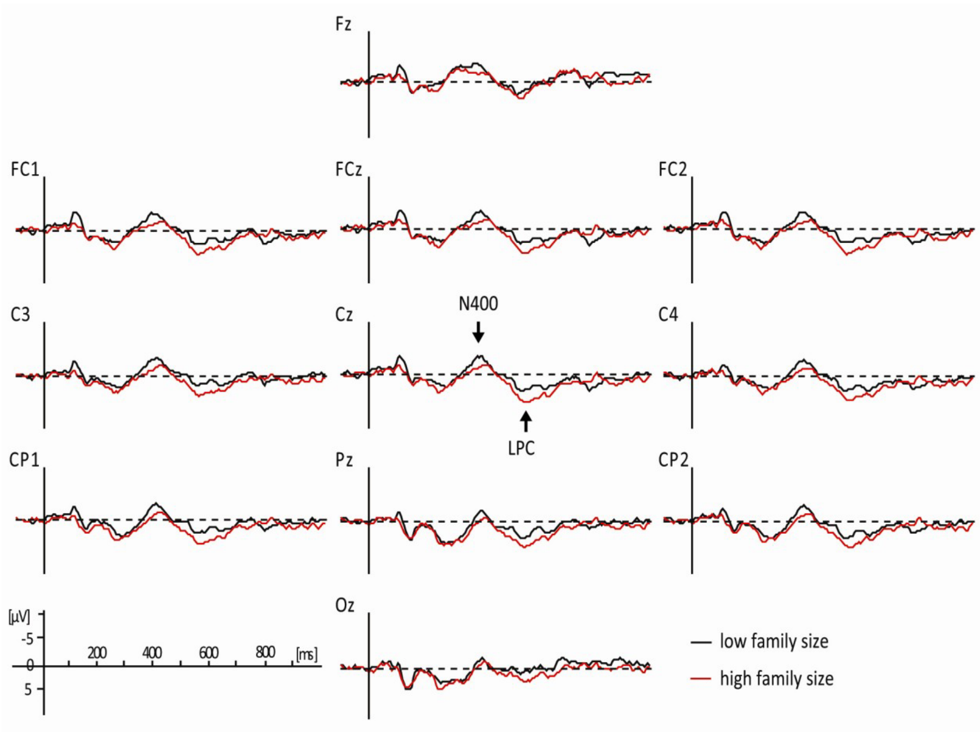

Figure 3.3. Grand average waveforms of Dutch words with a low family size compared to words with a high family size.

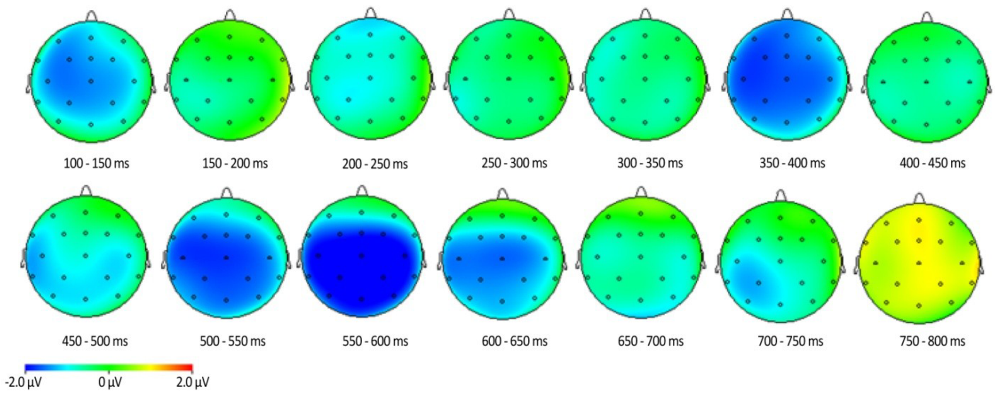

Figure 3.4. Voltage maps of the difference waves of Dutch words with low family size compared to Dutch words with high family size, for 50 ms time-windows.

Table 3.3. Main effect of Family Size (MFS) and Interaction effect of MFS by Site as reported by their F-values on the within-subjects test on the midline and lateral columns in L1 processing (Experiment 2) in time windows of 50 ms.

	Column	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750	750-800
MFS	midline	2.6	<1	1.5	<1	1.2	**12.7**	<1	3.0	**7.3**	**9.4**	**5.6**	1.3	1.3	1.0
	C1	3.0	<1	<1	<1	1.0	**10.3**	<1	4.3	**9.4**	**10.8**	**4.8**	1.3	1.7	<1
	C2	1.3	<1	<1	<1	1.5	**15.3**	<1	**4.9**	**7.4**	**8.1**	2.7	<1	<1	1.9
	C3	<1	<1	<1	<1	<1	4.4	<1	<1	3.5	3.4	1.6	<1	<1	1.4
MFS* Site	midline	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.1	1.7	1.9	<1	1.8
	C1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	C2	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.2	1.4	1.8	1.5	<1
	C3	<1	<1	1.3	<1	<1	1.3	<1	1.3	1.4	<1	<1	1.1	<1	<1
MFS* Hemisphere	C1	1.4	2.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	4.6	<1
	C2	2.4	**13.9**	3.5	**5.5**	2.6	2.4	<1	3.5	1.9	<1	1.4	<1	**5.9**	<1
	C3	<1	**6.1**	2.1	2.2	1.0	<1	<1	<1	2.5	<1	<1	2.9	**5.5**	<1

Note: underlined $p < .1$ **bold** $p < .05$, and **bold underlined** $p < .01$

Discussion

In Experiment 2, the ERP signal in the N400 (300-500 ms) time window was characterized by a negativity, starting around 300 ms with a frontal negativity, and gaining a wider, centro-parietal distribution, peaking at 400 ms. A significant effect of *Family Size* in this window was observed. Analyses of separate windows of 50 ms show that this effect was significant in the 350-400 ms time window. Though the duration of the effect was limited, the direction of the effect is as expected: more negative going waveforms for words with a low family size compared to words with a high family size. This is in line with the hypothesis that words that activate a large number of morphological family members are easier to process because more converging semantic information is available, but not in line with the hypothesis that the effects depend only on the amount of semantic activation generated.

The 500-800 ms time windows revealed a positivity, already starting around 450 ms following the negativity in the 300-500 time window, and peaking between 500 and 600 ms. This could reflect a Late Positive Complex (LPC) following the N400 (see also Müller et al., 2010, who observed LPC effects when manipulating orthographic and associative neighbourhood size). The ERP data revealed significantly less positive waveforms for words with a low family size than for words with a high family size. The observed activation in the 500-800 time windows suggests that even after the lexical decision has been made (that is, the decision not to press the button because the target is an existing Dutch word), family members remain activated, and resonance of activation persisted.

Interestingly, we also observed early effects of *Family Size* in the 100-300 ms time window as demonstrated by the interaction between *Family Size* and *Hemisphere* in the two most lateral columns. Words with a high family size were found to have higher positive amplitudes compared to words with a low family size in the left hemisphere. This suggests that family size may also affect early stages of word processing. It is, however, not clear to us whether these effects reflect the semantic activation of family members or are effects related to the processing of the word-form of the target word. We will come back to this issue in the General discussion section.

In Experiments 3 and 4, we examined cross-language L1 family size effects on cognate processing in an L2 context. Following the language non-selective access account of bilingual word processing, bilinguals co-activate words from the L1 when reading words from the L2 as long as there is enough formal overlap between the two words (for an overview, see Dijkstra & Van Heuven, 2002). Many studies report a facilitation effect of cognates compared to control words (e.g., De Groot & Nas, 1991; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Kroll & Stewart, 1994; Lemhöfer et al., 2008; Sanchez-Casas, Davis, & Garcia-Albea, 1992; Schwartz, Kroll, & Diaz, 2007; Voga & Grainger, 2007; Dijkstra et al., 2010). The question is whether during reading in the L2, this co-activation is restricted to the L1 non-target cognates themselves or whether activation spreads to words that are morphologically related to these L1 cognates.

As has been mentioned in the Introduction, in order to grasp L1 morphological family size effects on cognate processing in L2 lexical decision, the family size of the L2 needs to be controlled for. This was done in Experiment 3 in which English cognates with a high and a low Dutch family size were contrasted in an English lexical decision task while the English family size has been kept constant. If a high L1 family size facilitates cognate processing, then this should result in faster RTs for cognates with larger morphological families compared to cognates with a smaller number of family members.

L1 Morphological family size effects in L2 processing

Experiment 3: Behavioural data

Method

Participants. Nineteen right-handed native speakers of Dutch (mean age = 20.0 years old, SD = 2.75) with good knowledge of English received money or course credits to participate in this experiment. Experience with and proficiency in the (L2) English was assessed by using a language background questionnaire and the X-Lex vocabulary task (Meara & Milton 2003), respectively.

Stimuli. The stimulus set consists of 300 items, half of which are English words and half are pseudo-words. All word items were selected from the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Only mono-morphemic words with a lemma frequency of at least one per million in the CELEX database and a length between four and six letters were selected. For each item, the English family size values were calculated and logarithmically transformed.

The experimental word items were 60 English-Dutch cognates, i.e., translation equivalents that share their form in Dutch and English. The cognates could be either identical cognates (i.e., items that have complete orthographic overlap in two languages, such as *hotel* and *norm*), or non-identical cognates (e.g., *thief* and *planet*, in Dutch 'dief' and 'planeet', respectively). For the latter items, the overlap was not completely identical and differed on maximally two letter positions. The degree of orthographical overlap was calculated by the Levenshtein distance measure (Levenshtein, 1966; the minimal number of deletions, insertions, or substitutions that is required to transform the source string into the target string). For each cognate item, the Dutch family size was calculated and logarithmically transformed. Half of the cognate items had a high Dutch family size (above 30, mean 37.6) and the other half had a low Dutch family size (below 10, mean 3.6). The difference between the mean numbers of Dutch family members in both sets was statistically significant. Finally, to be sure that any significant effects could only be explained by differences in Dutch family size (high vs. low) and not by English family size or English or Dutch frequency, we controlled for these variables by keeping them constant over the two sets of cognates. Moreover, we controlled for Levenshtein distance and English bigram frequency (all p's $< .05$)[6].

The experimental word items were matched with 60 non-cognate English control items on English family size, English frequency, the number of English orthographic neighbours, English bigram frequency, and length in letters. Note that these items do not have a Dutch reading, and consequently no Dutch family size. The experiment also included 30 non-cognate filler words to reduce awareness of the presence of cognate items. These items were matched on English frequency and length to the cognate items. Characteristics of experimental and control items are presented in Table 3.4. Finally, 150 pseudo-words were included that resembled English words with respect to their orthography and phonology. They were created by replacing one or more letters of existing English words. The pseudo-words were matched to the experimental stimuli on length. The presentation order of the items was randomized for each participant individually and had the restriction that no more than three words or pseudo-words could follow each other directly.

[6] Because cognates are productive in terms of the number of family members, they generally also have a higher number of orthographic neighbours compared to words that are morphologically less productive. Thus, it was not possible to match them on English or Dutch orthographic neighbourhood size (mean number of orthographic neighbours for the high family size and low family size conditions, respectively: English neighbours 6.07/2.83, Dutch neighbours 3.37/1.93). However, regression analysis on the RT data revealed no significant effect of either Dutch and English neighbourhood size measure, while there was an effect of *Dutch Family Size*.

Table 3.4. Item characteristics of the experimental items used in the L2 lexical decision data (Experiment 3 and 4).

	Length	Log English frequency	Log English family size	English bigram frequency	Levenshtein distance	Log Dutch frequency	Log Dutch family size
Cognates with high family size	4.8	3.62	2.15	13.9	.83	3.44	3.58
Cognates with low family size	4.65	3.56	1.78	14.0	.70	2.95	1.06
Controls	4.97	3.61	1.74	11.7	-	-	-

Procedure. Participants performed an English lexical decision task. In this task, they have to decide whether or not the word they are presented with is an existing English word by pressing a button corresponding to the answer yes or no. The procedure concerning the presentation of the stimuli is identical to that of Experiment 1. The items were presented in two blocks of each 150 stimuli (requiring approximately seven minutes) with one pause in between.

Results

Data cleaning was first carried out based on the error rate for participants and word items. All participants had an error rate of 15% or less on the word items (mean accuracy 94%, range 88-100%). Therefore, no participant data were removed. The mean accuracy for the word items was 94% (range 21-100%). Six items (one cognate from the low family size condition: *altar*, two cognates from the high family size condition: *bible, lung*, and 3 controls: *cereal*, *debt*, *parcel*) that elicited errors in more than 30% of the trials were removed from the data set. RTs from incorrect responses or null responses were removed from the remaining data set (4.1 % of the remaining 2166 data points). Finally, outlier RTs that were 2.5 SD above or below the subject and item mean were removed (3.9% of the remaining 2077 data points). This resulted in a data set with 1994 data points.

Repeated measures analyses of variance (ANOVA) were conducted on the RT and accuracy data with *Family Size* (high versus low) as a within-subject factor. A main effect of *Family Size* was observed in the RT data [$F1(1,18) = 14.2$, MSE = 354.86, $p < .01$; $F2\,(1,55)$

= 3.16, MSE = 1793.83, $p = .08$], revealing slower RTs for cognates with a low Dutch family size compared to words with a high Dutch family size. Further, an ANOVA with *Stimulus Category* (cognate versus controls) as a within-subject variable revealed a facilitation effect for cognates [$F1(1,18) = 28.8$, MSE = 149.25, $p < .001$; $F2\,(1,112) = 7.67$, MSE = 2063.43, $p < .01$].

The accuracy data showed no main effect of *Family Size* in the accuracy rates on cognates [$F1 < 1$; $F2 < 1$]. Further, the ANOVA with *Stimulus Category* as a within-subject variable revealed that cognates had significantly higher accuracy scores than controls [$F1(1,18) = 6.67$, MSE = 0.001, $p < .05$; $F2\,(1,112) = 6.33$, MSE = 0.004, $p < .05$].

Mean response latencies and accuracy scores for cognates with high and low family size as well as mean response latencies for cognates and controls are displayed in Table 3.5.

Table 3.5. Mean response latencies and accuracy scores and their standard deviations between parentheses for cognates with high and low family size, and for cognates and controls in the L2 lexical decision data (Experiment 3).

	RT (SD)	Accuracy (SD)
Cognate high family size	561 (72.51)	.97 (.03)
Cognate low family size	583 (83.93)	.97 (.03)
Cognate	572 (77.51)	.97 (.03)
Control	593 (77.34)	.94 (.05)

Discussion

As predicted, the data of Experiment 3 revealed a processing advantage for cognates compared to non-cognate control words, indicating that participants activated both the target language and non-target language representations of cognate words.

We further predicted that, if non-target language (L1) words are activated during L2 processing, the L1 family members should be activated as well and influence L2 word processing. Indeed, as for the L1 data of Experiment 1, L1 family size had a facilitatory effect on the lexical decision latencies. Cognate words with a larger number of morphological derivates in the L1 were processed faster than cognate words with a smaller number of L1 family members. Importantly, this result indicates that the family size of the L1 is activated during L2 word processing. This finding for cognates is in line with Dijkstra et al. (2005), who observed L1 family size effects for interlingual homographs in L2 lexical decision. Furthermore, the direction of the effect is in accordance with the findings of Mulder et al. (in preparation) that activation of cross-language family members facilitates cognate processing in an L2 lexical decision task when the target language family size is controlled for.

In Experiment 4, the same materials were tested using ERPs. If family size modulates cognate processing in a way similar to what was observed in the behavioural task of Experiment 3, namely facilitating cognate processing, then this should translate into less negative waveforms in the N400 time window for cognates with a high family size compared to cognates with a low family size. This would be in line with the hypothesis that the activation of convergent semantics leads to less negative-going N400 waves for words with a high family size (as observed in Experiment 2).

Experiment 4: ERP data

Method

Participants. Nineteen native speakers of Dutch (mean age = 22.57 years old, SD = 3.32) were recruited and compensated for their time. All were right handed and had normal or corrected-to-normal visual acuity with no history of neurophysiological disorders. Participants were matched on English proficiency to the participants of Experiment 3 by means of the X-Lex vocabulary task (Meara & Milton 2003), and a language background questionnaire.

Stimuli. The stimuli were identical to those of Experiment 3.

Procedure. The procedure was identical to that of Experiment 3, except that the participants performed an English go/no-go lexical decision task. In this task, participants had to read words presented in isolation and pressed a response button whenever they saw an English pseudo-word (randomly appearing in 50% of the trials).

EEG recording. The settings for the EEG recording were identical to that of Experiment 2.

ERP data analysis– Data were analysed following the same procedure as in Experiment 2. Data points containing eye-blinks and button presses were removed from the data set (23% of the experimental trials). Data of six participants containing artefacts in more than 30% of the experimental trials were removed from the dataset. All target items were base-lined to the average of activity in the 100 ms before target onset.

Mean amplitudes were calculated for English target words with a high and a low Dutch family size in the three latencies windows that are similar to the ones used in Experiment 2: 100-300 ms to capture early activity prior to the N400, 300-500 ms to capture the N400 itself, and 500-800 ms to capture later activity. Repeated measures analyses of variance (ANOVA) were conducted with *Family Size* (high vs. low), *Site*, and *Hemisphere* (left vs. right) as within-subject factors. Separate ANOVAs were conducted to examine *Family Size* effects at the midline, and three lateral columns used in Experiment 2. Finally, to determine whether there was a cognate effect, separate ANOVAs with the factor *Stimulus Category* (cognate vs. control) were conducted in the three time windows mentioned above.

Results

Error rate. The mean percentages of errors on the overall task and on the target words in specific were 7.5% and 3.85%, respectively.

Event-related potentials. Grand-average waveforms at the midline sites for items with high and low family size, time-locked to the onset of the stimulus, are presented in Figure 3.5. Visual inspection of Figure 3.5 suggests a difference between the two conditions in both the 100-300 ms and 300-500 ms time windows, and the 500-800 ms time window: more negative going waveforms for items with a low family size in the former windows and more positive going waveforms in the latter compared to items with a high family size. Figure 3.6 displays the topographic maps obtained by interpolation from 27 sites used for analyses in the three time windows.

100-300 ms time window

The ANOVA with *Family Size* and *Site* as within-subject factors on the midline column showed no main effects of *Family Size*, nor was there an interaction between *Family Size* and *Site*. The ANOVA with *Family Size*, *Site* and *Hemisphere* on the lateral columns revealed a marginally significant effect of *Family Size* in Column 1 [$F(1,12) = 3.99$, MSE = 9.23, $p = .07$], showing more positive amplitudes for words with a high family size compared to words with a low family size.

Additional analyses on time windows of 50 ms (see Table 3.6) show that the main effect of *Family Size* is only marginally significant between 100 and 150 ms in Column 1, and between 150 and 200 ms on the midline and in Column 1, with more positive amplitudes for words with a high family size compared to words with a low family size. However, there was a significant interaction between *Family Size* and *Site* between 200 and 250 ms on the midline, and between 250 and 300 ms in Column 2. Finally, this interaction was found to be marginally significant in Column 3 between 250 and 300 ms. Follow-up *t*-tests show less positive amplitudes for words from a high family size compared to words with a low family size in the most frontal electrode site, but more positive amplitudes compared to words with a low family size in the other sites. No significant interactions between *Family Size* and *Hemisphere* were observed.

Finally, the ANOVA with *Stimulus Category*, *Site*, and *Hemisphere* as within-subject factors run to determine whether there were any effects of cognate status revealed no main effect of *Stimulus Category* and no significant interactions with *Site* or *Hemisphere* neither on the midline nor on the lateral columns. However, a marginally significant three-way interaction between *Stimulus Category*, *Site* and *Hemisphere* was observed for Column 1 [$F(1.9,22.6) = 2.90$, MSE = .076, $p = .08$], revealing more positive amplitudes in the left hemisphere compared to the right hemisphere for cognates in the central electrode site.

300-500 ms time window

The midline analysis revealed a significant main effect of *Family Size* [$F(1,12) = 5.88$, MSE = 7.56, $p < .05$]. Words with a high family size had less negative amplitudes than words with a low family size. A significant interaction was observed between *Site* and *Family Size* [$F(2.3,27.4) = 5.22$, MSE = 1.84, $p < .01$]. The interaction showed that the effect was reversed in the frontal electrode site of the midline column: Words with a high family size had more negative amplitudes compared to words with a low family size in the most frontal site, while being less negative in the other electrode sites. Follow-up *t*-tests revealed this effect of *Family Size* was not significant in the frontal electrode site [Fz: $t < 1$], but was significant or marginally significant in the other columns [FCz: $t(1,12) = 2.80$, MSE = 0.67, $p < .05$; Cz: $t(1,12) = 2.39$, MSE = 0.68, $p < .05$; Pz: $t(1,12) = 2.57$, MSE = 0.66, $p < .05$; Oz: $t(1,12) = 1.97$, MSE = 0.52, $p = .07$].

ANOVAs with *Family Size*, *Site,* and *Hemisphere* as within-subject factors on the lateral columns revealed a significant main effect of *Family Size* for Column 1 [$F(1,12) = 8.49$, MSE = 12.45, $p < .05$], and a marginally significant effect in Column 2 [$F(1,12) = 3.84$, MSE = 6.08, $p = .07$]. Again, words with a high family size induced less negative amplitudes. A significant interaction between *Family Size* and *Site* was obtained for Column 2 [$F(1.5,18.2) = 7.01$, MSE = 2.38, $p < .01$] and Column 3 [$F(1.4,17.1) = 8.15$, MSE = 2.46 , $p < .01$], showing more negative amplitudes for words with a high family size in the most frontal sites but less negative in the other sites. Follow-up *t*-tests revealed significant effects of *Family Size* effects mainly in the non-frontal sites of Column 2 and in all sites of Column 3 [column 2: F3/F4: $t(1,25) = -1.06$, $p = .30$; FC5/FC6: $t(1,25) = 1.17$, $p = .25$; CP5/CP6: $t(1,25) = 3.81$, MSE = .35, $p < .01$; P3/P4: $t(1,25) = 3.27$, MSE = .39, $p < .01$; column 3: FP1/FP2: $t(1,25) = -2.12$, MSE = .34, $p < .05$; T7/T8: $t(1,25) = 3.18$, MSE = .28, $p < .01$; P7/P8: $t(1,25) = 2.96$, MSE = .34, $p < .01$; O1/O2: $t(1,25) = 2.89$, MSE = .37, $p < .01$]. Finally, a three-way interaction between *Family Size, Site*, and *Hemisphere* was found to be significant in Column 2 [$F(2.1,25.3) = 3.84$, MSE = 0.53, $p < .05$] and approached significance in Column 3 [$F(2.0,24.1) = 2.67$, MSE = 0.48, $p = .089$]. Follow-up *t*-tests on the data of Column 2 revealed that words with a high family size had more negative amplitudes compared to words with a low family size in the frontal sites, and less negative amplitudes in the non-frontal sites, expect for column FC5 in the left hemisphere, where words with a high family size had larger negative amplitudes [FC5: $t < 1$; FC6: $t(1,12) = 2,14$, MSE = 0.42, $p = .054$].

Additional analyses on time windows of 50 ms. (see Table 3.6) showed a significant main effect of *Family Size* between 350 and 400 ms on all columns, becoming somewhat less lateral between 400 and 500 ms. Further, significant interactions between *Family Size* and *Site* between 350-400 ms at Column 3 and between 450-500 ms at Column 2 show that words with a high family size have less negative amplitudes compared to words with a low family size at central and posterior sites, while the effect is reversed or absent at the utmost frontal site of the columns. Finally, no significant interaction with *Hemisphere* was observed.

Finally, the ANOVA including *Stimulus Category*, *Site*, and *Hemisphere* as within-subject factors showed no main effect of *Stimulus Category*. However, a significant interaction between *Stimulus Category* and *Site* was obtained for the midline: [$F(1.9,23.8) = 3.47$, MSE = 1.70, $p < .05$], showing more negative amplitudes for cognates versus non-cognate control words in all sites except the most frontal site, in which the opposite effect was found. Follow-up *t*-tests only show a (marginally) significant effect of *Stimulus Category* at the two most posterior sites [Fz: $t = 1.42$, $p = .18$, FCz: $t < 1$, Cz: $t < 1$; Pz: $t(1,12) = -2.22$, MSE = .46, $p < .05$; Oz: $t(1,12) = -2.04$, MSE = .57, $p = .06$]. Further, the interaction between *Stimulus Category*, *Site*, and *Hemisphere* was found to be significant in Column 1 [$F(1.7,20.6) = 3.71$, MSE = 0.11, $p < .05$], and only marginally significant in Column 3 [$F(1.8,22.5) = 3.02$, MSE = 0.31, $p = .07$]. Follow-up *t*-tests revealed only a marginally significant effect of *Stimulus Category* at the centro-parietal electrode site in the left hemisphere for Column 1 [CP1: $t(1,12) = -1.98$, MSE = 0.47, $p = .07$], showing less positive amplitudes for cognates at this site. In Column 3, (marginally) significant effects were only observed at frontal-parietal and posterior sites in the right hemisphere [FP2: $t(1,12) = 2.20$, MSE = 0.37, $p < .05$; O2: $t(1,12) = -2.07$, MSE = 0.43, $p = .06$], showing less negative amplitudes for cognates relative to controls at FP2 but less positive amplitudes for cognates at O2.

500-800 ms time window

The ANOVA on the midline revealed no significant effect of *Family Size*, but showed a significant interaction between *Site* and *Family Size* [$F(1.9,23.1) = 6.98$, MSE = 1.39, $p < .01$]. Follow-up *t*-tests showed more positive amplitudes for words with a high family size compared to words with a low family size on all electrode sites except the most frontal site [Fz: $t(1,12) = -2.21$, MSE = 0.37, $p < .05$; FCz: $t(1,12) = 2.01$, MSE = 0.63, $p = .07$; Cz: $t(1,12) = 1.75$, $p = .11$; Pz: $t(1,12) = 2.32$, MSE = 0.46, $p < .05$; Oz: $t(1,12) = 1.77$, $p = .10$].

The ANOVA with *Family Size*, *Site*, and *Hemisphere* as within-subject factor on the lateral columns revealed a marginally significant main effect of *Family Size* [$F(1,12) = 4.29$, MSE = 11.39, $p = .06$] in Column 1, showing more positive amplitudes for words with a high family size. The interaction between *Family Size* and *Site* was significant in Column 2 [$F(1.5,17.4) = 9.95$, MSE = 1.73, $p < .01$] and in Column 3 [$F(1.7,20.1) = 9.21$, MSE = 1.31, $p < .01$]. Follow-up *t*-tests on these interactions revealed that words with a high family size revealed more positive amplitudes than words with a low family size in all sites but not the most frontal site [column 2: F3/F4: $t(1,25) = -3.45$, MSE = 0.21, $p < .01$; FC5/FC6: $t < 1$; CP5/CP6: $t(1,25) = 3.16$, MSE = 0.32, $p < .01$; P3/P4: $t(1,25) = 2.85$, MSE = 0.33, $p < .01$; column 3: FP1/FP2: $t(1,25) = -3.17$, MSE = 0.23, $p < .01$; T7/T8: $t(1,25) = 2.46$, MSE = 0.27, $p < .05$; P7/P8 : $t(1,25) = 3.29$, MSE = 0.28, $p < .01$; O1/O2: $t(1,25) = 2.74$, MSE = 0.32, $p < .05$]. Furthermore, a three-way interaction between *Family Size*, *Site*, and *Hemisphere* was obtained in Column 2 [$F(2.2,26.3) = 11.87$, MSE = 0.26, $p < .001$]. Follow-up *t*-tests showed significantly more positive amplitudes for words with a high family size in the non-frontal sites, but not in site FC5 in the left hemisphere, where less negative amplitudes are observed [FC5: $t = 1.71$, $p = .11$].

Analysis on the 50 ms time windows (see Table 3.6) revealed no main effects of *Family Size*. However, significant interactions between *Family Size* and *Site* were observed between 600-650 and 650-700 ms on the midline and most lateral columns c2 and c3, showing more positive amplitudes for words with a higher family size compared to words with a smaller family size at all sites, except for the most frontal site. A three-way interaction between *Family Size*, *Site*, and *Hemisphere* was observed in Column 2 between 600-650 and 650-700 ms.

Finally, the ANOVA with *Stimulus Category*, *Site*, and *Hemisphere* as within-subject factors run on the midline and lateral columns revealed no main effect of *Stimulus Category* and no interactions with *Site* or *Hemisphere*.

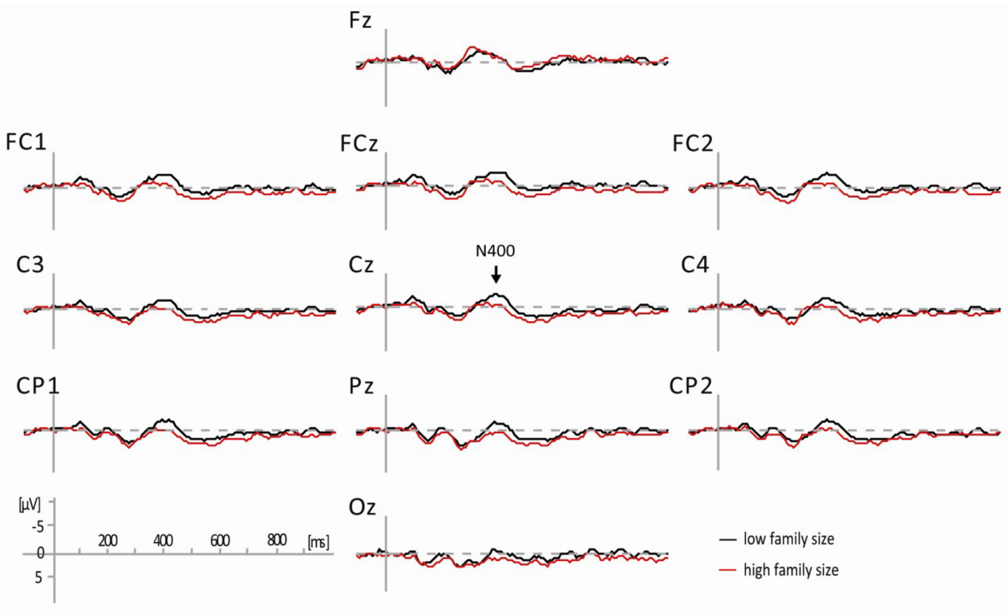

Figure 3.5. Grand average waveforms of English words with a low Dutch family size compared to English words with a high Dutch family size.

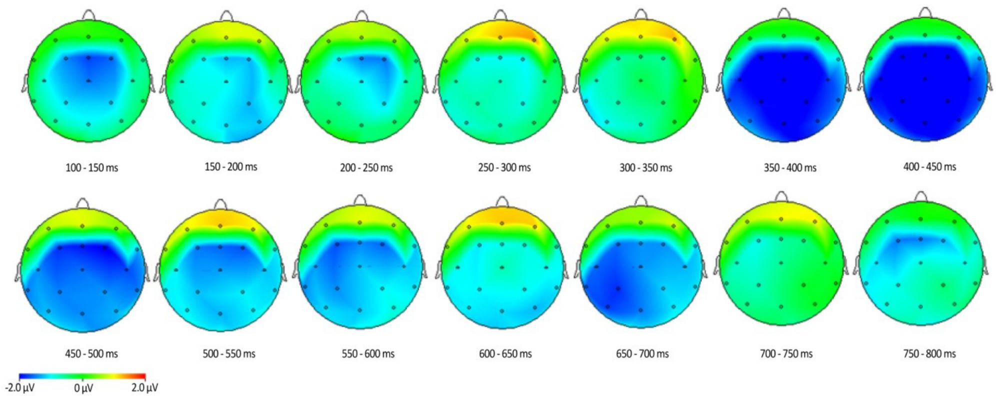

Figure 3.6. Voltage maps of the difference waves of English words with low Dutch family size compared to English words with high Dutch family size, for 50 ms time-windows.

Table 3.6. Main effect of Family Size (MFS) and Interaction effect of MFS by Site as reported by F-values on the within-subjects test on the midline and lateral columns in L2 processing (Experiment 4) in time windows of 50 ms.

	Column	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750	750-800
MFS	midline	2.6	3.8	<1	<1	<1	**6.6**	**10.2**	2.2	2.3	1.6	<1	1.9	<1	1.4
	C1	3.9	4.3	1.9	1.8	<1	**7.2**	**14.7**	**5.0**	3.9	4.3	1.9	3.5	<1	1.9
	C2	<1	<1	<1	<1	<1	**5.9**	**5.5**	1.4	<1	2.8	<1	1.8	<1	1.2
	C3	<1	1.1	<1	<1	<1	**9.2**	3.2	1.9	1.4	2.0	1.8	2.9	<1	1.5
MFS* Site	midline	4.3	3.6	**3.3**	4.9	1.9	2.7	6.1	7.4	8.5	**4.7**	**8.8**	3.4	2.1	1.6
	C1	2.2	<1	1.5	<1	<1	<1	2.0	1.5	1.7	1.6	<1	<1	<1	3.5
	C2	1.2	4.0	1.9	**8.0**	4.5	5.3	4.8	7.2	7.5	**4.3**	**15.9**	**7.5**	3.4	1.2
	C3	<1	3.3	1.9	3.3	2.8	**6.8**	5.2	7.7	6.9	5.6	**10.6**	**4.1**	2.4	1.5
MFS* Hemisphere	C1	<1	<1	1.3	<1	1.2	<1	<1	<1	<1	<1	<1	2.2	2.7	1.4
	C2	<1	<1	<1	<1	<1	<1	<1	2.3	2.7	<1	1.1	<1	<1	<1
	C3	<1	<1	<1	<1	2.1	<1	<1	<1	<1	2.6	<1	<1	<1	1.1

Note. underlined $p < .1$, **bold** $p < .05$, and **bold underlined** $p < .01$. The *F*-values are only marked as significant or marginally significant in the within-subject test when the effects were also significant in the multivariate tests. In cases in which an effect was (marginally) significant in the within-subjects test but had a *p*-value larger than .05 in the multivariate test, the *F*-value of the within-subjects test is not underlined as (marginally) significant.

Discussion

The most important finding of Experiment 4 was that morphological family size modulated cognate processing, inducing a less negative waveform for cognates with a high family size compared to cognates with a low family size in the N400 time window. The direction of the *Family Size* effect in the ERP data was the same as in the L1 ERP data of Experiment 2. Apparently, in this task situation, L1 family size facilitates word processing regardless of whether Dutch L1 speakers read in their L1 or their L2, English. Interestingly, the effect of *Family Size* seems to emerge, though not fully significant, as early as 100 ms upon stimulus presentation, and became significant in the ERP signal from 200 ms onwards. This is comparable to what was observed in the monolingual ERP data of Experiment 2.

The negative waveform observed in the N400 time window quickly shifts into a positive component in the 500-800 ms time window. *Family Size* was found to significantly affect this waveform: A more positive going waveform was observed for words with a high family size compared to cognates with a low family size. This is in line with the findings of Experiment 2. Visual inspection of the ERP suggests that this waveform is a continuation of the N400 rather than a combination of two differentiated components (N400 and LPC), as we proposed in Experiment 2, though we cannot exclude this latter possibility.

Interestingly, the ERP data showed larger negativities for cognates relative to non-cognate controls within the N400 time window. This contrasts with the facilitation effect that was observed in Experiment 3 on the same materials. The cognate facilitation effect is a well-established effect that has been observed in a large number of behavioural studies. Moreover, in a go/no-go semantic categorization study during which ERPs were recorded, Midgley et al. (2011) mainly observed less negative amplitudes in the N400 time window for cognates than for non-cognates.

However, Midgley et al. also observed more negative amplitudes for cognates than for controls at more posterior sites (Oz and Pz) of the midline column between 300 and 400 ms in the L2 block of the experiment. Interestingly, follow-up *t*-tests on our data show that the cognate effect was also only significant or marginally significant at these same posterior sites. Midgley et al. argued that the reversed cognate effect might reflect a conflict in the mapping of orthography to phonology that is exaggerated in the case of cognates due to the fact that the orthography maps onto two phonological representations. Future research should further investigate this issue.

However, from 400 ms onwards, Midgley et al. predominantly found less negative amplitudes for cognates relative to controls. The difference between the direction of the effect in the present study and the study of Midgley et al. might be attributed to task-related effects. In the latter study, participants had to read lists of words for meaning while making occasional button presses to probes belonging to a specific semantic category. No button presses to the cognate items were required, and the semantic go/no-go paradigm ensured semantic processing. In the go/no-go lexical decision task, participants were told not to press a button when they saw an English word, but only to press a button when they saw a pseudo-word. Participants were explicitly asked to judge the lexical status of the presented item in the target language and may have applied a response strategy consisting of detecting non-English cues rather than focusing on the actual lexical status of the stimulus. Any non-English lexical activation may then feed the inappropriate no-response. Thus, in the case of seeing an English-Dutch cognate, a response conflict may have arisen, because participants may have initially been inclined to press the button because the item was a correct Dutch word, but then had to inhibit this button press because the word was an existing English word as well. In the study of Midgley et al., this response competition was fully absent because the language membership of the items was not questioned.

Task differences have been observed to result in different cognate effects. For instance, in studies using the language decision paradigm, in which a participant is asked to determine whether the stimulus is a word in one language or the other, cognate inhibition effects were observed (cf. Dijkstra et al., 2010). With different experimental manipulations or designs, these studies suggest that cognate inhibition can arise when lexical information in the target language must be retrieved. Further research should show whether or not our explanation of the observed cognate inhibition effect in terms of response competition holds.

General discussion

Behavioural (e.g., Schreuder & Baayen, 1997) and MEG (Pylkkänen et al., 2004) studies on morphological family size have shown that this variable influences lexical processing. The behavioural studies suggest that the family size effect is mainly semantically driven (e.g., Schreuder & Baayen, 1997; De Jong et al., 2000). Our study addressed the role of morphological family size in L1 and L2 word processing. The aim of this study was two-fold. First, we wanted to show, for the first time, that also the ERP signal is sensitive to morphological family size effects. Second, we wanted to investigate if this sensitivity to L1 family size is restricted to L1 processing, or whether L2 processing can be influenced by it as well. There is ample evidence that in an L2 context, L1 lexical items become activated (see for an overview, Dijkstra & Van Heuven, 2002). In the present study, we investigated if this activation of the non-target language is restricted to the level of representation of the lemma itself, or whether activation is spread beyond the lemma level, to the morphological family of the activated lemma. This was done by examining family size effects in bilingual processing using both behavioural and electrophysiological measures. We investigated, if and when, during L2 cognate processing, the family members of the activated L1 cognates also become activated.

To set the stage for cross-language family size effects in L2 processing, Experiments 1 and 2 investigated family size effects in L1 processing. Experiment 1, a Dutch (L1) lexical decision task with Dutch (L1)-English (L2) bilinguals, replicated previous monolingual studies showing faster response latencies in lexical decision for Dutch words with a high family size. Exactly the same materials were used in a go/no-go lexical decision task (Experiment 2) while ERPs were recorded. As predicted, the ERP data showed an effect of *Family Size* in the N400 time window: Less negative amplitudes were observed for Dutch words with a high family size compared to words with a low family size. This effect persisted in the 500-800 ms time window with more positive amplitudes for words with a high family size. Interestingly, *Family Size* was also found to affect early processing stages as was reflected by a significant interaction between *Family Size* and *Hemisphere* showing that the effect of *Family Size* is left-lateralized. This experiment shows, for the first time, that the ERP signal is sensitive to differences in family size.

Experiments 3 and 4 investigated L1 family size effects in L2 processing, again using both behavioural and ERP measures. To study L1 family size effects in L2 cognate processing, the L1 family size was manipulated while the family size of the target (L2) language was controlled for. Importantly, the contrast in Dutch family size in Experiments 3 and 4 was comparable to those of Experiments 1 and 2. Experiment 3 showed facilitation for cognates compared to controls in terms of response speed. *Family Size* was found to modulate cognate processing: Faster RTs arose for cognates with high family size compared to cognates with low family size. This result suggests that activation of the non-target language spreads beyond the activated lemma itself, even activating family members of this non-target word. Experiment 4 revealed the same modulation of *Family Size* on cognate processing: Cognates with a higher family size showed less negative amplitudes than cognates with a high family size in the N400 time window. The effects arose in the ERP signal significantly from 200 ms onwards. Again, the effect of *Family Size* persisted in later time windows. Thus, similar to what was observed in Experiment 3, a large family size facilitated word processing. These experiments show that the family size of the L1 affects word processing even if the L1 is not the target language at that moment.

In the introduction of this paper, we argued that the direction of the family size effect in the N400 time window could differ along two hypotheses. First, more negative-going waveforms could be observed for words with a high family size compared to words with a low family size because more semantic information is activated. This would be in line with the findings of Holcomb et al. (2002) and Müller et al. (2010), who observed that words with a large number of orthographic neighbours elicit larger (i.e., more negative-going) N400 amplitudes compared to words with a smaller number of neighbours. Further, Müller et al. showed that the same pattern in the N400 effect could be observed for words with a large or small number of semantic associates.

The alternative hypothesis was that the kind of the semantic information would influence the N400 effect. Arguing that the semantics of family members are convergent with that of the target, words with a large number of family members should be easier to process than words with a smaller family size, given that more activation maps onto the same semantics. This should then translate into less negative N400 amplitudes for words with a high family size.

In the present study, we found evidence for this second hypothesis. In both the L1 and L2 ERP data, words with a large number of morphological relatives elicited more negative amplitudes in the N400 time window compared to words with a smaller family size. The discrepancy in direction of the N400 effect for morphological family size on the one hand, and orthographic and associative neighbourhood size on the other, raises an interesting point. The difference in direction of the N400 effect could reflect the sensitivity of this component to semantic convergence between target and activated items. While activating either a large number of orthographic neighbours or a large number of morphological family members should both generate a large amount of semantic activation, the activated semantic representations of the two types of words have a different relation to that of the target. The activated orthographic neighbours do not overlap in semantics with the target, while this is the case for family members. For example, the target *dog* does not share semantic overlap with its orthographic neighbours *fog* and *dot*, while morphological family members of this target such as *doggy*, *dog fight*, and *bulldog* do map on similar semantics. Thus, words with many orthographic neighbours show a larger N400 compared to words with few neighbours because more conflicting semantic information relative to the target is activated[7]. Family members, on the other hand, activate more overlapping semantic information than orthographic neighbours because they contain the target. As a consequence, they feed the activation of the semantic representation of the target, hence increasing the activation level of the target word. This will result in less negative N400 amplitudes for words with a large number of family members, because the target is processed more easily based on more semantic evidence feeding this target.

The observed larger N400 for words with a large number of semantic associative neighbours compared to words with a smaller number of semantic associates is particularly interesting, because these activated items overlap, just like morphological family members, in semantics with the target, while not being form-related to the target (as is the case for family members). For instance, the target *dog* should very likely activate semantic associates such as *animal*, *cat,* or *pet.* Though these associates converge, just like family members, with the target on a common concept, it is clear that the semantic relationship between these items and the target is much more diverse. The part of the semantic representation of the associate that overlaps with the target does not encompass the whole semantics of the target but just a small part of it. As a consequence, activating a large number of semantic associates will activate a large amount of irrelevant semantic information.

For activated family members, the semantic relationship they share with the target is in part always the same, because a part of their form overlaps completely or almost completely with that of the target (for example, *dog fight* contains the target *dog*). This means that a part of the semantics that is activated by the family members corresponds

[7] This assumption does not imply that neighbourhood size effects due to conflicting semantics should lead to inhibitory effects in behavioural experiments such as lexical decision. The commonly observed facilitation effects for orthographic neighbourhood size could be based on global lexical activation, feeding the positive response to a given target.

directly to the complete semantic representation of the target. This might boost the activation level of the target considerably. Just because of their formal overlap with the target, the activated semantics of the family members themselves are always more overlapping with that of the target than is the case for semantic associates.

The reason that associate neighbourhood size generates a different N400 effect than morphological family size should therefore reside in the fact that semantic associates, while partly feeding the semantic activation of the target, also activate a large amount of semantic information that is not overlapping with the semantics of the target. For example, a large part of the activated semantics of the associated word *cat* of the target *dog* is not dog-related at all. Therefore, activating a target with many semantic associates will generate a large amount of conflicting semantic information, which will generate a large N400 for these targets. Family members will always directly map on and hence feed the semantic representation of the target, just because they contain an element that overlaps in form with the target. A target with many family members will therefore generate a large amount of converging semantic activation and elicit less negative N400 amplitudes compared to targets with few family members.

The interpretation presented above is in line with studies that show that the N400 amplitude varies with semantic relationships between individual words in lists, when the words are attended (see for a review on characteristics of the N400, Kutas & Federmeier, 2000). Though many of these studies focus on semantic priming, they show that the N400 is sensitive to various types of semantic relationships. Importantly, the results of the present study do not contradict the interpretation of Müller et al. (2010) that more semantic activation due to the activation of orthographic neighbours or semantic associates leads to processing difficulties. Rather, the findings of this study extend the interpretation of these effects, relating it to the kind of semantic overlap between target word and activated item (cf. Carrasco-Ortiz, Midgley, & Frenck-Mestre, 2012, for an alternative explanation of differing N400 effects with respect to interlingual homophones).

Remarkably, in both data sets, significant family size effects arose around 150-200 ms in the time window preceding the N400 time window. In a linear regression analysis of ERP data obtained in monolingual visual lexical decision, Hauk, Davis, Ford, Pülvermüller, and Marslen-Wilson (2010) investigated the time course of different variables known to affect visual word processing. Effects of lexical frequency were observed that occurred at 110 ms and were left-lateralized. This lexical frequency effect was reported to reflect the familiarity of an individual word and its morphologically related forms. Moreover, they reported an effect of semantic coherence (as a predictor of whether words had a meaning consistent across the morphological families) around 160 ms that was observed in event-related regression coefficients. These findings suggest that early ERP effects before 200 ms might reflect word-form-related processes as well as lexical-semantic processes.

According to Hauk et al., the results of their analyses suggest that not only the semantic properties of a stimulus word per se are activated at early stages of processing, but also the morphological family of this word, together with the semantic properties of this family. Moreover, they argue that members of the family of a stimulus are at least partially activated at the semantic level. Our ERP data confirms this assumption. However, although the early effects of semantic coherence (i.e., the quantative measure of consistency in meaning of morphologically related word forms) observed by Hauk et al. are related to the effect of family size (i.e., the quantative measure of the number of morphological family members) observed in the present study, they might reflect different aspects of word processing. On the basis of our data, we cannot conclude whether the observed effects are lexical-semantic effects or rather effects that are purely word-form related. It is possible that the early effects only reflect formal aspects of word processing, such as familiarity of the letter string. Clearly, more research investigating early morphological effects is needed.

Interestingly, Pylkkänen et al. (2004) reported family size effects at 350 ms in the MEG signal, and argued this to be an effect affecting early stages of word processing prior to word selection. This finding is not consistent with a post-lexical account of family size. The M350 component has been proposed to be an early subcomponent of the N400, the N400 being sensitive to both lexical and post-lexical processes (cf. Pylkkänen & Marantz, 2003). In this view, the earlier effects in the N400 time window (and possibly also the effects between 250 and 300 ms) observed in the present study and the M350 effects observed by Pylkkänen et al. may reflect the same process, namely the interplay of activation between orthography, morphology, and semantics.

Further, family size effects are observed in time windows following the N400 window, until approximately 700-750 ms in the L1 and L2 data. While in the L2 data, visual inspection suggests that these late effects of family size seem to be a continuation of the N400 effect of family size, the ERP signal in the L1 data seems to contain two distinct components (N400 and LCP) that are affected by family size. Whatever the case, given that mean response latencies in the lexical decision task of Experiments 1 and 3 were shorter than 600 ms (including the motor planning of the physical response), a lexical decision about the target should already have been made at this point in time, though no button press was required for word targets in this task. Apparently, the activation of morphological family members persists after the actual lexical decision has been made.

In sum, the observed early effects lead us to conclude that the family size effect is not a pure post-lexical semantic effect and that formal aspects might be at play, while the observed effects in the N400 time window and the 500-800 ms time window confirm earlier behavioural findings that the family size effect is at least partially semantic in nature. Thus, we have shown in one single experiment without response component that the family size effect may depend on both the form and semantic relationship between target and family member. This suggests that it is a truly morphological effect.

What are the consequences of our findings for monolingual and bilingual models of word processing? First, the observed family size effects in L1 processing are in line with the MFRM model of De Jong et al. (2003). This monolingual model of morphological processing assumes that response latencies to words differ as a function of their morphological productivity (i.e., their family size). Family size effects are explained in terms of resonance of activation between a target word and the words that are morphologically related to this target: When a word has a high family size, more activation is resonated back from the activated family members to the semantic representation to which the target is linked, resulting in faster response latencies for these words compared to words with a low family size. Both the behavioural and ERP L1 data have shown that word processing is facilitated by an increased morphological productivity of words.

Interestingly, the observed family size effects in later time windows of the ERP signal, that is, after 600 ms, indicate that the process of resonance is at work even after the actual lexical decision to a target word has taken place. It suggests that the interaction between bottom-up processes and contextual information from the semantics of the target persists after the target word has been identified and selected. Because words are usually embedded in sentences and texts, activation of a wider semantic network is not unexpected in light of the fact that word meaning must be linked to and integrated in a situation model based on contextual information (cf. Van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998).

The observation that family size effects persist in the ERP data after the actual lexical decision has been made (without a physical response), suggests that family size effects are based on increased semantic activation rather than global lexical activation of family members. These two accounts could not be dissociated in lexical decision, because this paradigm always requires a response. In contrast, in a go/no-go lexical decision, no physical response to words is required, which allows us to examine any effects occurring after the lexical decision has taken place. The observed late family size effects that occur after 600 ms are not likely to reflect global lexical activation. Typically, family size effects based on global lexical activation would occur before word identification has been completed, and would not occur after the lexical decision has been made, because after word identification, activation of non-selected lexical candidates is assumed to be reset to zero (cf. Dell, 1986). In contrast, family size effects based on increased semantic activation could influence word processing even after the lexical decision has been made via the mechanism of resonance. This would indicate that at least the later effects are based on semantic activation. Nevertheless, this does not rule out the possibility that the actual lexical decision can still be based on global lexical activation. More research is needed to distinguish whether family size effects are true semantic effects and/or based on global lexical activation. While studies using progressive demasking have found no effects of family size, and argue that family size effects arise post-lexically (that is, after the target has been identified; Schreuder & Baayen, 1997), the early effects around 200 ms observed in our study suggest that the picture might be more complicated.

The observed L1 family size effect in the L2 data provides evidence in support of a language non-selective access account of word processing as proposed by the Bilingual Interactive Activation + model (BIA+; Dijkstra & Van Heuven, 2002). The BIA + model assumes parallel activation of words belonging to different languages that overlap in form. The results of Experiments 3 and 4 show that, during L2 cognate processing, L1 word representations can be co-activated due to their orthographic overlap with the target word. Moreover, these experiments showed that activation spreads beyond the word level, to the morphological family members of the non-target word. The BIA+ model does not provide a specific account for family size effects, but does assume interactive links within the lexicon between orthography and semantics. Cognates overlap in orthography and semantics, and are found to be processed faster than words that do not share both orthographic and semantic overlap with a word in the other language (i.e., non-cognate words like *bird*). If we apply the process of resonance as proposed by the MFRM model to the situation of cognates, this would lead to a facilitation for cognates with a high family size. Moreover, the net facilitatory effect of family size is expected to be larger for cognates than for non-cognate words, because the activated non-target language family members of a cognate add to the facilitation (because they are often also semantically related to the target cognate and hence activate related semantics). This is exactly what we observed. Thus, by extending the BIA+ model with this mechanism of resonance, the MFRM and BIA+ models can be integrated into one account on family size effects in bilingual word processing (see Figure 3.7).

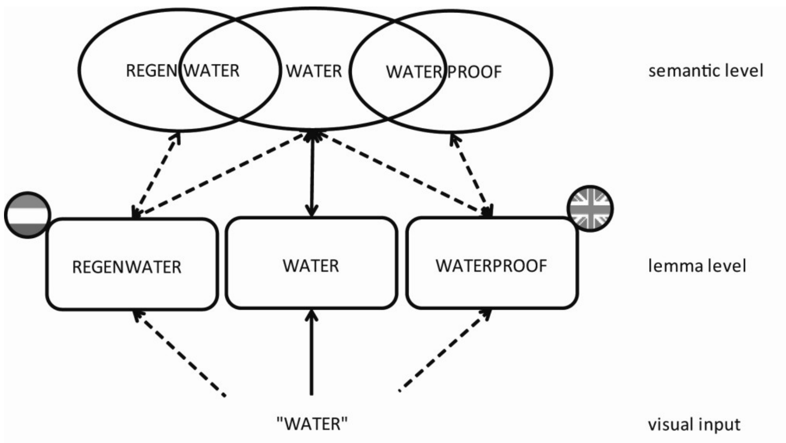

Figure 3.7. Schematic representation of the activation of the morphological family members of a Dutch-English cognate and the resonance between orthographic and semantic levels of representation.

The finding that L1 family size effects work in the same way in both L1 and L2 lexical decision suggests that information about language membership does not directly influence the family size effect in language specific lexical decision. Thus, when making a lexical decision, the activated language node in the mental lexicon does not restrict the contribution of activated non-target family members in any sense, nor does it change the direction of the family size effect. This suggests that, at least for cognates in lexical decision, activating family members simply results in more convergent semantic activation feeding the positive response to a target word. This does not mean that language membership is not important at all for the presence and direction of family size effects in cognate processing. Inhibitory effects of non-target language family size were observed in language decision, where the task requirements forced a clear decision about response language and family size fed a different response for each reading of a cognate (Mulder et al., in preparation). Future research should address this sensitivity of cross-language family size effects to language context and task requirements in more detail.

In sum, this study has shown, by using the ERP technique, that the contribution of morphological family size to word processing is substantial. Morphological family size influenced both response latencies and the ERP signal in both L1 and L2 processing, supporting the idea of resonance of activation between the target lemma and morphologically related family members within the lexicon. The results provide evidence for an integrated lexicon in which words within and across different languages are linked via fine-grained relationships and can be co-activated in parallel. The observed cross-language family size effects suggest that, during word processing, the language user takes into account all possible relevant information from both of his languages.

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Appendix

Experimental words used in Experiments 1 and 2

Words with a high Dutch family size: ijzer, koek, stoom, bloem, knoop, fiets, koorts, vrede, wand, stok, vogel, wiel, klank, plicht, poort, varken, jurk, zenuw, huid, nier, broek, vrucht, muur, stad, struik, schade, herfst, haak, jacht, hals, cijfer, zaag, mode, appel, darm, doek, fonds, zaad, molen, rente

Words with a low Dutch family size: stier, grap, hiel, mouw, pech, ober, stoep, ruzie, tapijt, kroeg, bocht, grot, keizer, riem, beker, tante, stank, pijl, poes, trui, zonde, neef, bijl, konijn, teen, touw, haast, duif, broer, kerel, reeks,minuut, spul, duim, oever, vuist, wang, lepel, bril, vijver

Experimental words used in Experiments 3 and 4

Cognates with a high Dutch family size: sport, toilet, nest, code, radio, norm, tent, model, lamp, winter, storm, gold, lung, grass, soup, lamb, silver, bible, river, rose, steam, crown, climb, flute, shoe, load, bread, apple, team, hotel

Cognates with a low Dutch family size: crisis, drama, logic, menu, mild, opera, flora, echo, truck, fruit, direct, trend, altar, symbol, pill, debate, myth, fort, flag, pilot, camel, humour, news, idol, fresh, stink, ideal, nation, paper, simple

Non-cognate controls: knife, tower, snake, crime, flower, smoke, habit, wrist, guard, kidney, fame, glory, prison, parcel, muscle, mercy, bike, wizard, cereal, tail, debt, source, torch, arrow, skill, fire, skirt, happy, damage, harm, bullet, ghost, fever, lake, wood, truth, bird, cloud, faith, guilt, silk, herb, thigh, wing, mirror, cattle, cave, donkey, duke, engine, duty, pigeon, throat, evil, with, frog, noise, horse, widow, fate

Effects of primary and secondary morphological family size in monolingual and bilingual word processing

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Chapter 4

This chapter is based on: Mulder, K., Dijkstra, T., Schreuder, R., & Baayen R.H. (under revision). Effects of primary and secondary morphological family size in monolingual and bilingual word processing.

Abstract

This study investigated primary and secondary morphological family size effects in monolingual and bilingual processing, combining experimentation with computational modelling. Family size effects were investigated in an English lexical decision task for Dutch-English bilinguals and English monolinguals using the same materials. To account for the possibility that family size effects may only show up in words that resemble words in the native language of the bilinguals, the materials included, in addition to purely English items, Dutch-English cognates (identical and non-identical in form). As expected, the monolingual data revealed facilitatory effects of English primary family size. Moreover, while the monolingual data did not show a main effect of cognate status, only form-identical cognates revealed an inhibitory effect of English secondary family size. The bilingual data showed stronger facilitation for identical cognates, but as for monolinguals, this effect was attenuated for words with a large secondary family size. In all, the Dutch-English primary and secondary family size effects in bilinguals were strikingly similar to those of monolinguals. Computational simulations suggest that the primary and secondary family size effects can be understood in terms of discriminative learning of the English lexicon.

Introduction

Reading a word is not just looking up this word in a dictionary. If it were that simple, word processing would be affected only by the number of words that share their beginnings and not by the word's more complex relationships to other words in the lexicon on dimensions such as orthographic or semantic relatedness. It turns out that during reading a word activates not only its own representation in the mental lexicon, but many other lexical representations as well, via a system of relationships that are not necessarily strictly word-form related. Words are not isolated units, but parts of larger networks. In the present study, we focus on the activation of morphological networks in the monolingual and bilingual mental lexicon during visual word processing.

Many behavioural and neurolinguistic studies have investigated the processing consequences of various relationships between words in the mental lexicon, with a great deal of attention directed towards orthographic relations between words (see Andrews, 1997, for an overview of studies on orthographic neighbourhood size). Recently, research has also focused on morphological relationships between words in the lexicon. One of these morphological relationships, called 'morphological family size', is defined as the number of morphologically related complex words in which a given word occurs as a constituent (Schreuder & Baayen, 1997). For instance, *heartless* and *heartache* are family members of the word *heart*. Words can differ considerably in their productivity in terms of the number of their morphological family members. For instance, the word *house* occurs in more than 30 morphologically related complex words (among which, for example, *house hold*, *garden house*, and *housing*), whereas the morphological family of *horizon* is restricted to only a few words (such as *horizontal)*.

Schreuder and Baayen (1997) showed that Dutch words with larger morphological families were processed faster and more accurately in a Dutch visual lexical decision task than Dutch words with smaller morphological families. The facilitatory effect of family size has been replicated for Dutch (Bertram, Baayen, & Schreuder, 2000, De Jong, Schreuder & Baayen, 2000; De Jong, 2002; Kuperman, Schreuder, Bertram, & Baayen, 2009), German (Lüdeling & De Jong, 2002), and English (Baayen, Lieber, and Schreuder, 1997; De Jong, Feldman, Schreuder, Pastizzo, & Baayen, 2002; Juhasz & Berkowitz, 2011). Moreover, several non-Germanic languages also revealed similar effects of family size (see Feldman & Siok, 1997, for Chinese; Moscoso del Prado Martín, Bertram, Häikiö, Schreuder, & Baayen, 2004; Kuperman, Bertram, & Baayen, 2008, for Finnish; Moscoso del Prado Martín et al., 2005, for Hebrew; Boudelaa & Marslen-Wilson, 2011, for Arabic). Importantly, the family size effect was observed to be predictive over and above other lexical properties such as word frequency, morpheme frequency, word length, orthographic neighbourhood size, bigram frequency (De Jong et al., 2000, Schreuder & Baayen, 1997), and age of acquisition (De Jong, 2002).

The traditional interpretation of the morphological family size effect holds that upon reading a word, many of its morphological family members become activated thanks to shared orthography, morphology, and semantics (Schreuder & Baayen, 1997). More specifically, activation is assumed to spread from a target word to its family members via direct semantic and orthographic connections. Schreuder and Baayen (1997) proposed to understand the family size effect along the lines of the multiple read-out model of Grainger and Jacobs (1996): Words that co-activate many other words (lemmas) give rise to more global lexical activation supporting a positive lexicality decision. By means of a computational simulation study, De Jong, Schreuder, and Baayen (2003) showed that read-out of global activation may not be necessary if activation is allowed to resonate between forms, lemmas, and meanings.

An unresolved question is whether activation can spread beyond immediately related concepts to concepts that are only indirectly linked to a target word. Studies of mediated priming have demonstrated that a target word such as *cheese* can be processed faster when it is preceded by a prime such as *cat* that is only indirectly related to the target in semantic memory via a mediating concept (*mouse*) than when it is preceded by a semantically unrelated prime (e.g., *table;* cf. De Groot, 1983). Mediated priming effects were observed in word naming (Balota & Lorch, 1986), in a double lexical decision task in which a lexical decision to both the target and prime was required and in which only indirectly related prime-target pairs were used, and in a single presentation lexical decision task in which the prime and target were presented with no obvious pairing and a lexical decision was required to both items (McNamara and Altarriba, 1988). However, a number of studies failed to find the mediated priming effect in standard lexical decision (e.g., Balota & Lorch, 1986; Chwilla, Kolk, & Mulder, 2000). As Chwilla et al. (2000) argued, mediated priming seems to occur only when the lexicality of both the prime and the target needs to be judged. In sum, these studies show that activation can spread beyond directly related concepts, albeit only under special experimental conditions. Applying this idea of spreading of activation to the case of family size, it is conceivable that activation spreads from immediate family members, which are directly related to the target in form and meaning, to more distant family members at greater distances in the lexical network, i.e., to words that are related to the target word only via their primary family members.

Recent studies (Baayen, 2010, and Baayen, Milin, Filipovic-Durdevic, Hendrix, & Marelli, 2011) indicate that more distant morphological relatives can influence compound processing. These studies propose a new measure, the secondary family size, as a means for gauging the relevance of more distant morphological relatives. Recall that the primary family size of a given noun contains all words, both derived words and compounds (except the noun itself) that contain that noun as a constituent. Baayen (2010) and Baayen et al. (2011) argued that although the primary family size is defined across both derived words and compound words, most of a given word's family members are compounds. In these studies, the secondary family measure was therefore operationalized on the set of compounds, and was further restricted to family members that are two-constituent compounds. In the present study, the focus is on the processing of monomorphemic words, and hence, a definition of secondary family including both compounds and derivations is applied. Informally, the secondary family size of a word can be defined as including all words that share a constituent with a word in a word's primary family, excluding the primary family members themselves (for a formal definition of secondary family size, see the Appendix). Figure 4.1 presents a schematic representation of the activation of primary and secondary family members of the target word *horse*.

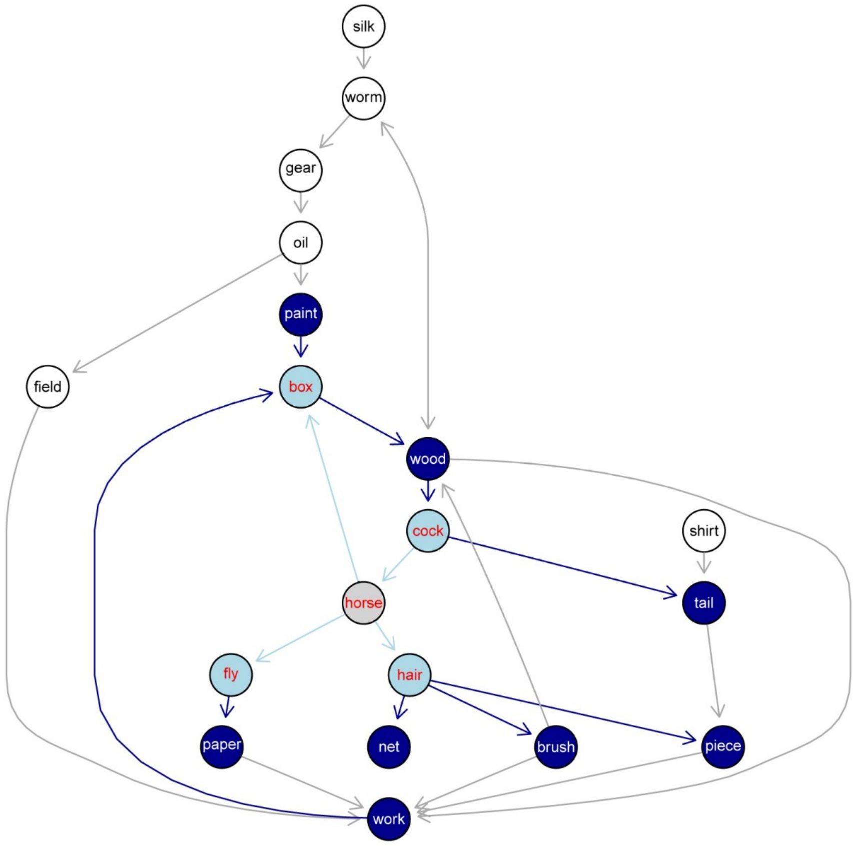

Figure 4.1. Activation of primary and secondary family members of the target word *horse*. In Figure 4.1, a target word, *horse*, is represented by a grey vertex in a directed graph. The directed edge connecting *horse* to *fly* indicates that *horsefly* is an existing compound. The constituents of the compounds in the primary family size of horse are shown with light blue vertices. If activation spreads along the edges of the graph (in both directions, the orientation of the edges only serves to indicate the order of modifier and head), then after having spread into the primary family, it might spread further, leading to the activation of further, semantically more distant, compounds such as *flypaper*, *hairbrush*, and *cocktail*. These more distant compounds are the secondary family members. In Figure 4.1, the constituents of these secondary family members (when not shared with compounds in the primary family) are represented by dark blue vertices.

If activation spreads from a target word, first into the primary family, and then on into the secondary family, the question arises whether the co-activation of secondary family members is facilitatory (just like the primary family size) or rather inhibitory. Theories restricting primary and secondary family size effects to the level of word form offer no prediction. Because activating primary family member word forms is facilitatory in lexical decision, activating even more word forms might also speed up 'yes' responses in this task. Alternatively, it is conceivable that activating many orthographically unrelated word forms (such as *hairbrush* for *horse*) would, due to feedback connections, reduce the bottom-up support from the letter layer to the word layer for the target word. For instance, the *h* and *r* in *horse* might become, due to spreading activation, more ambiguous between *horse* and *hairbrush*, and would therefore delay lexicality decisions.

However, theories seeking to explain the primary and secondary family size effects at the level of semantics make a clear prediction. The primary family members are semantically related to the target. Knowing what a *horse* is entails, for instance, knowing that horses have to deal with *horseflies*. The secondary family members tend not to be semantically related. A *workbox* is a box storing tools for sewing, a *cocktail* is a drink, and horses do not wear *hairnets*. The activation of unrelated meanings should therefore have a detrimental effect on response speed.

For response times to compounds in visual lexical decision as available in the English Lexicon Project (Balota et al., 2007), Baayen (2010) observed an effect of secondary family size, which was modulated by the size of the primary family size of the compound's head, and by the density of the compound graph (operationalized by the graph-theoretical concept of the strongly connected component, i.e., the subgraph for which it holds that any constituent can be reached by following the directed edges connecting modifiers to heads). The predicted inhibitory effect of secondary family size was present for compounds with a smaller right constituent family size, and most strongly so for compounds that were not part of the strongly connected component of the compound graph.

An inhibitory effect of secondary family size fits well within a semantic explanation of the family size effect. There is increasing evidence that the family size effect is at least partially semantic in nature. Schreuder and Baayen (1997) observed that positive correlations between family size and reaction times (RTs) increased when semantically opaque family members were excluded from the family size count (e.g., *honeymoon* is morphologically but not semantically related to *honey*; exclusion of opaque family members such as *honeymoon* from the family size count of *honey* increased the positive correlation between family size and RTs).

Moreover, De Jong et al. (2000) showed that the family size effect appeared for both regular and irregular past participles (e.g., *roei-geroeid*, 'row-rowed' vs. *v**e**cht-gev**o**chten*, 'fight-fought', even though the irregular past participle does not share the exact form with its mono-morphemic stem and other family members. Again, inclusion of a morphologically related but not semantically related form such as *vocht* (meaning 'moisture') in the family size count of *vecht* decreased the correlation between RTs and family size.

Moscoso del Prado Martín et al. (2005) reported an additional semantic characteristic of the family size effect in Hebrew. They observed that activated semantic fields of morphological roots that were related in meaning to a Hebrew word had a different effect on response latencies than unrelated activated semantic fields. In a Hebrew visual lexical decision task, Moscoso et al. not only observed the expected facilitation effect of family members that were related in meaning, but they also observed an inhibition of RTs when the number of family members that were not semantically related increased.

Finally, in an ERP study with Dutch monolinguals, Mulder, Schreuder, and Dijkstra (in press, Experiment 2) observed less negative N400 amplitudes for Dutch words with a large Dutch primary family size compared to words with a small Dutch primary family size. They pointed out that the observed pattern for activated family members is different from the ERP effects reported in the literature for orthographic neighbours and semantic associates (Müller, Duñabeitia, & Carreiras, 2010), because the latter activate semantic representations that are different or less compatible with that of the target, while primary family members always activate compatible semantic representations.

In sum, these studies show that the family size effect is at least partially semantic in nature. Moreover, the different effects for semantically related and unrelated family members observed by Moscoso et al. (2005) and Mulder et al. (in press) give rise to the hypothesis that semantic overlap between target word and family member can determine the direction of the family size effect. Apparently, if activation spreads too far out and reaches semantically unrelated words, then facilitation reverses into inhibition.

Until now, not many studies have investigated family size effects in bilinguals. During the acquisition of a second language (L2), bilinguals will learn new words and consequently start to develop morphological and semantic relationships between those words in their L2. It is therefore likely that the primary family size of the L2 starts affecting L2 word processing, even though the primary family size of words of their L2 may be not as large in the lexicon of bilinguals as the primary family size of words of their first language (L1). Moreover, if lexical activation spreads to more distant family members, as is observed in monolingual processing by Baayen (2010), even L2 secondary family members should be activated and affect L2 word processing.

Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, and Baayen (2005) investigated the role of L1 and L2 primary family size in the processing of Dutch-English interlingual homographs (e.g., *room*, meaning 'cream' in Dutch) by Dutch-English bilinguals. First, they conducted a re-analysis of available English (L2) lexical decision data from Dutch-English bilinguals by Schulpen, Dijkstra, and Schriefers (2003), which included both purely English words and Dutch-English interlingual homographs. This re-analysis revealed a facilitatory effect of L2 family size on the processing of purely English words and Dutch-English interlingual homographs. Furthermore, the interlingual homographs also showed inhibitory effects of the family size of the non-target language, Dutch (L1). The observed morphological family size effects were independent of the relative frequency of the two readings of the homographs. Interestingly, the same pattern was found when bilinguals made lexical decisions on interlingual homographs in their L1: Facilitation of the target language (Dutch) and inhibition of the non-target language (English). This study shows that bilinguals are sensitive to the primary morphological productivity of words of both the target and non-target language when reading in only one language. Moreover, the findings that activation of the non-target language family members of Dutch-English interlingual homographs in language-specific lexical decision inhibits target word processing supports the hypothesis that family size effects are mediated by semantic similarity.

Further bilingual evidence comes from Mulder et al. (in press, Experiments 3 and 4), who observed that Dutch-English bilinguals activate the cross-language (English) primary family size for Dutch-English cognates in a Dutch task context. Similar to the pattern of within-language effects observed for Dutch monolinguals (Experiments 1 and 2), a large cross-language family size led to faster response latencies in Dutch lexical decision task and less negative N400 amplitudes in a Dutch go/no-go task while ERPs were recorded. Also, the ERP effects for cross-language family size were different from effects for cross-language neighbourhood size observed in the literature and support the semantic interpretation of the family size effect that was outlined above.

The aim of the present study is to investigate whether and how extensively, during L2 word processing, activation spreads within the bilingual mental lexicon. More specifically, we want to investigate whether the secondary family size of L2 items affects L2 word processing or whether it is only the L2 primary family size that is activated. The literature on mediated priming and the secondary family size effects in the monolingual data reported by Baayen (2010) suggest that even distantly related lexical items can become activated during word processing in isolation. Moreover, the bilingual data of Dijkstra et al. (2005) show that bilinguals are sensitive to the primary morphological productivity of L2 items. However, assuming that the links between English words are less strong for Dutch-English bilinguals compared to English monolinguals, it is not evident that lexical activation in their second language spreads beyond directly related items.

Effects of secondary family size may even only affect items that have a strong representation in the bilingual lexicon, such as cognates. Cognates are words in both languages of a bilingual that share most of their form and meaning in these languages. Just because of their 'double nationality', cognates may be more strongly represented, and more easily accessed than words of similar frequency that belong to one language only. Cognates can be either identical in form (e.g., *hotel* in English and Dutch) or nearly identical (e.g., *altar-altaar* in English and Dutch, respectively). Bilingual research has shown that reading a cognate co-activates the target language and non-target language lexical representations of the cognate (see Dijkstra, 2005, for an overview of studies). In line with this observation, it has been proposed (Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010) that cognates are characterized by two overlapping orthographic representations that are linked to a (largely) shared semantic representation. The observation of a cognate effect (i.e., faster RTs to cognates than to non-cognates) can then be explained by a combination of co-activation and orthographic-semantic resonance. Reading a cognate will lead to co-activation of two overlapping orthographic representations, which will activate their corresponding primary and secondary family members in both languages. Reading a non-cognate, however, activates only one representation and its primary and secondary morphological family in only one language. As a consequence of the co-activation in cognates, which will activate a (largely) shared semantic representation, activation can pass more easily to other, more distant, items of the target language during word processing, strengthening the activation of the target language secondary family. Thus, activation of target language secondary family members is more like to be observed for cognates than for non-cognates. In addition, most co-activation is expected for cognates that have complete form overlap with words in their first language (i.e., identical cognates). Therefore, in this study, the stimulus materials will include both identical and non-identical cognates, in addition to purely English words.

In Experiment 1, we sought to replicate the effects of primary and secondary family size observed in monolingual research with our set of cognate and non-cognate items. Replicating the secondary family size effects reported by Baayen (2010) is of particular interest here, because, to date, these effects have not been replicated with new empirical data. This was accomplished by means of an English visual lexical decision task with English monolinguals. We expected that the distinction between cognates and non-cognates would be irrelevant for monolinguals, and therefore expected family size effects to affect the processing of cognates and non-cognates in the same way. In Experiment 2, the same task with the same materials was performed by Dutch-English bilinguals. To our knowledge, this is the first study that directly compares both primary and secondary family size effects in monolingual and bilingual processing. Moreover, this is the first study that addresses L2 family size effects in cognates.

After having reported the experimental results, we compare two theoretical frameworks for understanding the primary and secondary family size effects: the general framework of spreading activation and the more recently developed framework of discrimination learning. Over the years, spreading activation has proven to be a fruitful paradigm to investigate word processing, with influential interactive activation models such as IA and BIA (McClelland & Rumelhart, 1981; Dijkstra & Van Heuven, 1998), and the multiple read-out model (Grainger & Jacobs, 1996) being able to account for a wide range of effects. However, the non-interactive framework of naïve discrimination learning (Baayen et al., 2011) provides an alternative account of many previous findings on morphological processing. By means of computational simulation studies of the data of Experiments 1 and 2 with naïve discrimination learning, we will examine whether this type of approach is as successful as interactive activation models in explaining the present experimental data.

Before we turn to the two experiments and the modeling section, we will first discuss how family size measures were improved for use in our experiments.

Family Size Generation Study

A major resource for researchers working on morphological family size is the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). CELEX provides family size counts for English, Dutch, and German. These counts are highly informative and have proven to be useful in past and present-day research on family size. However, the CELEX database does not provide realistic frequency information for English spaced compounds (all have a frequency of zero) and therefore these are not included into the family size count of this database. Therefore, these counts may not provide a realistic representation of family size counts for speakers of English.

To improve the existing CELEX primary family size counts, we let Dutch (L1)-English (L2) bilinguals perform a Family Size Generation task in which they had to produce morphological family members for a list of English target words. These data were used to create a primary family size measure based on both the original CELEX count and the count obtained by the Family Size Generation task. We chose to select Dutch-English bilinguals and not English monolinguals for the generation of the family members, because the focus of the study is on family size effects in bilingual word processing. Having English monolinguals generate family members would probably result in overestimated family size counts for Dutch-English bilinguals. Inclusion of the most frequently generated spaced compounds known by bilinguals in the English family size count will likely result in a more accurate family size count for this participant group and a better prediction of response latencies in bilingual word processing. Moreover, we expect that this measure improves the available family size counts as provided by CELEX even for monolingual word processing, because (the most frequent) spaced compounds are now added to the existing count.

Method

Participants. Forty-five Dutch L2 speakers of English (mean age= 22.6 years old, SD = 3.49), mostly undergraduates at the University of Nijmegen, were paid to take part in this Generation Study. All were highly proficient in English, having learned English at school from the age of 11. All participants had normal or corrected-to-normal vision.

Materials. For the Generation Study, all word items that were to be used as experimental items in Experiments 1 and 2 were selected. A list of the items is provided in the Appendix. All items were monomorphemic nouns that did not have a homographic conversion verb. The length of the items ranged between three and eight letters.

We divided the stimuli over three lists. To obtain an equal number of stimuli in all lists and to be able to compare the lists in each version, we added some filler items that were the same in each version. The total number of items in the English lists was 50. The items of three English lists were matched on English log lemma frequency per million and log English CELEX family size as much as possible.

Procedure. Participants were tested in a noise-proof experimental room. They saw only words of one of the lists. The lists were randomized for all participants. Participants were given a list of stimulus words and were asked, for each stimulus word on the list, to generate other words in which the stimulus word could occur. The items were presented in capital letters in an Excel file on a HP Compaq Intel Core 2 computer with 1.58 GHz. Participants were asked to type the words in the fields directly following the target word. It was emphasized that they could write down a word even if they were not confident of the exact orthography of that word. Furthermore, they were told that they were allowed to skip a target word when they could not think of any words for that target word and return to that target word when they came up with new words. A time limit of thirty minutes was set to complete the task. A pilot experiment showed that this amount of time was enough for participants to respond to all the items and go through the list again to see if they could come up with some more words.

Results

For each item, we listed all family members that were generated. We did not consider inflected words (e.g., houses is not counted as a family member of *house*), and only included compounds and derivations (e.g., both *normal* and *age norm* are family members of *norm*). Finally, for each target item we counted the number of different words that were generated.

We then selected for each item those family members that were generated by at least three participants in order to include in our family size count only well-known family members and to exclude very low frequent family members. Next, we checked if these family members were present in the CELEX count, and if this was not the case, we added these items to the CELEX count. In this way, an "updated" version of the CELEX count was obtained containing family members that are nowadays commonly used but that were missing in the CELEX count. The correlation between the CELEX English family size counts and the new English family size measure (from now on, *English Primary Family Size)* combined family size measures was .87. Furthermore, the correlation of *English Family Size* with the mean lexical decision latencies from the English lexicon project (Balota et al., 2007) was -0.20. When replaced by our new measure, *English Primary Family Size*, this correlation increased to -0.29.

Discussion

The purpose of the Family Size Generation task was to improve the existing English primary family size count as provided by the CELEX lexical database. CELEX does not include spaced compounds into the English family size count. Our new family size measure, which includes the most common spaced compounds, is, as we shall see, a better motivated predictor of response latencies in both bilingual and monolingual word processing.

In Experiments 1 and 2, we applied the new English family size measure to assess family size effects in monolingual and bilingual language processing. In Experiment 1, we conducted an English lexical decision task with English monolingual speakers. The aim of this experiment was to replicate earlier monolingual research on morphological family size effects in visual word processing reporting facilitation effects of primary family size and inhibitory effects of secondary family size. Replicating the secondary family size effects reported by Baayen (2010) is of particular interest here, because, to date, these kinds of effects have not been replicated with new empirical data. In this experiment, we included both English-Dutch cognate and non-cognate items. Because the monolingual English speakers should be insensitive to the cognate status of the English items, we predicted no significant effect of cognate status and no interaction of cognate status with either primary or secondary family size.

Experiment 1 – English lexical decision with English monolinguals

Method

Participants. Twenty-eight native English speakers (mean age = 21.8 years old, SD = 3.53) were recruited at the University of Nottingham. None of the participants had any knowledge of Dutch. All participants had normal or corrected-to-normal vision. They were paid or received course credits for their participation.

Materials. The stimulus set consisted of 300 items, half of which were English words and half were non-words. All word items were selected from the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Only word items with an English lemma frequency of at least one per million in the CELEX database and a length between three and eight characters were selected. All items were mono-morphemic nouns that had no conversion verb. For each item, the English primary family size values were calculated and logarithmically transformed. The primary family size values were based on the new family size measure (*English Primary Family Size*, see Family Size Generation Study). These family size values were collinear with the values of the logarithmically transformed values of *SUBTLWF* (English SUBTLEX Frequency per million; Brysbaert & New, 2009). Recent research shows that *SUBTLWF* is a better predictor of response latencies than the English CELEX frequency measure (Brysbaert & New, 2009). In the remainder of this paper, we will use the term *English Frequency* to refer to the logarithmic transformation of *SUBTLWF*. To remove collinearity, we regressed *English Primary Family Size* on *English Frequency* and used the resulting residuals as new predictors of English family size uncontaminated by English frequency.

Secondary Family Size was operationalized on the set of bimorphemic words, including both derivations and compounds. In this respect, we slightly differ from Baayen (2010) and Baayen et al. (2011), whose family size definition was based on the processing of compounds, and therefore only included two-constituent compounds in the secondary family size count. Because the targets in our study are all monomorphemic words, a definition of secondary family size including all morphologically related words, thus including derivations, seems more appropriate. Moreover, in this way, the definitions of primary and secondary family size are more similar. The values for secondary family size were logarithmically transformed. The correlation between the measure of *English Primary Family Size* (residualized on *English Frequency*) and the measure of *Secondary Family Size* is positive, as expected, but with a magnitude or $r = .47$ ($p < 0.0001$), this correlation is small enough not to require further orthogonalization from the measure of *Primary Family Size*.

The experimental word items were 50 English-Dutch cognates, i.e., translation equivalents that overlap in form. Half of the experimental items were identical cognates (i.e., items that have complete orthographic overlap in English and Dutch, such as *hotel* and *norm*), whereas the other half were non-identical cognates in English and Dutch (e.g., *thief-dief* and *planet-planeet*). The latter items also shared their orthographic form in both languages, but the overlap was not completely identical and differed on maximally three letter positions. The degree of orthographical overlap was calculated by the Levenshtein distance measure (Levenshtein, 1966). The Levenshtein distance is the minimal number of deletions, insertions, or substitutions that is required to transform the source string into the target string. All cognates were pure noun cognates in the sense that both the English and Dutch word forms only belonged to the class of nouns. The Dutch noun frequency per million was taken from the CELEX database and was logarithmically transformed. It was made sure that these items had a Dutch noun frequency of at least one per million.

For each cognate item, the Dutch frequency and family size values were calculated. The Dutch lemma frequencies per million were extracted from the CELEX database (*Dutch Frequency*). The Dutch family size values (*Dutch Family Size*) were based on type counts of the family members listed in CELEX. Both the frequency and family size values were logarithmically transformed. The Dutch family size values were collinear with the Dutch frequency values. To remove this collinearity, we regressed the family size values on these frequency values and used the resulting residuals as a new predictor of Dutch family size uncontaminated by Dutch frequency. The Dutch secondary family size counts of the items (*Dutch Secondary Family Size*) were obtained by summing the positional family sizes of their family members. The secondary family size values were logarithmically transformed.

The cognate items were matched to 50 control items on *English Primary Family Size*, *English Frequency*, and *Length* (in letters). Moreover, the set of cognate items was matched to the set of control items on *Imageability*, *Familiarity*, *Age of Acquisition* (extracted from the MRC Psycholinguistic database; Wilson, 1988), and *English Bigram Frequency* (extracted from the database of the English Lexicon Project).

Table 4.1 displays the characteristics of the cognates and controls. The experiment also included 50 filler words and 150 pseudo-words that were matched to the experimental stimuli on *Length*, and for the filler word items also on *English Frequency*. The 150 non-words resembled English words with respect to their orthography and phonology, and were created by replacing one or more letters of existing English words. The experiment consisted of two item blocks. The presentation order of the items within a block was randomized individually and had the restriction that no more than three words or non-words could follow each other directly.

Table 4.1. Item characteristics of the experimental items used in Experiment 1.

	Identical cognate	Non-identical cognate	Control
Length	5.04	5.28	4.82
English Frequency	2.85	3.07	2.99
English Primary Family Size	2.39	2.62	2.47
English Secondary Family Size	3.68	3.34	4.79
Imageability	5.26	5.81	5.14
Familiarity	5.20	6.00	5.14
Age of Acquisition	2.35	2.82	2.51
English Bigram Frequency	8.01	8.10	8.02

Procedure. Participants performed an English visual lexical decision task. In this task, participants decide whether or not the visually presented stimulus is an existing English word by pressing a button corresponding to either the answer 'yes' or 'no'. The task was developed and carried out in *Presentation* version 13.0 (Neurobehavioural Systems, www.nbs.com) and was run on a HP Compaq Intel Core 2 computer with 1.58 GHz memory and a refresh rate of 120 Hertz. The participants were seated at a table at a 60 cm distance from the computer screen. The visual stimuli were presented in white capital letters (24 points) in font Arial in the middle of the screen on a dark grey background. Participants were tested individually in a soundproof room.

Participants first read the English instructions, which informed them that they would be presented with word strings and which asked them to push the 'yes' button if the letter string they saw was an existing English word and to push the 'no' button if it was not. They were asked to react as accurately and quickly as possible.

Each trial started with the presentation of a black fixation point '+', which was displayed in the middle of the screen for 700 ms. After 300 ms the target stimulus was presented. It remained on the screen until the participant responded or until the timeout at 1500 ms. The visual target stimulus disappeared when the participant pressed the button, or when the time limit of 1500 ms was reached, and a new trial was started after an empty black screen of 500 ms.

The experiment was divided in two parts of equal length. The first part was preceded by 20 practice trials. After the practice trials, the participant could ask questions before continuing with the experimental trials. The two parts each contained 150 experimental trials. Each part began with three dummy trials to avoid lack of attention during the beginning of the two parts. The end of the first part was indicated by a pause screen. The experiment lasted for approximately 16 minutes.

Results

Data cleaning was first carried out based on the error rate for participants and word items. All participants had an error rate of 10% or less on the word items. Therefore, no participant data were removed. The overall error rate on the experimental word items was 3.8% of the total of 2800 data points. Six word items that elicited errors in more than 15% of the trials were removed from the data set. Interestingly, these word items were all cognate words (*chaos*, *norm*, *flora*, *psalm*, *villa,* and *cigar*). RTs from incorrect responses or null responses were removed from the remaining data set (2.39% of the data points). This resulted in a data set with 2569 data points. Inspection of the distribution of the response latencies revealed non-normality. A comparison of a log transform and an inverse transform (RT = -1000/RT) revealed that the inverse transform was most successful in solving this non-normality.

Response latencies were analysed with a linear mixed effects model with subject and item as crossed random effect factors (see, e.g., Baayen, 2008; Baayen, Davidson, & Bates, 2008). We first fitted a simple main effects model to the data including all 2569 data points.

Besides *English Frequency*, *English Primary Family Size* and *English Secondary Family Size*, other predictors were considered that could affect lexical decision latencies. To assess the value of our new measure of primary family size in comparison to the original CELEX measure, we included the predictor *CELEX Primary Family Size*. Further, in order to test whether cognate items were processed differently from non-cognate items, we included a factor *Cognate* with the levels ‘cognate’ and ‘non-cognate’. Moreover, to account for possible differences between identical cognates and the other stimuli that do not have complete overlap between English and Dutch, the factor *Identical Cognate* (with the levels

Identical cognates and Other items (the latter including non-identical cognates and non-cognate controls)) was considered. As another bilingual factor, Dutch Primary Family Size and Dutch Secondary Family Size were included in the analyses to see whether the family size of another language could affect response latencies in English lexical decision. This should obviously not be the case for English monolinguals that have no knowledge of Dutch, but they could affect the responses of Dutch-English bilinguals. Inclusion of these factors increases similarity between the monolingual and bilingual analyses.

Furthermore, to be able to remove any auto-correlation from the error, we included *PreviousRT* (the logarithmically transformed response latency at the previous trial) and *Trial* (the rank of the item in the experimental list) as predictors (cf. Baayen, 2008 and Baayen & Milin, 2010). Finally, *OLD* (OLD-20; defined as the mean of the closest 20 Levenshtein Distance orthographic neighbours; see Balota et al., 2007, and Yarkoni, Balota, & Yap, 2008) was included as a predictor to account for effects of similarity between English words.

We performed a stepwise variable selection procedure in which non-significant predictors were removed to obtain the most parsimonious model. Important to note here is that the predictor *CELEX Primary Family Size* was not significant and did not correlate with with the mean lexical decision latencies. When replaced by our new measure, *English Primary Family Size*, this correlation increased to 0.20. Next, potentially harmful outliers (defined as data points with standardized residuals exceeding 2.5 standard deviation units) were removed from the data set. We then fitted a new model with the same significant predictors to this trimmed data set.

The final model incorporated three parameters for the random-effect structure: a standard deviation for the random intercept for item (SD = .09), a standard deviation for the random intercept for subject (SD = .20), and a standard deviation for the by-subject random slopes for *Trial* (SD = .05). Justification for the use of these random-effect factors was provided by likelihood ratio tests (all p-values < .05). Other random-effect parameters were tested, but were not significant. The standard deviation for the residual error was .31. Three predictors (*English Primary Family Size*, *English Frequency*, and *PreviousRT)* reached significance as main effects. In addition, an interaction between *Identical Cognate* (identical cognates versus non-identical cognates and controls) and *English Secondary*

Family Size was present. Table 4.2 summarizes the coefficients of the main and interaction effects for the resulting models. Figure 4.2 visualizes the significant partial effects of *English Frequency* (panel a), *PreviousRT* (panel b), and *English Primary Family Size* (panel c) and the interaction of *Identical Cognate* and *English Secondary Family Size* (panel d).

Table 4.2. Coefficients of the main effects and interaction effects of the final model, together with the estimate, standard error, t-value, p-value, and lower and upper 95% confidence intervals in Experiment 1. The reference value for Identical Cognate is *False*.

	Estimate	Std. Error	t-value	p-value	Left CI	Right CI
Intercept	-1.527	0.087	-17.587	0.000	-1.701	-1.354
Trial	-0.015	0.011	-1.335	0.182	-0.037	0.007
English Frequency	-0.101	0.022	-4.597	0.000	-0.144	-0.057
English Primary Family Size	-0.050	-0.023	-2.210	0.027	-0.095	-0.005
Identical Cognate *True*	-0.069	0.045	-1.520	0.129	-0.159	0.022
English Secondary Family size	-0.002	0.006	-0.338	0.736	-0.015	0.010
PreviousRT	0.078	0.019	4.064	0.000	0.040	0.116
Identical Cognate *True* : English Secondary Family Size	0.027	0.012	2.209	0.027	0.003	0.051

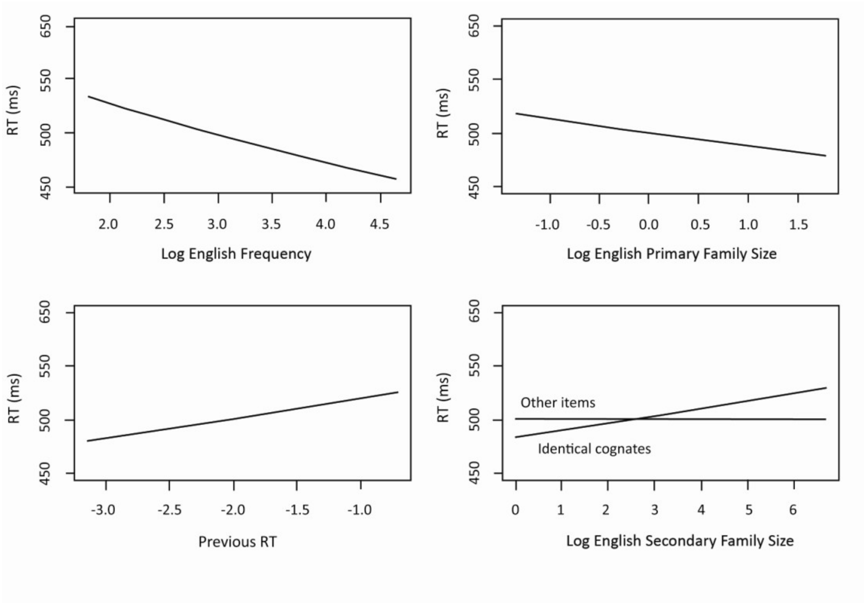

Figure 4.2. Partial effects of the significant predictors on response latencies in English lexical decision Experiment 1 (monolinguals).

Both *English Frequency* and *English Primary Family Size* had a facilitatory effect on response latencies. The main effect of *English Secondary Family Size* did not reach significance, but *English Secondary Family* size did emerge in a significant interaction with *Identical Cognate*. Furthermore, *PreviousRT* had a negative correlation with response latencies, showing that a slow response is often preceded by a slow response.

Discussion

In this experiment, we replicated the primary family size effect as reported in earlier monolingual research (e.g., Schreuder & Baayen, 1997; Baayen et al., 1997; Bertram et al., 2000; De Jong, 2002): *English Primary Family Size* had the expected facilitatory effect on response latencies. The primary family size measure based on the counts obtained from the Family Size Generation Study turned out to be a better predictor than the original CELEX measure for primary family size. Correlations with the observed response latencies were significantly higher for the new measure than for the CELEX measure (r = .20 versus r =

.00, respectively). This shows that the addition of spaced compounds to the original family size count resulted in an improved predictor of family size effects in monolingual lexical decision.

There was no main effect of *Cognate,* which showed that, overall, cognates were not processed significantly differently from non-cognates. Moreover, both *Dutch Primary Family Size* and *Dutch Secondary Family Size* did not produce significant effects. This is not surprising given the fact that the English monolinguals in our study did not have any knowledge of Dutch. Hence, they should neither process cognates differently from controls, nor should they be sensitive to the morphological productivity in Dutch of the cognate items.

There was no main effect of *English Secondary Family Size*, but this variable turned out to interact significantly with a variable distinguishing between identical cognates and other stimuli (*Identical Cognate*), showing inhibitory effects in identical cognates but not in the other stimuli. The observed direction of the effect is in line with Baayen (2010), who also observed that large secondary family sizes can slow lexical processing. Because most of a word's secondary family members are not semantically related to its meaning, activation of these secondary family members will interfere with the interpretation of the presented stimulus.

An effect of secondary family size that emerges only for the identical cognates was not predicted. This finding challenges the assumption of simple spreading of activation, because in this view activation is expected to spread to all items, to both cognates and controls. As the English monolinguals are insensitive to the cognate status of the items, an explanation of the interaction would logically not involve language membership of the items but should be sought elsewhere. Since the identical cognates, the non-identical cognates, and the controls were carefully matched for primary and secondary family size, length, and frequency (see Table 4.1), we can rule out that an imbalance in, say, primary productivity would be at issue. It might be argued that the identical cognates, many of which are of non-germanic origin, are characterized by special orthotactics (e.g., *echo, flora, volume, sultan*). However, we were not able to detect any significant differences in the mean letter unigram and bigram frequencies between the cognate subsets. Furthermore, a potential difference in phonotactics leaves unexplained why secondary family size would emerge specifically for words with relatively infrequent letter n-grams.

Importantly, the interaction of secondary family size with identical cognates does not logically entail that the monolinguals were sensitive to the historical origin of the identical cognates, but rather that these subjects were sensitive to the specific distributional characteristics of the mapping of form characteristics to meanings. Anticipating the results of our computational modeling to be discussed below, it turns out that this interaction falls out as a straightforward consequence of the distributional properties of English. First, however, we consider whether Dutch-English bilinguals show the same pattern of results: facilitation from the primary family size, but inhibition from the secondary family size for identical cognates only.

In Experiment 2, we used the same materials in an English lexical decision task, this time using Dutch-English bilinguals. Having developed morphological and semantic relationships between words from their L2, English, these bilinguals should activate morphological family members of English words. Although the morphological family size of English words might be lower for bilingual than for monolingual speakers, English primary family size is expected to affect bilingual word processing in a way similar to monolingual processing, facilitating comprehension. Moreover, if the participants are sufficiently proficient, secondary family size effects might also be visible, in which case it should be restricted to the identical cognates only.

In addition, assuming that the bilinguals activate both target and non-target representations when reading a cognate, we will consider non-target language (Dutch) primary and secondary family size effects in the set of cognates as well. Given the semantic overlap between the Dutch family members and the cognate target word, we expect that the direction of the Dutch primary and secondary family size effect patterns with the effect of English primary and secondary family size.

Experiment 2 – English lexical decision with Dutch-English bilinguals

Method

Participants. Thirty-three students of the University of Nijmegen (mean age 22.8 years, SD = 3.48) took part in this experiment. All participants had normal or corrected–to-normal vision and were native speakers of Dutch, having English as their second language. They had learned English at school from around the age of 11. Participants were paid or received course credits for participating in the experiment.

Materials. The 50 cognate and 50 non-cognate control items were identical to those used in Experiment 1. The experiment further included 50 English filler words and 150 pseudo words that were matched to the experimental stimuli on length, and for the filler word items, also on English frequency.

Procedure. The procedure of the lexical decision task was identical to the procedure of Experiment 1. After completing the lexical decision task, participants performed the LexTALE task (Lemhöfer & Broersma, 2012). This task was used to obtain a general indication of their proficiency in English in terms of vocabulary knowledge. Based on their scores, all participants could be qualified as proficient at the advanced or upper intermediate English proficiency level (mean corrected accuracy score 80% *(% correct$_{av}$;* see Lemhöfer & Broersma, 2012), range 63%-97%). Finally, participants were asked to fill out a language background questionnaire. The total session lasted approximately 25 minutes.

Results

Data cleaning was first carried out based on the error rate for participants and word items. Participants with an error rate of more than 15% on the word items were removed from the data set, which resulted in the exclusion of the data from three participants.

Eleven word items (cognates: *baron, flora, norm, cigar, pill,* controls: *dusk, cattle, thigh, cellar, lad,* and *torch*) that elicited errors in more than 15% of the trials were removed from the data set. After removal of these items, we were left with 2670 data points on the word items. RTs from incorrect responses or null responses were removed from the remaining data set (2.92% of the data points). This resulted in a data set with 2591 data points. Inspection of the distribution of the response latencies revealed non-normality. A comparison of a log transform and an inverse transform (RT=-1000/RT) revealed that the inverse transform was most successful in solving this non-normality.

As before, response latencies were analysed with a linear mixed effects model with subject and item as crossed random effects. We considered the same predictors as in Experiment 1. Because bilinguals are expected to be sensitive to non-target language frequency and non-target language family size effects, *Dutch Frequency*, *Dutch Primary Family Size*, and *Dutch Secondary Family Size* we also considered as predictors.

To obtain the simplest best fitting model, we applied the same procedure of variable selection and exclusion as in Experiment 1. Potentially harmful outliers (defined as data points with standardized residuals exceeding 2.5 standard deviation units) were removed from the data set. A new model with the same predictors was fit to this trimmed data set. The final model incorporated five parameters for the random-effects structure of the data: a standard deviation for the random intercepts for subject (SD = .18) and item (SD = .08), as well as a standard deviation for the by-subject random slopes for *Identical Cognate* (SD = .07) and *Trial* (SD = .03), and a correlation parameter for the by-subject slope for *Identical Cognate* and the by-subject random intercept (r = .30). The standard deviation for the residual error was .26.

The final model contained five numerical predictors (*English Primary Family Size*, *English Frequency*, *OLD, English Secondary Family Size* and *PreviousRT*), one factorial predictor (*Identical Cognate*) and one interaction (*Identical Cognate:English Secondary Family Size*). The relevant statistics and corresponding coefficients of the final model are reported in Table 4.3. The significant partial effects of *English Frequency* (panel a), *English Primary Family Size* (panel b), *Identical Cognate* (panel c), *English Secondary Family Size* by *Identical Cognate* (panel d), *OLD* (panel e) and *PreviousRT* (panel f) of the final model are visualized in Figure 4.3.

Table 4.3. Coefficients of the main effects and interaction effects of the final model, together with the estimate, standard error, t-value, p-value, and lower and upper 95% confidence intervals in Experiment 2. The reference value for Identical Cognate is False.

	Estimate	Std. Error	t-value	p-value	Left CI	Right CI
Intercept	-0.964	0.093	-10.313	0.000	-1.150	-0.777
English Frequency	-0.174	0.019	-9.053	0.000	-0.213	-0.136
English Primary Family Size	-0.054	0.021	-2.603	0.009	-0.096	-0.013
Identical Cognate *True*	-0.173	0.039	-4.395	0.000	-0.252	-0.094
English Secondary Family Size	0.000	0.006	0.070	0.945	-0.011	0.012
OLD	-0.071	0.023	-3.083	0.002	-0.117	-0.023
PreviousRT	0.102	0.017	6.062	0.000	0.068	0.136
Identical Cognate *True* : English Secondary Family Size	0.026	0.010	2.486	0.013	0.005	0.046

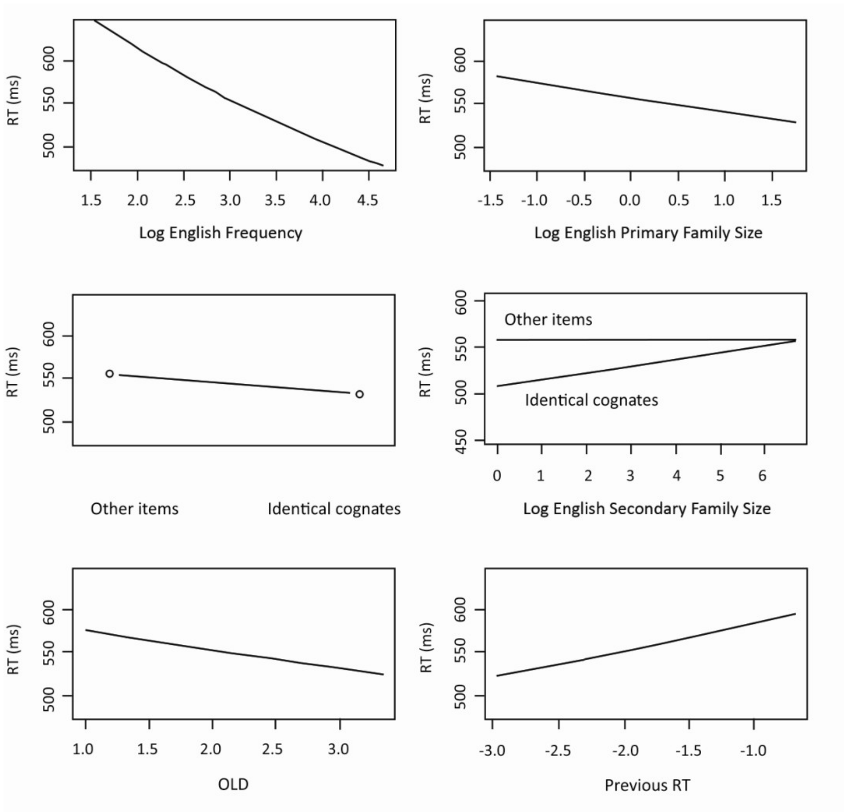

Figure 4.3. Partial effects of the significant predictors on response latencies in English lexical decision Experiment 2 (bilinguals).

As expected, we observed facilitatory effects on response latencies for both *English Frequency* and *English Primary Family Size*. Moreover, there was a significant interaction between *Identical Cognate* and *English Secondary Family Size*, showing inhibition for identical cognates with increasing English secondary family size. The model did reveal a processing advantage for cognates in comparison to non-cognate controls. This facilitation effect was exclusively carried by the identical cognates: There was no significant difference between non-identical cognates and controls (hence the inclusion of *Identical Cognate* in the final model rather than *Cognate*). Finally, *PreviousRT* and *OLD* emerged as significant predictors of response latencies. The inhibitory effect of *PreviousRT* shows that items are responded to slower when the response latency of preceding word item is high, while the facilitatory effect of *OLD* reveals a processing advantage for words with few close orthographic neighbours[8]. Finally, the positive correlation parameter for the by-subject random intercepts and random slopes for *Identical Cognate* indicate that slower participants responded less quickly to identical cognates.

Discussion

The results of Experiment 2 replicate the monolingual pattern observed in Experiment 1 with respect to both English primary and secondary family size. *English Primary Family Size* had a facilitatory effect on response latencies. This result extends the observed English primary family size effects in Dutch-English bilinguals of Dijkstra et al. (2005) on the processing of Dutch-English interlingual homographs in English lexical decision to the situation of cognates. Importantly, this effect shows that the bilinguals in our study were sensitive to morphological and semantic relationships for these words in their L2 and that they are sensitive to the morphological productivity of these L2 words during reading. There was no indication that English primary family size effects varied with the degree of form overlap with Dutch words, since no significant interaction between *English Primary Family Size* and either *Cognate* (cognates versus non-cognates) or *Identical Cognate* (identical versus other items) was observed.

Further, as expected, the bilinguals were sensitive to the cognate status of the stimuli. A cognate facilitation effect was observed that was entirely driven by the identical cognates and was absent for non-identical cognates. This dissociation between identical and non-identical cognates is in line with predictions made by localist connectionist models like BIA+ that predict a gradual decrease in response latencies with an increase in similarity for non-identical cognates and a steep decline in response latencies going from

[8] However, Yarkoni, Balota, and Yap (2008) observed that OLD-20 produced a positive coefficient in their monolingual data. In other words, faster responses were observed when words are more similar to other words. In our bilingual data, the reverse pattern was observed (see also Ferrand et al., 2011, who observed that OLD-20 had little influence on the processing of French monomorphemic words tested in Chronolex). The discrepancy between these results illustrate the inconsistency in findings reported in the literature concerning effects of orthographic similarity. These inconsistencies may be due to several factors, including stimulus characteristics.

non-identical to identical cognates. This prediction was confirmed by bilingual lexical decision data of Dijkstra, et al. (2010; see also Van Assche, Duyk, Hartsuiker, & Diependaele, 2009). However, it should be noted that more than two-thirds of our non-identical cognates differed on two or three letter positions (e.g., *toma**to** – toma**at***). This suggests that the amount of overlap in these non-identical cognates may have been too small to trigger a cognate facilitation effect for these items.

Importantly, similar to what was observed in the monolingual data, there was a significant interaction between *Identical Cognate* and *English Secondary Family Size*, revealing longer response latencies for identical cognates with a large secondary family size. This shows that, even though bilinguals process words in their non-dominant language, they are sensitive to a larger chain of morphological relations, going beyond the primary family size. The finding that the facilitation for identical cognates relative to non-identical cognates and controls was attenuated for identical cognates with a large secondary family size can be explained by assuming a semantic origin of family size effects. The activated secondary family members of identical cognates are semantically unrelated to their target, and hence, constitute activated semantic noise. When the secondary family of an identical cognate is large, slower responses are produced relative to identical cognates that activate less semantically incongruent information. Again, similar to what was observed in the monolingual data, the question arises of why the secondary family size effect is only observed for identical cognates and not in non-identical cognates and controls. Anticipating the results of our computational modeling to be discussed below, we argue that the observed interaction is a consequence of the distributional properties of English.

Interestingly, no effects of *Dutch Primary Family Size* and *Dutch Secondary Family Size* were observed. This could be due to the fact that in this experiment, the English family took away part of the effect of Dutch family size ('the winner takes it all'). We argue that cross-language family size effects are likely to be found in a paradigm in which the family size of the target language is kept constant, and in which the family size of the non-target language is contrasted. A recent study by Mulder, Schreuder, and Dijkstra (in press) on cross-language family size effects using behavioural and ERP measures indeed showed these cross-language effects in lexical decision on cognates when the family size of the target language was kept constant[9].

A joint analysis of Experiment 1 and Experiment 2, with the same random effects structure as for Experiment 2, supported the presence of an effect of *OLD* in the second but not the first experiment (t = -2.7). It also supported a reduction in the magnitude of the effect of *Identical Cognate* for the monolinguals (t = -4.4). However, with increased power, the main effect of *Identical Cognate* reached significance (t = -2.2), indicating that, surprisingly, identical cognates may have a processing advantage even for monolinguals. The interaction of *Identical Cognate* by *Secondary Family Size* (t = 3.2) was not modulated further by an interaction with *Language* (monolingual/bilingual), indicating that across both experiments, the magnitude of the effect of S*econdary Family Size* was highly similar, and restricted to identical cognates. The joint analysis further revealed that bilinguals responded less quickly than monolinguals (t = 6.39), and that the effect of word Frequency was stronger for the bilinguals (t = -3.49). A similar reduction in the magnitude of the frequency effect as a function of response speed was observed by Baayen and Milin (2010) within a monolingual context across subjects.

In the Introduction, we asked whether the observed English family size effects are due to the resonance of activation between family members and targets in the lexicon, or whether these effects can be explained by more general learning principles applied to speakers' experience with the words of their language. In the following section, we will first discuss how interactive activation models account for the observed effects. Then, we present an alternative explanation in terms of computational simulations of the data of Experiments 1 and 2 with a model that works with just a single forward pass of activation, naïve discrimination learning.

[9] Note, however, that cross-language effects of Dutch orthographic neighbourhood size were observed in English lexical decision with Dutch-English bilinguals in a factorial design in which both the English and Dutch neighbourhood for English non-cognate words were varied (Van Heuven, Dijkstra, & Grainger, 1998). More research is needed to clarify discrepancies between different cross-language effects.

Simulation study

Within the framework of spreading activation, the MFRM model (Morphological Family Resonance Model; De Jong, Schreuder, & Baayen, 2003) was a first attempt to specifically model family size effects. This monolingual interactive activation model explains family size effects by means of resonance between lemmas (see also Schreuder & Baayen, 1995) and the semantic and syntactic representations to which these lemmas are linked. When a semantic representation of a target word is linked to many associated lemmas (primary family members), a large amount of activation spreads back and forth between this semantic representation and the associated lemmas, gradually increasing the shared semantic activation and the activation level of the target lemma. Such resonance within the morphological family will thus amplify the rate at which the activation of the target lemma increases, speeding up recognition.

While this assumption of resonance of the model can account for the observed facilitation effect of primary family size, it cannot account for the inhibitory effect of secondary family size. Baayen (2010) argued that this inhibitory effect arises because secondary family members generally activate semantic representations that do not overlap with that of the target word, under the assumption that lexical decision involves discrimination between semantically relevant and irrelevant meanings. Thus, activation of secondary family members such as *horse power* does not lead to faster responses to the target *work*, because their activated meaning will not strengthen the activation level of the target but rather compete with it. In interactive activation models, such as MFRM, resonance between morphological family members will always lead to facilitatory effects of family size. The MFRM fails to predict the inhibition from the secondary family size, and also fails to provide an indication of why this effect would be restricted to identical cognates.

There are at least two ways in which interactive activation models might be adjusted to make the right predictions. The first possibility is to assume that identical cognates are characterized by two morphemic representations (rather than one), which are connected by inhibitory links. Recent evidence on French-English orthographically identical cognates from Peeters, Dijkstra, and Grainger (in press) suggests that this is a viable possibility for identical cognates. By adding inhibitory links between identical cognates, and by removing the links between non-identical cognates and control translation equivalents, the observed pattern of results (inhibition for identical cognates, no facilitation from secondary family size elsewhere) can be obtained. The second option lies in considering a task-decision system that can base its decisions on subsets of the activated representations, for instance, only on the basis of those semantic representations that are directly compatible with the target word. This suggestion would be in line with electrophysiological evidence from Mulder et al. (in press), who argue that ERP effects for family size are different from ERP effects for orthographic neighbourhood size and associative neighbourhood size because of their semantic overlap with the target word.

Instead of explaining the effects of primary and secondary family size in terms of interactive activation and task-decision level effects, in this paper, we can ask whether these effects can also be understood as a consequence of discrimination learning. Baayen et al. (2011) proposed a model, the naïve discriminative reader (NDR), that is a simple two-layer network with as (localist) input units letter unigrams and bigrams, and as (localist) output units, lexical meanings. In this model, there is a single forward pass of activation, from the input units to the output units. The model is a decompositional model in the sense that complex words and phrases are decomposed at the semantic level into the meanings of their constituents (e.g., *tea trolley* into *tea* and *trolley*).

The activation of a simple, mono-morphemic, word's meaning is obtained by summation over the weights from its letter unigrams and bigrams to its meaning. The activation of complex words and word n-grams is obtained by summation over the activations of the component meanings. Reaction times in the visual lexical decision task are modeled as inversely proportional to this (summed) activation. The model does not posit any separate representations for morphemes, complex words, or phrases. Nevertheless, it correctly captures whole word frequency effects, stem frequency effects, and phrase frequency effects (see Baayen, Hendrix, & Ramscar, 2013). The model is theoretically anchored in the theory of discrimination learning (Wagner & Rescorla, 1972; Ramscar, Yarlett, Dye, Denny, & Thorpe, 2010), as formalized by the Rescorla-Wagner equations (see Appendix).

These equations, which formalize a substantial body of research on animal and human learning, characterize the strength of the association of a cue to an outcome as a complex dynamic system, the behaviour of which changes over time as a function of past experience. The association strengths between cues and outcomes increase or decrease depending on how well the cues predict a given outcome. The magnitude of the changes in association strength for a given cue and outcome are smaller when there are more cues present at a learning trial. The NDR model actually estimates the association strengths (weights) of cues (letters and letter bigrams) to outcomes (meanings) by means of the equilibrium equations for the Rescorla-Wagner equations derived by Danks (2003), obviating the need to simulate the learning process step by step. This opens the way for efficient estimation of the weights directly from large corpora.

It is worth noting that the weights are completely and exclusively determined by the distributional properties of the input. In other words, estimation of the weights is deterministic given the model input, typically words (or word n-grams) and their frequency of occurrence in a corpus or lexical database. For monomorphemic words, such as the words examined in the present study, the estimated activation of a given word's meaning proceeds without the intervention of free parameters. The activation of a word's meaning is completely and exclusively determined by the weights from that word's letter unigrams and bigrams to its meaning, which in turn are determined completely and exclusively by the corpus from which the weights are estimated.

The NDR model differs in several aspects from connectionist models such as the triangle model of Harm and Seidenberg (2004). First, the triangle model is more comprehensive, as it models the relation between orthography and pronunciation. The NDR in its current implementation therefore offers an implementation of only a part of a much richer cognitive system. Second, the NDR model is a localist model that does not make use of hidden layers, and it does not seek to understand higher-order generalizations in terms of patterns of activation over hidden units (see, e.g., Elman, 1990; McClelland & Rumelhart, 1986). Third, the NDR model learns from `raw' language data; no transformations of frequency such as used by the triangle model (equation 6) of Harm and Seidenberg (2004) are required. The NDR model has in common with the triangle model that it seeks to understand lexical processing without positing hierarchies of discrete form units for morphemes and words mediating the mapping from letter sequences to meaning.

The primary family size effect arises in the NDR model because a word's morphological family members provide a consistent learning environment that helps strengthen the weights from the word's letter unigrams and bigrams to its meaning. For instance, *teapot* and *teasing* both contain the orthographic string *tea*. In the case of *teapot*, the model strengthens the weights from the unigrams and bigrams of *tea* to the meaning 'tea', whereas in the case of *teasing*, the weights to 'tea' are decreased. The greater the number of family members, the stronger the weights from the letter unigrams and bigrams to 'tea' become.

Understanding the effect of secondary family size is less straightforward. For compounds, Baayen (2010) observed complex non-linear interactions of secondary family size with head family size and membership of the strongly connected component of the English compound graph. Only a partial explanation of the secondary family size was presented, based on the observation that the orthographic similarity of modifier and head co-varied with the predictors in the interaction.

For monomorphemic words, the effect of family size has not been studied within the framework of naïve discrimination learning. Furthermore, the explanations suggested for compounds do not carry over to simple, monomorphemic, words. If the NDR correctly predicts a secondary family size effect for the words used in Experiments 1 and 2, then the effect must be due to the distributional properties of the words in the language in interaction with discrimination learning.

Simulation Experiment 1

For Experiment 1, a naïve discrimination network was set up for 27049 orthographically distinct lemmas with up to 10 letters from the CELEX lexical database, which jointly represent 18.1 million word tokens. The weights from the 721 letter unigrams and bigrams to the 16539 different constituent meanings were estimated using the equilibrium equations of Danks (2003), using the *ndl* package of Arppe, Milin, Hendrix, and Baayen (2011). The activations of the word meanings were obtained by summation over the weights from the letter unigrams and bigrams in the orthographic input to these meanings. Excellent results are already obtained when simulated reaction times are defined as minus the logarithm of the activations. The logarithmic transform removed most of the skew from the distribution of activations, and the change of sign is motivated by the straightforward consideration that words that have been learned better (greater activation) can be responded to faster (shorter latency). Slightly improved results ensue when not only the target word's activation is taken into account, but also the summed activations of competitors, which is expected to speed responses (cf. the multiple read-out model of Grainger & Jacobs, 1996). To this end, we estimated from the data an activation threshold $\theta = 0.092$ such that the summed activation of all meanings (except the target meaning) above this threshold correlated maximally with the observed by-item mean response latencies. The resulting activation, α_θ, is a second predictor of the response latencies, along with the activation of the target meaning α_{target}. In order to estimate the relative weight of these two predictors, we made use of a linear model regressing observed reaction time on α_{target} and α_θ,

$$\text{log observed RT} \sim \beta_0 + \beta_1 \log(\alpha_{\text{target}}) + \beta_2\, \alpha_\theta \qquad (1)$$

resulting in the estimates 0.0124 for $\log(\alpha_{\text{target}})$ and -0.04577 for α_θ (both $p < .05$). Simulated reaction times were defined as the fitted values of this regression model.

In order to compare the simulated latencies with the observed latencies, we calculated mean RTs for Experiment 1, which were also log-transformed. The correlation between the observed and simulated reaction times was 0.32 ($t(92) = 3.20$; $p < 0.01$).

In order to evaluate the extent to which effect sizes are comparable for the observed and simulated reaction times, we regressed the simulated latencies on the predictors that reached significance in the analysis of the observed latencies in Experiment 1: word frequency, primary family size count, secondary family size, cognate status (identical, non-identical, control) and cognate status by secondary family size. Figure 4.4 plots the coefficients (excluding the intercept) of the model fitted to the simulated latencies on the horizontal axis, and the coefficients of the model fitted to the observed latencies on the vertical axis. Table 4.4 presents the coefficients of the model fitted to the simulated latencies along with their corresponding *t*-value and *p*-value.

Table 4.4. Coefficients of the main effects and interaction effects of the model of Simulation Study 1, together with the estimate, standard error, t-value, p-value, and lower and upper 95% confidence intervals.

	Estimate	Std. Error	t-value	p-value
Intercept	6.757	0.747	9.041	<0.0001
English Frequency	-1.036	0.232	-4.466	<0.0001
English Primary Family Size	-0.472	0.238	-1.980	0.051
Cognate*Identical*	-0.360	0.527	-0.683	0.497
Cognate*Non-identical*	-0.058	0.499	-0.117	0.907
English Secondary Family Size	-0.026	0.081	-0.324	0.747
Cognate*Identical* : Secondary Family Size	0.168	0.136	1.237	0.220
Cognate*Non-identical* : Secondary Family Size	0.046	0.140	0.327	0.744

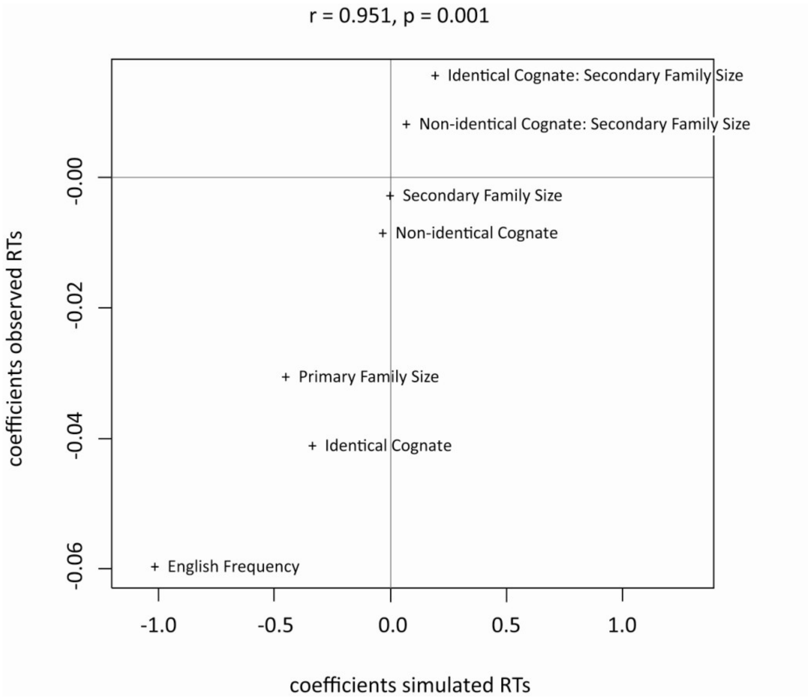

Figure 4.4. Simulated and observed coefficients for the regression models fitted to Experiment 1.

The correlation of the two sets of coefficients was 0.95 ($t(5) = 6.84$; $p = 0.001$). With just 94 items, only the coefficients of frequency and family size reached significance for the simulated latencies. However, the relative effect sizes are estimated accurately, which indicates that the effects of frequency, primary and secondary family size, as well as cognate status, can all be understood as arising in a dynamic system based on simple and well-understood principles of learning that is exposed to the distributional properties of English form to meaning mappings.

It is worth noting that virtually the same results are achieved by a model that has no free parameters whatsoever, i.e., by a model that takes only the activation of the target meaning into account. The full model, however, fits well with earlier work on multiple-readout of evidence for lexicality. The present model shows that the insights originally formulated within the interactive activation framework can be integrated within the framework of naïve discrimination learning.

To see why an effect of secondary family size arises in the model, we first call attention to the pervasive role of compounding in structuring the English lexicon. Compounding is the most productive word formation process in English, and most familial ties are carried by compounds. For instance, *tea* and *bus* are secondary family members through a morphological chain carried by two compounds, *tea-trolley* and *trolley bus*. The secondary family size effect hinges on the links in such chains, in the present example, *trolley*. When *trolley* co-occurs with *tea*, the weights from its unigrams and bigrams to the meaning 'tea' are strengthened. Whenever *trolley* occurs in *trolley bus*, the weights from *trolley* to 'tea' decrease and for 'bus' are strengthened.

More specifically, the weights of *trolley* to 'tea' co-determine the weights of *tea* to 'tea' through the sums in the Rescorla-Wagner equations $\sum_{\text{PRESENT}(C_j,t)} V_j$ in equation (3) of the Appendix. When *trolley* occurs in few other compounds, the letter unigrams and bigrams of *trolley* will contribute little to these sums for the outcome 'tea', other things being equal. As a consequence, the change in the weights on the connections from the letter unigrams and bigrams of *tea* to the meaning 'tea' will not be affected much. However, when *trolley* occurs in many other compounds, and develops negative weights to 'tea', then the connection weights of *tea* to 'tea' will be adversely affected. With reduced weights, activations decrease, and hence simulated RTs for 'tea' increase.

We cannot offer a detailed explanation, however, of why the effect of secondary family size is restricted to the identical cognates, both for monolingual speakers of English, for the simulation, and as will become apparent below, for Dutch-English bilinguals. Apparently, the co-occurrence patterns of orthographic cues and meanings in English are such that in the course of learning, identical cognates acquire a processing advantage that decreases with increasing secondary family size.

Simulation Experiment 2

For the modeling of Experiment 2, we explored two different modeling strategies. The first strategy pursues the idea that the experience with Dutch and English is completely merged into a single unified network. The second strategy explores the possibility that Dutch and English have separate networks that are accessed in parallel.

Both strategies make use of the same English instance base as was used for Experiment 1, complemented by a Dutch instance base that we also derived from CELEX. As for English, only lemmata with less than 11 letters were included, resulting in an instance base with 29802 unique lemmata representing 33.7 million word tokens, and comprising 9486 different constituent meanings.

When it is assumed that English is integrated into the network of Dutch (strategy 1), the weights are calculated from the combined Dutch and English instance bases. Within this joint instance base, we assigned the same meaning representations to the identical and non-identical cognates in both languages. We defined simulated latencies as minus the log of the activation (-log(a)), as in the simulation study of Experiment 1, resulting in a correlation with the observed latencies of 0.29 ($t(90) = 2.929$; $p = 0.0043$).

For the bilingual latencies, further inspection indicated a multiple read-out approach to improve results, as was the case for Experiment 1**.** The summed activation of meanings other than the targeted meanings exceeding an activation threshold of 0.31 turned out to co-predict the observed response latencies in a linear model regressing observed RT on -log(a) ($\beta = 0.025$; $p = 0.0004$) and the activation α_θ exceeding the activation threshold ($\beta = -0.078$; $p = 0.0084$).

The activation α_θ was orthogonal to the lexical predictors, and captures subjects' response strategies. It was estimated from the data by regressing the observed RTs on α_θ for a range of thresholds and selecting that threshold value for which the largest (negative) correlation was observed.

We then regressed α_θ out of the observed RTs. The model regressing the denoised RTs on the lexical predictors provided a slightly better fit (the AIC improved from -232 to -237). The correlation of the denoised RTs and the activations of the meanings -log(a) was 0.35 ($t(90) = 3.51$; $p = 0.0007$). Note that as a consequence of this denoising, the model for the Dutch-English bilinguals has two free parameters, namely, the intercept and slope used to regress α_θ out of the observed RTs.

Next, we examined whether the relative effect sizes for the simulated latencies resemble the effect sizes for the observed latencies. We used the same model specification as for Experiment 1, regressing the simulated latencies on word frequency, primary and secondary family size, cognate status (identical, non-identical, control), cognate status by secondary family size, and OLD. Coefficients for observed and simulated latencies were highly correlated ($r = .835$; $p < 0.01$). Table 4.5 presents the coefficients of the model fitted to the simulated latencies along with their corresponding *t*-value and *p*-value.

Table 4.5. Coefficients of the main effects and interaction effects of the model of Simulation Study 2a, together with the estimate, standard error, t-value, p-value, and lower and upper 95% confidence intervals.

	Estimate	Std. Error	t-value	p-value
Intercept	9.998	0.926	10.801	<0.0001
English Frequency	-1.359	0.222	-6.125	<0.0001
English Primary Family Size	-0.472	0.238	-1.982	0.051
Cognate*Identical*	-0.865	0.500	-1.730	0.087
Cognate*Non-identical*	0.563	0.504	1.117	0.267
English Secondary Family Size	0.025	0.081	0.313	0.755
OLD	-1.048	0.261	-4.010	0.0001
Cognate*Identical* : Secondary Family Size	0.089	0.127	0.697	0.488
Cognate*Non-identical* : Secondary Family Size	-0.019	0.135	-0.138	0.891

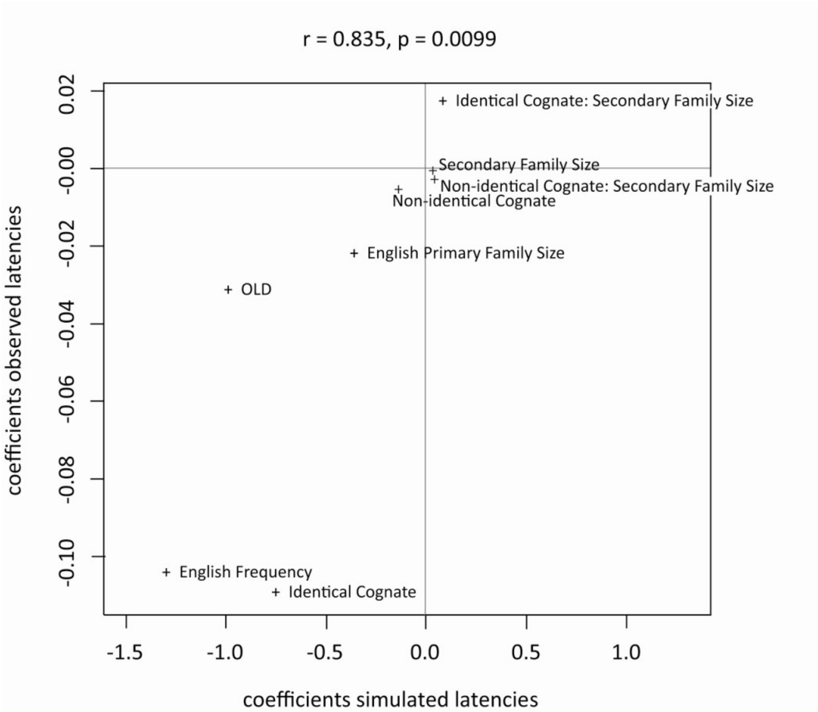

Figure 4.5. Simulated and observed coefficients for the regression models fitted to Experiment 2, using a single integrated network.

However, Figure 4.5 clarifies that the effect size of secondary family size for identical cognates status is much too small. This may in part be due to a non-optimal coding of translation equivalents in the morphological families of the two languages. Working with this model, however, leads us to think that the Dutch system in this bilingual model is acting as a source of noise masking the effect of the English system that was visible for the monolinguals.

We therefore also explored strategy 2, according to which Dutch and English are learned in two separate networks. When a word is read, its orthographic cues (letter unigrams and bigrams) are activated. These cues activate meanings in both networks. For a given input, say *frog* ('kikker'), with orthographic cues (*f, r, o, g, #f, fr, ro, og, g#*), the activation of the meaning 'frog' is calculated for English, by summation over the weights from the cues to the meaning in the English lexicon, resulting in the English activation α_E. The activation of the corresponding meaning in Dutch, α_D, was obtained in the same way. Note that strategy 2 remains compatible with the hypothesis of non-selective access, as both networks are accessed in parallel.

For each network, we calculated an activation threshold, such that the summed activation of non-targeted meanings with activations exceeding this threshold correlated maximally with the response latencies. As for the preceding simulations, the summed activation for Dutch, $\alpha_{\theta,D}$, turned out to be a significant predictor of the response latencies. This was not the case for the summed activation for English**,** however. Log-transformed simulated reaction times were defined as

$$\text{log simulated RT} = -0.0107 \log(\alpha_D) - 0.01903 \log(\alpha_E) + 0.0291\ \alpha_{\theta,D}. \qquad (2)$$

The three weights, the free parameters of this model, were obtained by means of the linear regression model

$$\text{log observed RT} \sim \beta_1 \log(\alpha_D) + \beta_2 \log(\alpha_E) + \beta_3\, \alpha_{\theta,D}. \qquad (3)$$

The correlation between the by-item observed and simulated reaction times was 0.33 ($t(90) = 3.37$, $p = 0.0011$), indicating a good fit at the item level.

Interestingly, the coefficient of $\alpha_{\theta,D}$ was positive, indicating that Dutch-English participants doing lexical decision in English are slowed by the activation of inappropriately activated meanings in their mother tongue. The positive slope of $\alpha_{\theta,D}$ for bilinguals contrasts with the negative slope of the corresponding activation for monolinguals.

For evaluating goodness of fit at the level of effect sizes, we inspected the correlation between the coefficients of the regression models fitted to the observed and expected RTs, which indicated a satisfactory fit ($r = .93$, $t(6) = 6.28$, $p < 0.001$, see Figure 4.6). Furthermore, those and only those coefficients that reached significance for the observed latencies also reached significance (all $p < 0.10$, i.e., significant in the expected direction) in the model for the simulated latencies. Table 4.6 presents the coefficients of the model fitted to the simulated latencies along with their corresponding *t*-value and *p*-value.

Table 4.6. Coefficients of the main effects and interaction effects of the model of Simulation Study 2b, together with the estimate, standard error, t-value, p-value, and lower and upper 95% confidence intervals.

	Estimate	Std. Error	t-value	p-value
Intercept	6.433	0.017	377.556	<0.0001
English Frequency	-0.023	0.005	-4.453	<0.0001
English Primary Family Size	-0.012	0.006	-2.046	0.044
Cognate*Identical*	-0.023	0.012	-1.908	0.060
Cognate*Non-identical*	0.001	0.012	0.074	0.941
English Secondary Family Size	-0.001	0.002	-0.598	0.551
OLD	-0.015	0.006	-2.454	0.016
Cognate*Identical* : Secondary Family Size	0.005	0.003	1.742	0.085
Cognate*Non-identical* : Secondary Family Size	-0.0001	0.003	-0.017	0.987

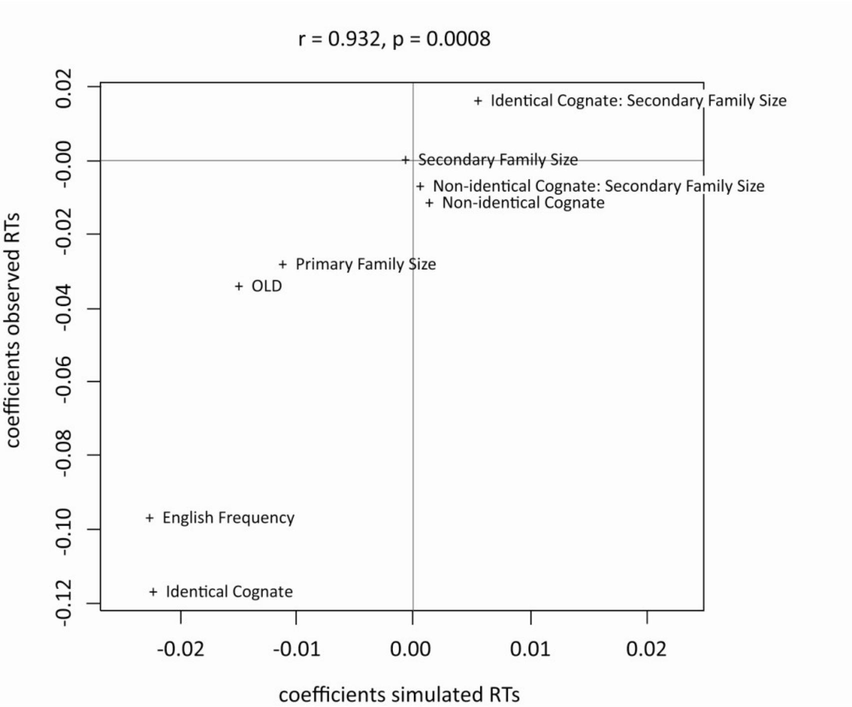

Figure 4.6. Simulated and observed coefficients for the regression models fitted to Experiment 2, using two separate networks.

Strategy 2 clearly leads to a superior model, although at the price of one additional free parameter. The improved results indicate that the Dutch and English networks are likely to be subject to domain-specific learning. However, the simulations with the NDR are based on task-specific data of a particular target language. It can therefore not be excluded that task-specific mechanisms have affected learning. More simulations are needed to clarify this.

In summary, naïve discrimination learning is successful in accounting for primary and secondary family size effects in both monolingual and bilingual processing. Importantly, the NDR model reproduces the interaction between secondary family size and identical cognate status observed across both experiments. Furthermore, it also captures the processing advantage of identical cognates, even for monolinguals (an effect that the joint analysis of both experiments revealed to be robust across the two groups of participants). The good fits obtained indicate that the effects of cognate status and family size (both primary and secondary) can be understood as arising from a simple learning system (as defined by the Rescorla-Wagner equations) that is exposed to language use. It is also worth noting that a joint analysis of the simulated latencies for Experiment 1 and Experiment 2 reveals a significant interaction of word frequency by language, with a reduced frequency effect for monolinguals ($p = 0.04$), replicating the same interaction for the observed latencies.

General discussion

The aim of this paper was to investigate the co-activation of lexical representations in the bilingual mental lexicon. Lexical representations can be related in many ways. In terms of their orthography or/and phonology, lexical representations might share a part or even their complete form (e.g., the English word *book* and Dutch word *boek*). At the semantic level, lexical representations might overlap in meaning (e.g., the English word *bicycle* and Dutch word *fiets*). When there is overlap in both form and meaning, lexical representations might also be related in theirs of their morphology (e.g., the English words *book* and Dutch words *bookcase, boek,* and *boekenkast*). In this paper, we have explored the degree to which these different forms of relationships play a role in bilingual word processing. We addressed this issue by looking at primary and secondary L2 family size effects (due to morphological and semantic overlap) on the processing of cognates by Dutch-English bilinguals.

We first tested English monolinguals on the selected stimulus materials with more precise primary family size counts in a lexical decision task (Experiment 1). The new primary family size measure turned out to be a better predictor than the original CELEX family size counts. An overall facilitatory effect of primary family size was observed; a secondary family size effect was observed for identical cognates only. A higher English secondary family size led to inhibition for identical cognates.

In the data for Dutch bilinguals, facilitatory English primary family size effects were observed for both cognates and English control items. These results demonstrate that

Dutch bilinguals are sensitive to the primary morphological productivity of L2 words, extending the results of Dijkstra et al.'s (2005) study on interlingual homographs (e.g., words that share their form but not their meaning in two languages) to the situation of cognates. Dijkstra et al. observed facilitatory effects of the primary family size of the target language in both English and Dutch lexical decision. Our study replicated this effect for cognates.

Further, an important finding of our study is that Dutch-English bilinguals were even sensitive to the secondary family size of words of their L2. Similar to what was observed for the English monolinguals in Experiment 1, a higher English secondary family size slowed down the processing of identical cognates. An inhibitory effect of secondary family size fits well within a semantic explanation of the family size effect as proposed by Mulder et al. (in press), and outlined in the Introduction of this chapter.

The finding that secondary family size only affected the processing of identical cognates in both the bilingual and monolingual data was not expected. Though the direction of the secondary family size effect (i.e., inhibition) is in accordance with the effect of secondary family size observed by Baayen (2010) for English two-constituent compounds with small head primary family sizes, it is not clear why there was no effect for English (mono-morphemic) control words or English-Dutch non-identical cognates in either the monolingual or the bilingual data.

We initially argued that, in bilinguals, secondary family size effects are more likely to affect the processing of cognates, and, specifically, identical cognates, rather than English control words. The underlying reason for this assumption is that identical cognates may have linked representations in the bilingual mental lexicon due to their formal overlap with words in their dominant language, and, consequently, the subsequent co-activation of items in both languages would facilitate the spreading of activation to the primary and secondary family members of the L2. In support of this, Experiment 2 indeed showed that English (L2) secondary family size only affects identical cognates but not non-identical cognates and English controls. However, the finding that secondary family size only affects identical cognates in the monolingual data as well does not support this argument. Moreover, a further surprising result revealed by the more powerful omnibus analysis of both experiments was a significant processing advantage for identical cognates not only for bilinguals but also for monolinguals. This suggests that the observed effect of English secondary family size for identical cognates in the bilingual data are unlikely to be a consequence of a facilitated spreading of activation due to the co-activation of items in the non-target language and therefore an explanation for this effect should be sought elsewhere.

Although the facilitatory effect of English primary family size can be accounted for by interactive activation models such as MFRM, spreading activation alone cannot explain the observed inhibitory effects of English secondary family size nor why it only affects identical cognates. Without additional assumptions, spreading of activation between morphological family members in interactive activation models will always lead to facilitatory effects. The effects observed in Experiments 1 and 2 show that resonance of activation between indirectly related lexical items in the lexicon cannot be the mechanism underlying the slower responses to words with a larger number of secondary family members. It is worth noting that the secondary family size effect seems to challenge a simple multiple read-out mechanism (Grainger & Jacobs, 1996), according to which a lexical decision can be facilitated when many competitors are highly activated. Under such an account, one would expect secondary family members to facilitate lexicality decisions, instead of inhibition.

As we argued above, this problem with MFRM and interactive activation models more generally can be resolved in at least two ways. First, by assuming that identical cognates have two, mutually inhibiting, morphemic representations (Peeters et al., in press). Second, in more complex interactive activation models like BIA+ (Dijkstra & Van Heuven, 2002), a task-decision system could be involved that can make task- and trial-dependent decisions by basing itself flexibly on multiple information sources (also see Mulder et al., in press).

In contrast, the results of Experiments 1 and 2 were simulated successfully by the naïve discriminative reader model, which replicated the critical interaction of identical cognate status by secondary family size. These simulations provide an alternative account for how family size effects arise, and the differences between interactive activation models and the NDR model indicate that they are not completely functionally isomorphic. Instead of being seen as a consequence of activation spreading in a network of lexical nodes, they are understood as a consequence of the process of learning to map orthographic input onto meanings. The weights on the connections evolve during learning to optimally discriminate between different meanings, given the distributional properties of the language and its writing system to which the learner is exposed[10]. In this dynamic systems approach, it is found that primary family members tend to facilitate learning, whereas secondary family members appear to render learning more difficult. As a consequence, response latencies in the visual lexical decision task are shorter for words with large primary families, but longer for words with large secondary families. For the present data, our simulation studies strongly suggest that the inhibitory effect of secondary family size specifically for identical cognates is a consequence of how the distributional properties of English happen to fall out for identical cognates.

When working with interactive activation models, the question arises whether family size effects are a consequence of activation spreading among word forms, or among word meanings. For the primary family size effect, there is a growing body of evidence, as discussed in the introduction, that word meanings are crucially involved. For the secondary family size effects, a semantic locus also seems more likely. As observed above, it is only a semantic account that straightforwardly predicts an inhibitory effect. In the introduction of this paper, we argued that the semantic (in)congruence between a target word and its family members determines whether facilitation (for semantically related meanings) or inhibition (for semantically unrelated words) is observed. In current interactive activation models, such as BIA or BIA+, the mapping between representations is based on purely formal (i.e., orthographic) information links. In contrast, the NDR model works with a direct mapping from orthographic cues to semantic outcomes. It is this direct mapping, crucially framed within the well-motivated learning regime of the Rescorla-Wagner equations, which enables it to account for effects of semantic (in)congruence, and as a consequence, for the observed primary and secondary family size effects.

Within the framework of naïve discrimination learning, the question of whether word forms or word meanings are at issue does not arise, as the model rejects morphemes

[10] For simulation studies with naive discrimination learning addressing the crucial importance of language-specific distributional properties for understanding cross-linguistic differences in the effects of letter transpositions, see Baayen (2012) in response to Frost (2012).

and word forms as superfluous theoretical constructs. In this respect, the NDR model resembles the triangle model of Harm and Seidenberg (2004). Family size effects, both primary and secondary, are now an emergent property of a dynamic system learning the mapping of letters and letter bigrams to meanings.

Interestingly, the model that best fits the bilingual data is a model based on two separate networks that are accessed in parallel. It is important to note that, even though the model argues against the idea of a fully integrated bilingual lexicon, it is compatible with the hypothesis of language non-selective access (cf. discussion in Van Heuven et al., 1998), and indicates that the Dutch and English networks are subject to domain-specific learning. This architecture is consistent with the finding that associations between words within and between languages are not necessarily identical in L1 and L2 processing (Van Hell & De Groot, 1998). This supports the proposal that words such as cognates do not necessary have a fully shared representation in the lexicon but that part of their, at least semantic, representation is separate (cf. Peeters et al., in press).

The simulation studies also integrated the notion of multiple read-out (Grainger & Jacobs, 1996) by including as a predictor the thresholded summed activation of competitors. For English monolinguals, this activation was facilitatory: Participants used this activation as evidence for a positive lexicality decision. For Dutch-English bilinguals, however, this activation, restricted to the Dutch network, was inhibitory, indicating that these participants found it difficult to suppress misleading information provided by their mother tongue. These results show that the naïve discriminative reader model can be extended with task-specific components, and illustrate the more general point that the learning network in this model is only a small part of a much richer cognitive system.

The simulation study in terms of naïve discrimination learning is insightful in several ways. First, it clearly shows that simulations by interactive activation models like MRFM and BIA+ may result in qualitatively problematic outcomes as long as parts of the network (e.g., the mapping orthography on semantics or the decision component) are not fully implemented. Simulations with more complete and complex frameworks like Multilink (Dijkstra & Rekké, 2010) are therefore in order. Second, the innovative study on discrimination learning presented here has focussed on structural issues (i.e., the mapping of orthography on semantics during learning) and has not considered how to simulate different patterns of results that follow from processing differences due to task demands. Models like BIA+ and the IC model (Green, 1998) explicitly include a task-decision system to account for systematic, task-dependent variability in empirical results across tasks. It remains to be seen how a naïve discrimination learning framework can be extended to include a rich task system.

In the present study, following the multiple read-out approach, we have made a first step by showing that a task component specific to lexical decision can be integrated in the NDR model, and that this integration results in a better fit to the observed response latencies. We think it is impressive to see how far this new localist framework can come with very simple assumptions, a minimum of free parameters, and full-scale corpus data.

Finally, the NDR model provides an intriguing new perspective on what a lexical network might look like. The intuitive and familiar representation of a lexical network formally is that of a graph with words as vertices and lexical (familial) relations as edges. In such a framework, the primary family size measure captures what in graph theory is called the edge degree of a vertex. The network of the NDR, by contrast, is much simpler in structure, with edges from orthography to meaning, but with no edges between semantic vertices. What the NDR shows is that nevertheless the Rescorla-Wagner learning principles allow a simple two-layer network to absorb in its weights many of the semantic properties that in the familiar interactive scenario take place between word vertices. The challenge for future research is to separate out effects that truly belong to the Rescorla-Wagner network learning to map form onto meaning, from effects that are a genuine part of the network of relations between the meanings themselves.

To summarize, our study is the first to investigate and model both primary and secondary family size effects in monolingual and bilingual word processing. After developing a more sensitive measure for English primary family size effects, we observed effects of both the primary and secondary family size for cognates in English visual lexical decision, for both monolinguals and bilinguals. The simulations were a first step to model primary and secondary family size effects in both monolingual and bilingual word processing within the framework of naïve discrimination learning. Whereas interactive activation models are challenged by the inhibitory effect of secondary family size for identical cognates, naïve discrimination learning provides an adequate account for the observed primary and secondary family size effects and the latter's interaction with cognate status. Our study shows that, despite a lower proficiency in English compared to monolinguals, Dutch bilinguals show the same surprising interaction of secondary family size and cognate status. Apparently, bilinguals are able to build lexical networks for their second language that are remarkably isomorphic with the networks of monolinguals.

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Appendix

Formal definition of secondary family size

A formal definition of the secondary family size of a word ω (e.g., *horse* in Figure 1) proceeds as follows. Let F denote the set of bimorphemic words sharing ω as a constituent (the word with the constituents in light blue in Figure 1). This set includes all words with ω in first or in second constituent position. Let G denote the set of all words sharing at least one constituent with a word in F (all words with constituents that are colored in Figure 1; note that $F \subset G$). The secondary family size is defined as the cardinality of the set of words S which contains all words in G that are not in F (the words with a constituent represented by a dark blue vertex in Figure 1):

$$S = G \setminus F. \qquad (1)$$

Just as the primary family size measure, the secondary family size measure is log-transformed to remove a strong rightward skew from its distribution.

Formal description of the Rescorla-Wagner equations

Let PRESENT(X,t) denote the presence of cue (letter unigram or letter bigram) or outcome (meaning) X at time t, and ABSENT(X, t) denote its absence at time t. The Rescorla-Wagner equations specify the association strength (or weight) V_i^{t+1} of cue C_i with outcome O at time $t+1$ by means of a recurrence relation

$$V_i^{t+1} = V_i^t + \Delta V_i^t. \tag{2}$$

The change in association strength ΔV_i^t is defined as

$$\Delta V_i^t = \begin{cases} 0 & \text{if } \textsc{absent}(C_i, t) \\ \alpha_i \beta_1 \left(\lambda - \sum_{\textsc{present}(C_j,\, t)} V_j\right) & \text{if } \textsc{present}(C_j, t) \ \& \ \textsc{present}(O, t) \\ \alpha_i \beta_2 \left(0 - \sum_{\textsc{present}(C_j,\, t)} V_j\right) & \text{if } \textsc{present}(C_j, t) \ \& \ \textsc{absent}(O, t) \end{cases} \tag{3}$$

Standard settings for the parameters are $\lambda = 1$, all α's and β's equal to 0.1.

<u>Items used in Experiment 1 and 2</u>

Between parentheses are the values of the new family size measure obtained from the Family Size Generation Study.

Identical cognates: alcohol (5), ark (0), baron (5), camera (5), chaos (2), ego (11), flora (4), globe (5), god (9), horizon (3), hotel (4), lip (6), minister (11), moment (5), norm (14), opera (4), oven (4), psalm (3), shirt (12), sultan (1), tent (1), toilet (8), truck (2), villa (0), volume (4)

Non-identical cognates: admiral (2), advice (8), altar (1), athlete (2), bible (5), camel (3), canal (2), cigar (6), coffee (7), flesh (8), friend (10), honey (9), jewel (7), melon (4), method (7), pill (2), planet (3), prince (4), soup (7), sword (7), tea (25), thief (5), tomato (4), tongue (4), year (9)

English control items: fame (6), throat (6), gun (21), eagle (6), duke (5), widow (3), silk (4), berry (11), fate (9), funeral (4), bench (8), basket (7), lion (5), lad (1), wife (5), noise (6), horse (36), skill (4), donkey (1), torch (1), cellar (3), pigeon (2), bird (26), road (20), animal (5), arrow (2), loss (3), thigh (1), engine (6), window (6), cattle (1), spine (5), carrot (4), tale (6), guilt (6), dusk (1), spider (5), muscle (5), cab (4), faith (8), wealth (2), sale (13), law (18), frog (7), giant (1), cave (5), peace (16), heaven (4), wood (37), chest (3)

Cross-language orthographic neighbourhood effects

Chapter 5

This chapter is based on: Mulder, K., Dijkstra, T., & Schreuder, R. (under revision). Cross-language orthographic neighbourhood size effects in lexical decision: The effect of response competition.

Abstract

We examined cross-language neighbourhood size effects for Dutch-English bilinguals in an English (L2) lexical decision task. English words and non-words with no orthographic neighbours in English and Dutch, called cross-language hermits, were contrasted with English words and non-words that either had neighbours in only English or Dutch, or in both languages. Cross-language hermits were processed slower than words with neighbours from English or from both English and Dutch, but faster than words that only had Dutch neighbours. In contrast, facilitation arose for cross-language hermit non-words compared to non-words with neighbours in English or in both languages, but inhibition compared to non-words with only neighbours in Dutch.

Simulations of word latencies by the BIA+ model (Bilingual Interactive Activation Plus model; Dijkstra & Van Heuven, 2002), revealed facilitation rather than inhibition for cross-language hermits compared to non-hermits. Interestingly, monolingual naming latencies for these word items obtained from the English Lexicon Project replicated this pattern of facilitation for cross-language hermits, while monolingual lexicon decision latencies from both the English and British Lexicon Project patterned with the results of the experiment, showing longer response latencies for cross-language hermits. We argue that bilingual neighbourhood effects in the present study reflect response competition rather than lexical competition.

Introduction

Researchers investigating bilingual processing have devoted a great deal of attention to the question of whether access to words in the bilingual mental lexicon is language-selective or non-selective in nature. Though there are some studies that found support for the view that bilinguals only activate the appropriate language-specific lexical representations in the lexicon when reading in one of their languages (e.g., Gerard & Scarborough, 1989, Macnamara & Kushnir, 1971; Caramazza & Brones, 1979; Soares & Grosjean, 1984), a far larger number of studies on bilingual word processing have provided evidence that upon reading word, word representations from the other language of a bilingual can become activated (see Dijkstra, 2007, for a review).

Activation of non-target language words does not always occur and is restricted to certain conditions. Reading an English word such as *cat* will likely activate the lexical representation of Dutch words like *kat* or *nat* (meaning 'cat' and 'wet', respectively), while reading the word *bike* will probably not activate the lexical representation of Dutch words like *fiets* ('bike') or *tafel* ('table'). Thus, a prerequisite for activation of non-target language lexical representations is that they share formal characteristics with the input.

Words that differ in only a single letter substitution are called 'orthographic neighbours' (Coltheart, Davelaar, Jonasson, & Besner, 1977). Words can be neighbours within one language (e.g., *light* and *night* in English) or between languages (e.g., *night* in English and *nicht*, meaning 'niece', in Dutch). Following a language non-selective access account, upon reading a word, both orthographic neighbours from the target and non-target language should be activated and influence target word processing. As an example, reading the English word *wood* should activate, besides English form similar words such as *good* or *word*, Dutch orthographic neighbours such as *rood* (meaning 'red') and *wond* (meaning 'wound'). Because there is neither a complete form overlap between input and non-target language neighbours (as is the case for interlingual homographs) nor additional meaning overlap (as is the case for cognates), neighbourhood size is one of the few experimental manipulations that can provide evidence for an integrated lexicon with language non-selective access, using words that belong to one language only.

Van Heuven, Dijkstra, and Grainger (1998) tested this account by manipulating the number of non-target language (Dutch) orthographic neighbours in progressive demasking and lexical decision with Dutch-English bilinguals. They observed that both the number of orthographic neighbours of the target language and non-target language influenced target language word processing. The cross-language neighbourhood size effects disappeared when testing monolinguals on the same materials.

In two lexical decision experiments, Bijeljac-Babic, Biardeau, and Grainger (1997) presented French-English bilinguals with words preceded by orthographically related primes from the target or non-target language. Response latencies to words preceded by primes from the non-target language were significantly longer than to words from prime-target pairs from the same language, suggesting that lexical representations from both the target and non-target language were activated.

More recently, Midgley, Holcomb, van Heuven, and Grainger (2008) supported these behavioural results by providing electrophysiological evidence for cross-linguistic neighbourhood effects. The specifically focused at the N400, a component that is sensitive to semantic aspects of word processing (e.g., Kutas & Hillyard, 1980). The amplitude of the N400 is assumed to reflect how easily a word can be semantically integrated into the current context, whether the context is a single word, a sentence, or a discourse (Kutas & Federmeier, 2000, p.464). ERP recordings of highly proficient French-English bilinguals reading in either French or English revealed that words with many cross-language neighbours generated a more negative-going ERP waveform in the region of the N400 than words with few cross-language neighbours. Moreover, the cross-language neighbourhood size effects in the N400 ERP component arose earlier and were more widely distributed for L2 (English) target words than L1 (French) target words. The authors conclude that "words with more cross-language neighbours suffer from the co-activation of the lexical representations of these neighbours, as reflected in the typically longer RTs found to these stimuli in behavioural studies [...]".

An important question that has generated much debate is how activated orthographic neighbours affect word processing. Monolingual research on orthographic neighbourhood effects has produced mixed results. Facilitatory effects of within-language neighbourhood size were found in monolingual English lexical decision (e.g., Andrews, 1989, 1992; Forster & Shen, 1996; Johnson & Pugh, 1994; Sears, Hino & Lupker, 1995; Ziegler & Perry, 1998; Pollatsek, Perea, & Binder, 1999), while inhibitory and null-effects were observed for French, Spanish, and Dutch lexical decision experiments (e.g., Carreiras, Perea & Grainger, 1997; Coltheart, Davelaar, Jonasson & Besner, 1977; Grainger, O'Regan, Jacobs & Segui, 1989; Grainger, 1990; Perea & Rosa, 2000). Word naming studies, on the other hand, are more consistent and generally reveal facilitatory effects of neighbourhood size, at least for low frequency words (e.g., Andrews, 1989, 1992; Peereman & Content, 1995; Sears et al. 1995; Grainger, 1990; Carreiras et al., 1997).

The findings of studies on cross-language neighbourhood size mainly show inhibitory effects for words with a large number of non-target language neighbours. Van Heuven et al. (1998) observed inhibition from Dutch between-language neighbours (and facilitation for English within-language neighbours) on English lexical decision latencies with Dutch-English bilinguals. Bijeljac-Babic et al. (1997) observed that the amount of inhibition for prime-target pairs from different languages (relative to prime-target pairs of same language) increased as a function of the subject's proficiency in the prime word's language. In their ERP study, Midgley et al. (2008) observed larger N400 amplitudes for words with many non-target language neighbours, indicating larger processing costs for these words compared to words with a smaller number of non-target language neighbours.

Orthographic neighbourhood size effects are assumed to arise during the word identification stage of word processing. At the heart of the discussion on neighbourhood size effects is the question of which mechanism underlies the selection of the target word. Interactive activation models of word processing such as IA (interactive activation; McClelland & Rumelhart, 1981) and SOLAR (self-organizing lexical acquisition and recognition; Davis, 1999) assume that there is lexical competition between form similar words (called 'lateral inhibition'). Upon reading a word, orthographic neighbours are activated and compete for selection with the target until the appropriate target word exceeds a given threshold for activation. The logical prediction that follows from this theoretical position is that competing neighbours slow down the identification of the target word.

In line with the these monolingual models, the BIA + model of bilingual word comprehension (Bilingual Interactive Activation Plus, Dijkstra & Van Heuven, 2002) assumes that in bilinguals neighbours from both the target language and the non-target language can become activated and influence word processing. Crucially, even words that have a single non-target language neighbour and no target language neighbours are predicted to be processed more slowly than words with no neighbours in both languages.

One problem of interactive activation accounts is that the facilitation effects of neighbourhood size observed in both monolingual and bilingual experiments cannot be explained in terms of lexical competition only. To account for the observed facilitatory effects in monolingual lexical decision, Grainger and Jacobs (1996) extended the IA model with multiple read-out criteria. They argued that positive responses to words in a task such as lexical decision can be based on two criteria: either on a criterion set on individual word activation or on a criterion set on summed lexical activation. Following Andrews (1989), the first criterion entails that words with many neighbours produce higher levels of resonance between word and letter representations, which will speed up word processing. The latter criterion implies that there is more global lexical activation when more neighbours are activated, which will result in faster response latencies for words with many neighbours. Thus, by adding the possibility that lexical decisions can be based on summed lexical activity, interactive activation models can in principle account for facilitatory effects. The relative importance of both mechanisms (global activation and lexical competition) in a given task should determine the direction of the neighbourhood size effect.

Admittedly, part of the conflicting results on within-language neighbourhood size could be due to confounds in experimental designs. Different experimental designs have been used in which either the number or frequency of within neighbours have been manipulated, comparing words with few neighbours to words with many neighbours or varying the frequency of the neighbours for words with multiple neighbours. Given these differences, studies may not be directly comparable. Moreover, neighbourhood size effects in the lexical decision task are observed to be sensitive to several factors that are not always considered, including the type of non-words that are used as distracters and the word frequency of the target items, the facilitatory effect being stronger for low-frequency words (see Grainger and Jacobs, 1996). In an overview of studies on neighbourhood size effects, Andrews (1997) concluded that empirical evidence on neighbourhood effects is not as contradictory as has been claimed. She argued that the observed inhibitory or null effects can nearly all be attributed to a systematic feature of the stimuli or task.

Being aware of these methodological issues, Bowers, Davis, and Hanley (2005) argued that, in order to measure orthographic neighbourhood size effects, the critical neighbourhood size contrast that must be considered should not be between words with few and many neighbours, but between words with no neighbours and words that have one or more neighbours. They pointed out that word processing models like IA and SOLAR predict little difference between words with few and many neighbours (Davis & Andrews, 1996), because there is no additional competition for words with many neighbours due to a normalization of the total amount of activity at the word level. Thus, in order to have a pure measurement of neighbourhood size effects, words with one or more neighbours should be contrasted with words with no neighbours, the so-called *hermit* words.

Bowers et al. (2005) addressed this issue by having monolingual English participants learn new words (e.g., *banara*) that were neighbours of familiar hermit words (e.g., *banana*) and respond to these familiar words in a semantic categorization task. They observed that repeated exposure to the novel neighbour word made it more difficult to semantically categorize the familiar words. Interference effects even became larger with more training on the novel words. The authors concluded that the impact of the new neighbours on semantically classifying the hermit words is likely to reflect lexical competition and is in accordance with the predictions made by the IA and SOLAR models.

In the present study, cross-language neighbourhood size effects were studied by contrasting hermit with non-hermit words in English lexical decision. English words that had no orthographic neighbours in both English and Dutch, called *cross-language hermits*, were contrasted with English words that had neighbours in Dutch but not in English, with English words that had only English and no Dutch neighbours, and with English words that had neighbours in both languages. The aim of this study was two-fold. First, we wished to replicate the findings of Van Heuven et al. (1998) on cross-language neighbourhood size effects with this more pure contrast of neighbourhood size. To our knowledge, since the publication of their paper in 1998, these between-language results have not been replicated in a paradigm in which the neighbourhood size of both the target and non-target language are manipulated, and in which this neighbourhood size contrast is used.

Second, we wanted to see whether, by comparing hermits to non-hermit words in this bilingual setting, the inhibition effect of within-language neighbourhood size as observed by Bowers et al. (2005) could be replicated. If this is the case, then this would provide support for lexical competition accounts of interactive activation models. By applying the same contrast in target and non-target language neighbourhood size to non-word stimuli, we can not only collect a control data set for comparison to the observed patterns of the word data, but this non-word manipulation should also provide us with useful insights on orthographic neighbourhood effects when the stimulus is linked to a different response. To be able to contrast our findings with the assumptions made by the BIA + model, we will present a simulation with the BIA + model on the experimental words used in the lexical decision task.

Experiment 1: English lexical decision

Method

Participants. Forty-one Dutch L2 speakers of English (mean age 22.6 years old, SD = 2.58), mostly undergraduates at the University of Nijmegen, were paid or received course credits to take part in this experiment. All were highly proficient in English, having learned English from the age of 11 onwards. All had normal or corrected-to-normal eyesight.

Materials. One hundred and five English four- and five-letter words were selected from the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). All words were mono-morphemic non-cognate words consisting of one or two syllables and having a frequency of at least 2 occurrences per million. The numbers of within language (English) and across language (Dutch) orthographic neighbours (based on neighbouring word forms) were extracted from the CELEX database for English and Dutch. The number of English neighbours was checked with the OrthoN measure from the English Lexicon Project database (Balota et al., 2007) for English.

The 105 experimental English word items were divided into four different stimulus categories: 30 English words that had no neighbours in both English and Dutch (cross-language hermits, e.g., *abbey*), 15 English words that had no neighbours in English, but did have neighbours in Dutch (e.g., *bias* with Dutch neighbour *baas*), 30 English words that had neighbours in English but not in Dutch (e.g., *faint* with English neighbours *paint* and *saint*), and 30 English words with neighbours in both languages (e.g., *wood* with English neighbours such as *good* and *mood* and Dutch neighbours such as *woud* and *rood*, etcetera). Unfortunately, the asymmetry in the number of items in the stimulus categories could not be resolved due to the limited number of existing English words that have neighbours in Dutch but not in English. The items of the four categories were matched on log-transformed values of *SUBTLWF* (English SUBTLEX frequency per million; Brysbaert & New, 2009), English and Dutch bigram frequency, and length. Furthermore, the stimulus categories containing items with English or Dutch neighbours were matched on the mean number of neighbours in these languages[11].

The same contrast in within-language and between-language neighbourhood size for the word items was applied to non-words. The four non-word categories each contained 30 items and were matched to each other and to the four word categories on length, English and Dutch bigram frequency, and the number of English and Dutch neighbours. Characteristics of the experimental word and non-word items are presented in Table 5.1, and a list of the items is given in the Appendix.

To obtain an equal number of words and non-words, we added 45 word filler items and 30 non-word filler items to the item set. The word and non-word fillers were matched on length and English and Dutch bigram frequency to the experimental word items. This resulted in a total stimulus set of 300 items.

The items were presented in two blocks. The presentation order of the items within a block was randomized individually and had the restriction that no more than three words or non-words could follow each other directly.

[11] The mean numbers of English and Dutch neighbours were comparable to the means of the English and Dutch large N conditions reported by Van Heuven et al. (1998). Obviously, because the contrast in this study was many versus few neighbours, instead of none versus some (the main contrast in the present study), the means for their low N conditions did not match our low N condition. Finally, note that the word items in Van Heuven et al.'s study had a higher English frequency than the words in our study. This is because hermit words are generally low frequent words.

Table 5.1. Characteristics of the experimental stimuli.

	Stimulus category	Length	Log SUBTLWF	English neighbours	Dutch neighbours
Word					
	Cross-language hermit	4.97	2.79	0	0
	Only Dutch neighbours	4.6	2.66	0	2.5
	Only English neighbours	4.97	2.91	4.2	0
	Neighbours in English and Dutch	4.73	3.06	5.1	3.4
Non-word					
	Cross-language hermit	4.97	-	0	0
	Only Dutch neighbours	4.83	-	0	3.6
	Only English neighbours	4.93	-	3.9	0
	Neighbours in English and Dutch	4.87	-	4.8	3.7

Procedure. Participants performed an English visual lexical decision task. In this task, participants have to decide whether or not the visually presented stimulus is an existing English word by pressing a button corresponding to either the answer 'yes' or 'no'.

The task was developed and carried out in *Presentation* version 13.0 (Neurobehavioural Systems, www.nbs.com) and was run on an HP Compaq Intel Core 2 computer with 1.58 GHz and a refresh rate of 120 Hz. The participants were seated at a table at a 60 cm distance from the computer screen. The visual stimuli were presented in black capital letters (24 points) in font Arial in the middle of the screen on a white background. Participants were tested individually in a sound proof room.

Participants first read the English instructions, which informed them that they would be presented with word strings and which asked them to push the 'yes' button if the letter string they saw was an existing English word and to push the 'no' button if the letter string they saw was a non-word. They were asked to react as accurately and quickly as possible.

Each trial started with the presentation of a black fixation point '+', which was displayed in the middle of the screen for 700 ms. After a blank screen of 300 ms, the target stimulus was presented. It remained on the screen until the participant responded or until a maximum of 1500 ms passed by. The visual target stimulus disappeared when the participant pressed one of the response buttons, or when the time limit of 1500 ms was reached. After a blank screen of 500 ms, a new trial was started.

The experiment was divided in two blocks of equal length. The first block was preceded by 20 practice trials. After the practice trials, the participant could ask questions before continuing with the test trials. The two blocks each contained 150 experimental trials. Each block began with three dummy trials to avoid lack of attention during the beginning of the two blocks. The end of the first block was indicated by a pause screen. The experiment took approximately 16 minutes.

After the experiment participants performed the XLEX-task (Meara & Milton, 2003). This task was used to obtain a general measure of proficiency in terms of vocabulary knowledge. The mean score on the XLEX-task was 4275 (range 3000-5000). Moreover, participants were asked to fill out an off-line pencil-and-paper questionnaire about their level of proficiency in the English language. Based on their scores on the XLEX-task and their answers from the questionnaire, all participants could be considered as intermediately or highly proficient in English.

Results

Data cleaning was first carried out based on the error rate for participants. The participant accuracy mean on the word items was 89.5% percent (range 66%-99%) and 91% percent (range 44%-99% percent) on the non-word items. The data from three participants with an error rate of 25% or more on the word or non-word items were removed from the data set. Next, word and non-word items that elicited errors in more than 35 percent of the trials were removed from the data set. This resulted in the exclusion of three word items (*lunar, lapse,* and *gorge*) and four non-word items (*goast, hount, sooth, lawer*). Moreover, *groap*, *mair*, and *pleat* were removed for being potentially inappropriate. After removal of these items, we were left with 8170 data points. RTs from incorrect responses or null responses were removed from the data set (7.2% of the 8170 data points). Outlier RTs that were above or below 2.5 SD from the item or participant mean (4.3% of the remaining data points) were removed from the data set. This resulted in a data set with 7354 data points. Table 5.2 presents the mean RTs and mean accuracy and their standard deviations for the different words and non-words.

Table 5.2. Mean RTs (in ms) and their standard deviations between parentheses for the word and non-word stimuli.

	Stimulus category	English neighbour	Dutch neighbour	RT (SD)	Accuracy (SD)
Word					
	Cross-language hermit	-	-	615 (65)	90 (.09)
	Only Dutch neighbours	-	+	635 (64)	87 (.09)
	Only English neighbours	+	-	599 (66)	94 (.06)
	Neighbours in English and Dutch	+	+	594 (61)	94 (.06)
Non-word					
	Cross-language hermit	-	-	652 (82)	96 (.05)
	Only Dutch neighbours	-	+	638 (76)	97 (.05)
	Only English neighbours	+	-	694 (84)	93 (.07)
	Neighbours in English and Dutch	+	+	685 (84)	90 (.08)

The RT and accuracy data were first analysed separately for the word and the non-word data by means of a 2 x 2 repeated measures ANOVA with *English neighbour* (2 levels: *without* and *with* English neighbours (i.e., cross-language hermits and words with only Dutch neighbours versus words with only English neighbours, and words with neighbours in English and Dutch) and *Dutch neighbours* (2 levels: *without* and *with* Dutch neighbours (i.e., cross-language hermits and words with only English neighbours versus words with only Dutch neighbours, and words with neighbours in English and Dutch) as within-subject factor. Planned pair-wise comparisons were conducted at a significance level of $p < .05$ in case of a significant main effect.

RT data. A significant effect of *English neighbour* revealed that words with English neighbours were processed faster than words without any English neighbours [$F1(38) =$

41.55, MSE = 718.99, $p < .001$, $F2(99) = 8.68$, MSE = 2857.50 $p < .01$]. Further, a marginally significant main effect of *Dutch neighbour* was observed in the by-participant analysis only [$F1(38) = 2.98$, MSE = 737.18, $p = .09$, $F2 < 1$], showing slower RTs for words with Dutch neighbours compared to words without Dutch neighbours. Moreover, there was a significant interaction between *English neighbour* and *Dutch neighbour* in the by-participant analysis [$F1(38) = 15.92$, MSE = 386.23, $p < .001$, $F2(99) = 1.41$, $p = .24$], which shows that RTs for words with no neighbours in English were even slower when these words do have Dutch neighbours.

Planned comparisons revealed that response latencies to cross-language hermits were slower than for words with only English neighbours and slower than for words with neighbours in both languages, but faster than for words with only Dutch neighbours. There was no significant difference in response latencies between words with English neighbours and neighbours in both languages.

The non-word data revealed a significant effect of *English neighbour* [$F1(38) =$ 107.16, MSE = 686.93, $p < .001$; $F2\,(110) = 25.48$, MSE = 2068.50, $p < .001$], showing a facilitation effect for non-words with no English neighbours compared to non-words with English neighbours. Further, a significant main effect of *Dutch neighbour* was obtained in the by-participant analysis only [$F1(38) = 8.49$, MSE = 625.40, $p < .01$; $F2\,(110) = 1.97$, MSE = 2068.50, $p = .16$], showing that non-words with Dutch neighbours were rejected faster than non-words without Dutch neighbours. Finally, the analyses revealed no interaction between *English neighbour* and *Dutch neighbour* [$F1 < 1$; $F2 < 1$].

Planned comparisons revealed that response latencies to cross-language hermits were faster than for words with only English neighbours and for words with neighbours in both languages, but slower than for words with only Dutch neighbours. There was no significant difference in response latencies between words with English neighbours and neighbours in both languages.

Accuracy data. There was a significant main effect of *English neighbour* [$F1(38) =$ 28.45, MSE = .004, $p < .001$; $F2(99) = 7.18$, MSE = .009, $p < .01$] in the word data. Further, a marginally significant effect of *Dutch neighbour* was observed in the by-participant analyses only [$F1(38) = 3.74$, MSE = .003, $p = .06$; $F2 < 1$]. There was no significant interaction between *English neighbour* and *Dutch neighbour* [$F1(38) = 2.93$, MSE = .003, $p = .095$; $F2 < 1$].

Planned comparisons showed that cross-language hermits were responded to significantly less accurately than words that only have English neighbours or English and Dutch neighbours, but significantly more accurately than words with only neighbours in Dutch. Moreover, there was no significant difference in accuracy scores between words with only English neighbours and words with neighbours in both languages.

The non-word data also revealed a significant main effect of *English neighbour* [$F1(38) = 46.38$, MSE = .002, $p < .001$; $F2(110) = 18.84$, MSE = .004, $p < .001$], but no significant main effect of *Dutch neighbour* [$F1(38) = 2.00$, MSE = .001, $p = .17$; $F2 < 1$]. However, there was an interaction between *English neighbour* and *Dutch neighbour* in the by-participant analysis only [$F1(38) = 9.56$, MSE = .001, $p < .01$; $F2(110) = 2.33$, MSE = .004, $p = .13$].

Planned comparisons revealed that cross-language hermit non-words were responded to significantly more accurately than non-words with only English neighbours and non-words with both English and Dutch neighbours. However, there was no significant difference in accuracy between cross-language hermit non-words and non-words with only Dutch neighbours, but there was a significant difference between words with English neighbours only and words with neighbours in both languages.

Additional analysis. We conducted an additional analysis on a subset of 14 items of each word category. This was done to avoid possible confounds in the word data due the imbalance in the number of word items in each category. Moreover, we wanted to rule out that the observed difference in the main analysis might be due to a slight difference in frequency. Though the categories were all matched on frequency (log *SUBTLWF*, see the Method section) by means of independent sample *t*-tests, it cannot be excluded that frequency distribution of items in combination with their total number played a role. Therefore, an analysis of a subset that is matched more closely on frequency is informative and should result in a pattern similar to the main analysis if the RT difference between conditions is due to our neighbourhood manipulation. Furthermore, we matched the cross-language hermits to the word items with Dutch and/or English neighbours on *Age of*

Acquisition (ratings taken from Kuperman, Stadthagen-Gonzalez, & Brysbaert, in press), *Imageability* (ratings taken from the MRC Psycholinguistic Database, Wilson, 1988; Coltheart, 1981, and the Bristol Norms). Table 1 of the Appendix shows the matching of these items.

The RT and accuracy data were analysed by means of a 2 x 2 repeated measures ANOVA with the same within-subject factors as were used in the main analysis. Table 2 of the Appendix reports the mean RTs and mean accuracy scores for the subset data. A significant effect of *English neighbour* revealed that words with English neighbours were processed faster than words without any English neighbours [$F1(37) = 28.24$, MSE = 1240.95, $p < .001$; $F2(52) = 5.19$, MSE = 2843.63, $p < .05$]. Further, a significant main effect of *Dutch neighbour* was observed in the by-participant analysis only [$F1(37) = 6.38$, MSE = 1100.99, $p < .02$; $F2\ (52) = 1.1$, MSE = 2843.63, $p = .29$], showing slower RTs for words with Dutch neighbours compared to words without Dutch neighbours. Finally, there was a significant interaction between *English neighbour* and *Dutch neighbour* in the by-participant analysis [$F1(37) = 4.59$, MSE = 879.59, $p < .05$; $F2 < 1$], which shows that RTs for words with no neighbours in English were even slower when these words do have Dutch neighbours. Analysis of the accuracy data revealed significant main effects of *English neighbour* [$F1(37) = 10.02$, MSE = .004, $p < .01$; $F2(52) = 1.64$, MSE = .010, $p = .21$] and *Dutch neighbour* [$F1(37) = 5.57$, MSE = .004, $p < .05$; $F2 < 1$] in the by-participant analyses. There was no significant interaction between *English neighbour* and *Dutch neighbour* [$F1(37) = 1.46$, MSE = .005, $p = .24$; $F2 < 1$].

Planned comparisons revealed that responses to cross-language hermits were slower but not more accurate than responses to words with only English neighbours and to words with neighbours in both languages. Further, cross-language hermits were responded to faster and more accurately than for words with only Dutch neighbours. There was no significant difference in response latencies and accuracy between words with English neighbours and neighbours in both languages.

Discussion

Both the analyses of the RT and accuracy data revealed significant differences between cross-language hermits and words with neighbours in one or both languages. The analyses of a subset of 14 word items revealed a similar pattern in both the RTs and accuracy scores. This shows that the observed effects are unlikely to be due to items characteristics such as differences in frequency. It indicates that the observed differences between the stimulus categories are a consequence of the presence or absence of neighbours in English and Dutch.

Cross-language hermits were processed significantly more slowly and less accurately than words with English neighbours or neighbours in both languages. This facilitation of within-language neighbours is commonly observed for English (for an overview, see Andrews, 1997), but argues against the predictions made by interactive activation models in terms of the direction of the effect. However, these results could be accounted for in an interactive activation framework by assuming that facilitation in lexical decision could arise due to an increased degree of global lexical activation, response latencies being based on a measure of summed activation of all positively activated word representations (Grainger & Jacobs, 1996).

Cross-language hermits were found to be processed significantly faster and more accurately than words with only Dutch neighbours. This result supports the inhibition effects of cross-language neighbourhood size observed by Van Heuven et al. (1998), Bijeljac-Babic et al. (1997), and Midgley et al. (2008). Dutch neighbours were activated and inhibited English word processing. In line with the assumption of interactive activation models on word processing, we argue that this inhibition effect could reflect lexical competition.

The non-word data showed an analogous but reverse pattern. The analyses on the non-word data showed a facilitation effect in both the RT and accuracy data for cross-language hermit non-words compared to non-words that have neighbours in English or in both languages. Again, in line with the account of interactive activation models, English neighbours were activated and competed for selection, slowing down the rejection of non-words.

Further, we observed a facilitation effect for the English non-words with Dutch neighbours compared to the cross-language hermits in the RT data. Apparently, activation of the non-target language, Dutch, was beneficial to rejection of the non-words. These results indicate that neighbourhood effects cannot be explained solely in terms of lexical competition, because activation of Dutch neighbours should then result in an inhibition effect. Moreover, explaining this facilitation effect in terms of global lexical activation would leave unexplained why English neighbourhood size had an effect in the opposite direction (inhibition). Finally, the effect seems unlikely to be due to stimulus characteristics such as word-likeness in English or Dutch, because all items were matched on English and Dutch bigram frequency.

However, these results for the non-word data make sense when one assumes that the activated Dutch neighbours are linked to the appropriate no-response in this task (see Dijkstra, 2005, for an account along these lines). The activated Dutch neighbours of the non-word target may still have competed for selection, just like English neighbours for non-hermit non-words, but this competition was most likely aborted faster for activated Dutch neighbours than for activated English neighbours, because the Dutch neighbours feed the appropriate no-response, and hence reduce the probability that the target is an English word. Consequently, the time out for lexical search may be reached earlier in this case. The English neighbours of a non-word target, on the other hand, are linked to a yes-response and enforce the response competition, leading to slower rejection latencies.

A similar argument in terms of response competition may hold for the observed effects in the word data. Facilitation effects would arise if the activated neighbours are linked to the appropriate language response, while inhibition effects would occur in the case of a conflicting response. We will elaborate further on this argument in the general discussion.

Finally, both the word and non-word RT data and word accuracy data show that the contributions of non-target language neighbours are nullified when an item has English neighbours as well. In line with Van Heuven et al.'s (1998) reasoning concerning cross-language neighbourhood effects on non-word rejection, these results can be explained by arguing that it is the summed lexical activity in the most activated lexicon, rather than the sum of lexical activity across languages, that influences the response latencies to these items. If it were the summed cross-language lexical activity, then a facilitatory effect of the activated Dutch neighbours should have reduced the inhibition caused by the activated English neighbours, producing faster response latencies for non-words with neighbours from both languages compared to non-words with English neighbours only. This similar but reversed line of reasoning is also applicable to words with neighbours in English or both English and Dutch neighbours. Thus, explaining cross-language neighbourhood size in terms of global activation is problematic when the direction of the effects of neighbours from the two languages is different (facilitation versus inhibition). Rather, it is language specific global activation that can account for these effects.

In sum, explaining orthographic neighbourhood size effects in terms of response competition in addition to lexical competition and global activation may provide a solution for explaining both facilitation and inhibition effects for words and non-words in language specific lexical decision. In the next section, we report a simulation with the BIA + model on the word stimuli used in Experiment 1. This simulation is not sensitive to any task-dependent constraints and only assumes lexical competition between items within and across languages. If response competition between the target item and the activated neighbour, rather than lexical competition, determines the direction of neighbourhood size effects, then the BIA+ model should not be able to simulate the observed findings of Experiment 1. More specifically, by assuming that lexical competition is the main determiner of neighbourhood size effects, simulations with the BIA+ model on our word stimuli would result in inhibition effects for activated neighbours from both languages.

Simulation study

Characteristics of the BIA+ model

The BIA + model is an extension and adaptation of the BIA model (Bilingual Interactive Activation; Dijkstra & Van Heuven, 1998). The model distinguishes a word identification system and a task-decision system (see Figure 5.1 for a graphic representation of the model). The word identification system contains pools of sub-lexical and lexical orthographic and phonological representations, as well as semantic representations. Moreover, it incorporates a language node that specifies the language membership of each word in the lexicon.

Word identification is assumed to proceed in a series of interactive processing steps that take place in a similar manner for orthographic, phonological, and semantic representations. Upon presentation of a written input word *gold*, its corresponding features at each letter position are activated. These excite particular letter representations (*g,o,l, d*, among these) that contain these features. These letter representations then activate possible word candidates in both languages (such as the English words *gold*, *good*, and *hold*, and the Dutch words *goud* and *geld*). Identification of the appropriate word will occur through a process of activation and inhibition within and between activation levels. Activated word candidates suppress other word candidates through a mechanism called 'lateral inhibition'. They also reduce the activation of irrelevant letters via top-down connections. Because the input word continues to receive most bottom-up activation, it will gradually become the most activated word candidate, and it will ultimately be identified.

Word candidates also activate the language node to which they are connected. In the BIA + model, the function of this language node in the word identification process is restricted to determining language membership and its degree of activation therefore directly reflects global lexical activity in a particular language. Top-down inhibition from the language node to activated words from the other language, which was implemented in original BIA model (Dijkstra & Van Heuven, 1998) is not present in the BIA+ model. Rather, non-linguistic context effects (such as how the task-relevant language is used for responding) are accounted for by the task-decision system. This system incorporates task schema specifications of instructions, task demands, and participant expectancies. The word identification system provides output to the task-decision system, while there is no influence of the task-decision system on the activation state of words. The decision mechanism of the task-decision system continuously weighs the different kinds of activation input produced by the word identification system in order to come to a response. In lexical decision, responding will often be based on selection of the appropriate lexical item (reaching the critical threshold for activation).

Importantly, both the BIA and BIA+ model explain neighbourhood size effects in terms of lexical competition in the word identification system. Activated neighbours from both languages become activated and compete for selection until the target word is identified. Inhibitory effects of within- and between-language neighbourhood size are expected to arise because the activated words inhibit each other (lateral inhibition).

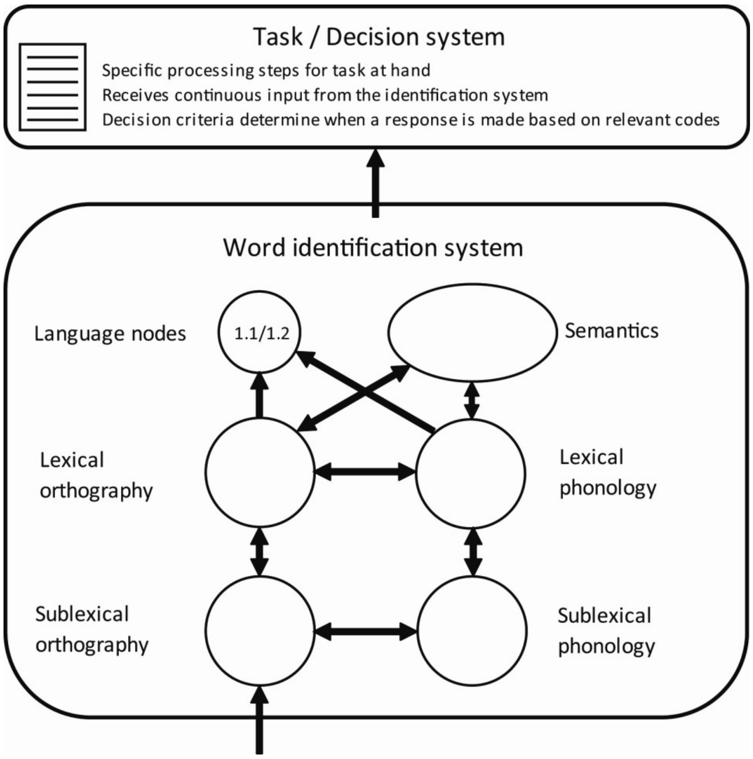


Figure 5.1. Graphical representation of the BIA+ model (reproduced from Dijkstra & Van Heuven, 2002).

Method

Materials. The 105 experimental English words of Experiment 1 were used in the simulation study.

Procedure. To allow for a direct comparison, simulations were run for the set of items of Experiment 1 that remained after data cleaning was carried out. Separate simulations were run for the four and five letter words. Parameters were set as in the original Interactive Activation model for 4-letter words. In addition, adjustments that account for 5-letter words were made (letter-to-word excitation: 0.056, letter to word inhibition: 0.05). Standard resting level activations were used for all Dutch and English words (between 0 for the most frequent word and -0.92 for the least frequent word across languages). The specific settings for the language nodes were not adapted. In this way, simulations with this model do not distinguish the BIA+ model from the original BIA model (Dijkstra & Van Heuven, 1998).

Results

Table 5.3 shows the mean number of cycles to reach threshold for selection for the four experimental conditions and their computed RTs. These simulation RTs were obtained by multiplying the mean cycle times for each category by the number that was obtained from dividing the mean empirical RTs from Experiment 1 by the mean cycle times from the simulation. In this way, more realistic estimates of the RTs could be obtained. The cycle times were subjected to an ANOVA with *English neighbour* and *Dutch neighbour* as between-group factors. These analyses correspond to the *F2* analyses conducted on our empirical data.

Table 5.3. Mean number of cycles and corresponding computed mean RTs for the English hermit and non-hermit words simulated by the BIA+ model.

	English neighbour	Dutch neighbour	Mean cycle time	Estimated RT
Cross-language hermit	-	-	17.65	575
Only Dutch neighbours	-	+	18.29	596
Only English neighbours	+	-	19.59	638
Neighbours in English and Dutch	+	+	19.47	634

The ANOVA revealed a significant effect of *English neighbour* [$F(99) = 152.131$, MSE = .366, $p < .001$], showing shorter cycle times for words without English neighbours compared to words that have English neighbours. Further, a significant main effect for *Dutch neighbour* showed that words with Dutch neighbours word processed significantly slower than words without Dutch neighbours [$F(99) = 4.10$, MSE = .366, $p < .05$]. Finally, a significant interaction between *English neighbour* and *Dutch neighbour* [$F(99) = 8.84$, MSE = .366, $p < .01$] revealed that when a word, in addition to having no English neighbours, has no Dutch neighbours, it is processed faster than when it does have Dutch neighbours.

Planned comparisons showed that cycle times for cross-language hermits were significantly faster than for both words with only English or only Dutch neighbours, and for words with neighbours in both languages. There was no significant difference between words with only English neighbours and neighbours in both languages.

Discussion

The simulations with the BIA+ model showed clear effects of orthographic neighbourhood size. Cross-language hermits produced significantly shorter response latencies than words that have one or more English and/or Dutch orthographic neighbours. The direction of the effect was similar for words with only Dutch or only English neighbours, both slowing down word processing. Following the assumptions made by this model, this inhibitory effect reflects lexical competition between the target word and the activated neighbour words.

Interestingly, similar to what was observed in Experiment 1, no significant processing difference was observed between English words that only have neighbours in English and English words with neighbours in both languages, suggesting that more lexical activation in the lexicon due to the activation of between-language neighbours induces no additional lexical competition. The difference between words with only Dutch neighbours and words in neighbours from both languages approached significance. This supports the reasoning that it is the activated neighbours from the target language that are most important when processing an English word, because they are causing more interference.

In sum, the simulation pattern concerning orthographic neighbourhood size is only partially compatible with the observed results of Experiment 1, and suggests that the observed orthographic neighbourhood effects in our experimental data cannot solely be explained by lexical competition. Moreover, the discrepancy between the results call for an extension of the BIA model in terms of response competition. We will come back to this in the General Discussion.

General discussion

The aim of the present paper was to investigate cross-language orthographic neighbourhood size effects by focusing on hermit words and non-words. English words and non-words that had no neighbours in English and Dutch (cross-language hermits) were contrasted with words and non-words that either had neighbours in English or Dutch, or in both languages. The items were tested in an English lexical decision task with Dutch-English bilinguals.

The word data revealed slower response latencies and lower accuracy scores for cross-language hermits compared to words with English neighbours or neighbours in both English and Dutch, but faster response latencies and higher accuracy scores compared to English words with only Dutch neighbours. With these findings, we replicate the inhibitory cross-language orthographic neighbourhood size effects observed by Van Heuven et al. (1998).

The non-word data showed the reverse pattern. Cross-language hermit non-words were rejected faster and more accurately than non-words with English neighbours and neighbours in both languages, but were rejected slower than non-words that only had Dutch neighbours. Interestingly, the difference in response latencies and accuracy scores between words with only English neighbours and neighbours in both languages was significant neither in the word data nor in the non-word data, suggesting that the contribution of the activated non-target language neighbours was negligible when a word also had activated target language neighbours.

The data were then simulated by the BIA+ model. The simulation data showed a facilitation effect for cross-language hermits compared to words with neighbours in one or both languages. Further, the language membership of the activated neighbours was not relevant for the direction of the neighbourhood effects, as both types of neighbours slowed down word processing. Finally, similar to what was observed in Experiment 1, there was no additional competition from Dutch neighbours when words already had English neighbours.

In what follows, we will discuss our experimental data in the light of three mechanisms that play a role in visual word processing: lexical competition, global lexical activation, and response competition. We will first compare our empirical results to the simulations run by the BIA+ model, which assumes lexical competition. Next, we will discuss Grainger and Jacobs' (1996) account in terms of global activation. Finally, we will argue for an explanation of bilingual neighbourhood size effects in terms of response competition, and we will propose an extension of the BIA+ model to account for conflicting neighbourhood size effects.

Our findings concerning the word data were only partially compatible with the simulated results of the BIA+ model. The BIA+ model assumes inhibitory links between words in the lexicon. Activated word candidates compete for selection and decrease the activation level of other words in the lexicon, irrespective of the language they belong to, via lateral inhibition. According to this model, activation of both target and non-target language neighbours should inhibit target language word processing. The results of Experiment 1 indeed confirm this inhibition effect for between-language neighbours.

However, our finding that within-language neighbourhood size facilitates word processing is in clear contradiction with this prediction and the BIA+ model does not account for this facilitation. However, Van Heuven et al. (1998) argued that the capability of the original BIA model to simulate facilitation effects for English neighbourhood density depended on the setting of the top-down inhibition parameter, which is different according to the degree of proficiency in the L2. Activated lexical candidates activate the language node they are connected to, and the activated language node sends top-down inhibitory feedback to all the words in the other language. In this way, the activation of the Dutch language node inhibits activation of all English words in the lexicon. Moreover, this inhibition is strengthened because of the lower frequencies of the English words relative to Dutch, causing the Dutch words to be activated earlier than the English words. This inhibition effect is stronger for English words with a small number of English neighbours, which shows a relative facilitation effect for words with a large English neighbourhood size. However, these facilitatory effects disappear when the inhibition parameter in the model is set to zero. Unfortunately, as Van Heuven et al. admit (1998, p. 477), the BIA model is not capable of simulating these facilitatory effects in monolinguals. Thus, top-down inhibition from the language node does not seem to be the mechanism that can account for orthographic neighbourhood size effects across populations.

The BIA+ model does not assume this top-down inhibition from the language node on non-target language lexical candidates and explains neighbourhood effects solely in terms of lexical competition within the word identification system. The task-decision system triggers a response based on the information provided by the word identification system. When there is lexical competition between word candidates, a response will presumably not be selected by the task-decision system until the appropriate lexical candidate has been selected based on individual word activation. Lateral inhibition from the activated neighbours delays the selection of the target word and, consequently, delays the triggering of the response, resulting in inhibition effects for words with neighbours compared to hermit words. However, by merely assuming that the input for the task-decision system is the gradually increasing activation of the selected target word, the model cannot account for facilitatory effects of neighbourhood size.

Grainger and Jacobs (1996) argued that apart from lexical competition, a response to words can be based on global lexical activation in the lexicon. Their multiple read-out model (an extension of the IA model) was able to simulate the facilitatory effects of within-language neighbourhood size when lexical decisions were based on a response criterion set on summed lexical activity. When more neighbours are activated, there is more global lexical activation, which will result in faster response latencies. However, our results did not reveal a significant difference in response latencies between words with only English neighbours and neighbours in both languages. If it were the summed activation of both activated English and Dutch neighbours that triggered a response, then response latencies to words with both English and Dutch neighbours should significantly be slower than to words with only English neighbours. The activated Dutch neighbours would then reduce the facilitatory effects caused by the activation of the English neighbours.

Only by assuming that lexical decisions can be based exclusively on the summed activation of the word candidates of the language relevant for the task at hand, can this result be accounted for in terms of global activation. In other words, summed lexical activation should be based on language-specific lexical activation rather than on activation across languages, at least when the task is language specific lexical decision.

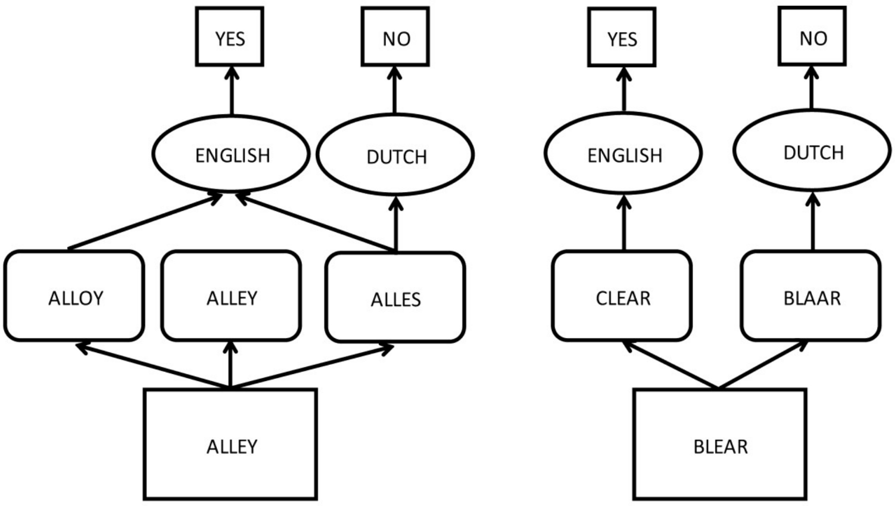
This entails that language membership information must be checked in order to determine which activated lexical items contribute to the summed global activation. One prediction following from this is that in English-Dutch generalized lexical decision, in which participants have to indicate whether or not the stimulus is a word in both of their languages, English words with neighbours in both languages should have a processing advantage over English words with only English neighbours, because both activated languages are equally relevant for the task (cf. Dijkstra, Moscoso del Prado Martín, Schulpen, Baayen & Schreuder, 2005).

To elaborate on this point, we propose that the effect of global lexical activation is based on an interaction between the language node and the response binding of the stimulus. Clearly, when there is more than one response option in a language specific experimental task, as in lexical decision where participants press a 'yes' or 'no' button corresponding to the language membership of the stimulus, activated lexical items in the bilingual lexicon must be linked to one response or the other in terms of their language membership. For example, in an English lexical decision task with Dutch-English bilinguals, both the activated English target word and its activated Dutch and English neighbours will activate their language membership information at the language node. The activated language nodes will feed the response mechanism in the task-decision system in order to build up the probability for a given response. English word candidates will collectively activate the yes-response, whereas Dutch word candidates will activate the no-response. When the appropriate word has been selected (lexical competition is resolved) or a large amount global activation has reached a set threshold, the task-decision system will weigh this input, which is linked to a certain response, against the activation that has already been built up in favour of the other response, and the response is selected.

Crucially, we do not propose top-down effects from the language node on the activation levels of the lexical items (see Dijkstra & Van Heuven 2002, for arguments against such top-down effect). This means that language node activation does not influence lexical competition. Rather, we argue that there is only bottom-up activation sent from the language node to the response mechanism in the task-decision system. Because this activation flow occurs during word identification, it could alter the threshold for selecting the appropriate response. Thus, when activation input has been sent to the decision system based on either global activation or on the activation level of the target item, the response mechanism might have already received a certain amount of activation for a given response, which may facilitate or inhibit the selection of the appropriate response.

In this way, activated Dutch neighbours of English word items will feed the inappropriate no-response in English lexical decision on words during word identification, inducing response competition in the task-decision system between the appropriate yes-answer for the selected English target word and the inappropriate no-answer. Activated English neighbours, on the other hand, feed the appropriate response to the English target words. In this case, the task-decision system arrives faster at a given response when this response has already been fed. This explains the facilitatory effects of within-language neighbours and inhibitory effects of cross-language neighbours compared to cross-language hermits.

The same reasoning holds for non-words. Non-word rejection occurs when in a set time frame, no matching lexical candidate has been selected. During the lexical search, activated neighbours activate their language node, which is linked to a certain response in the task-decision system. In the task-decision system, the longer the time becomes during which no lexical candidate is selected that matches the input, the more likely the chance is that the no-response will be selected. After lexical search has been finished, the input from the word identification system will be weighed against the activation that has already been built up in favour of a certain response. This could result in either facilitation or inhibition effects depending on the response that had been fed. Figure 5.2 illustrates these stimulus-response bindings[12].



[12] Though not explicitly specified in Figure 2, the language user may use sub-lexical information to make a lexical decision (see Van Kesteren, Dijkstra, & De Smedt, in press).

Figure 5.2. Schematic representation of stimulus-response binding for English words and non-words in an English lexical decision with Dutch-English bilinguals. The visual input (lowest level) is connected to activated word candidates from both languages, which in turn activate their language membership information at the language node. The two language nodes to which the words from the two languages are connected feed a different response in language specific (in this case English) lexical decision. Note: The target non-word is not directly connected to the 'no' response, but the 'no' response is fed when insufficient activation is collected after a set deadline.

Although our response binding account holds for most conditions, the absence of a significant RT difference between items with only English neighbours and items with both English and Dutch neighbours is puzzling. Understandably, neighbours from the target language exert the largest effect on response latencies, especially because they are linked to a positive response. The Dutch neighbours feed the negative response to English targets. It appears that the selection of a positive response is prioritized by the task-decision system relative to a negative response, even if the positive response is not appropriate, as in case of non-words. This mechanism could be considered as a specific kind of response bias or as the allocation of extra attentional capacity to the 'yes'-response.

Note that our account of response competition does not imply that lexical competition is not important at all, nor does it go against Grainger and Jacobs' explanation in terms of global lexical activation. Our account is in agreement with their account based on global activation when we assume that the summed lexical activity is a combination of language node activation and response-binding. The observed language-specific summed lexical activation seems to occur when the activated languages have a different response binding specific to a given task and thus provide conflicting information to the task-decision system. In our study, all activation for the target language English feeds the yes-response in contrast to the non-target language Dutch.

Further, our response binding account is in line with Smits, Martensen, Dijkstra, and Sandra (2006), who argued that besides lexical competition, two additional decision processes have to be assumed in bilingual word recognition tasks: a language check, and a response deadline for non-target language responses. In an English (L2) naming task with Dutch-English bilinguals, Dutch-English homographs, presented in a list containing items from both languages, yielded longer naming latencies, more Dutch responses, and more errors when the items had a high frequency reading in Dutch. However, in a pure English list there was no difference in naming latencies between homographs and controls, but homographs did elicit more errors than controls. The authors argued that the apparent effect of stimulus list competition across the two experiments was a consequence of reduced competition in a pure list, which could be situated either at the lexical level or the decision level. Most importantly, they concluded that lexical competition cannot be the only mechanism that controls in which language a response is given: in word processing models, a decision component is needed that determines the ultimate response by combining different sources of evidence, including language membership information and task demands.

In sum, lexical competition and global activation by itself are not sufficient for explaining neighbourhood size effects. Rather, our account reserves a role in bilingual word recognition for response competition induced by task constraints. A paradigm such as language-specific lexical decision typically distinguishes two responses and induces response competition, while this response competition might be less relevant in tasks such as word or picture naming or progressive demasking (see Keuleers and Brysbaert, in press, for a discussion on this issue).

To support this line of reasoning, RTs to the experimental items from Experiment 1 were compared to monolingual lexical decision latencies and naming latencies for these words from the English Lexicon Project (ELP, Balota et al., 2007) and the lexical decision latencies from the British Lexicon Project (BLP; Keuleers, Lacey, Rastle, & Brysbaert, 2012). Because these RTs were obtained in monolingual English experiments, we divided our words into two categories: English hermits and words with English neighbours, collapsing all English words with English neighbours and all without English neighbours (see Table 3 of the Appendix for the mean RTs for all four word categories). Table 5.4 presents the mean lexical decision and naming latencies in ELP for our experimental stimuli. The mean RTs are based on the items of Experiment 1 after data cleaning, containing 43 English hermits (29 cross-language hermits and 14 words with only Dutch neighbours) and 59 non-hermits (29 words with only English neighbours and 30 words with neighbours in both English and Dutch).

Table 5.4. Mean lexical decision and naming RTs to the experimental items of Experiment 1 taken from the English Lexicon Project and British Lexicon Project.

Lexicon	Stimulus Category	Lexical decision RT	Word naming RT
ELP	English hermits	629	610
	Words with English neighbours	616	623
BLP	English hermits	566	-
	Words with English neighbours	545	-

Interestingly, the means for the ELP and BLP lexical decision latencies show the same inhibition for hermits as was observed in Experiment 1. The mean naming latencies from the ELP database, on the other hand, seem to pattern with the simulated means of the BIA + model[13]. Language specific word naming by monolinguals, in contrast to language specific lexical decision in which there is a “yes” and a “no” response, does not necessarily involve response competition given that the response language is a fixed task requirement. This implies that, in monolingual word naming, differences between words with and without target-language neighbours should rather be attributed to lexical competition. The same argument could explain the inhibitory effects of orthographic neighbourhood size observed in the semantic categorization task of Bowers et al. (2005), in which hermit and non-hermit words were contrasted. In this paradigm, responses are not based on the language membership of the target and there is no response competition based on the language membership of the activated neighbours and the target linking to different responses. Thus, the similarity in result pattern of the BIA+ simulations with both the monolingual naming data from the English Lexicon Project and the word categorization data from Bowers et al. (2005) suggests that an account for our bilingual lexical decision data requires a specification of the interaction between language node activation and the task-decision system in terms of response competition.

[13] Note, however, that many naming studies have observed facilitatory effects of neighbourhood size, but these studies have not used the hermit versus non-hermit contrast.

In sum, this study has extended and confirmed the findings of Van Heuven et al. (1998) on cross-language neighbourhood effects by contrasting cross-language hermits with words that had neighbours in only one language or both the target- and non-target language. Moreover, the same contrast was applied to the non-words. This manipulation entailed a "cleaner" measurement of neighbourhood size effects and allowed us to compare our results with the assumptions made by interactive activation models, which only predict a difference between hermit and non-hermit words and not between words with few and many neighbours. Our findings suggest that an explanation in terms of lexical competition and global activation only is not sufficient to account for neighbourhood size effects in word and non-word processing. We argued for a specification of the BIA+ model in terms of response competition in the task-decision system when the task involves language specific lexical processing. We conclude that, although in a non-selective access account on word processing, language membership activation does not necessarily influence activation levels of activated word candidates, the language node seems to play an important role in the process of bilingual lexical decision.

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Appendix

Word items used in Experiment 1 and the Simulation Study. The number of orthographic neighbours is indicated between parentheses.

Cross-language hermits: arrow, sugar, digit, exist, raise, equal, doubt, faith, empty, ghost, attic, first, abbey, elbow, knife, often, posit, eagle, habit, ivory, asset, evoke, lunar, proud, razor, maybe, merit, amaze, envy, glory

Words with only Dutch neighbours: movie (1), guard (1), fluid (2), hazel (4), cabin (1), proof (2), clerk (3), lapse (1), erupt (1), urge (11), obey (1), view (3), liar (4), void (1), bias (11)

Words with only English neighbours: queen (3), ample (3), nurse (3), cheap (2), debt (2), apply (3), angle (1), couch (6), share (15), cheek (4), smoke (3), snake (5), float (3), mouth (4), scarf (5), judge (3), peach (7), drown (5), porch (6), chest (3), skill (5), haunt (5), brush (3), allow (3), gorge (4), goose (4), nasty (4), cloud (2), faint (5), noise (4)

Words with English and Dutch neighbours: duck (15/6), wood (10/8), hawk (4/3), quit (5/12), bird (4/3), dish (5/1), grow (6/6), tune (7/4), blame (5/1), spoon (5/3), shift (3/3), pride (6/4), glove (3/2), sheet (6/4), paint (6/3), scare (9/2), space (5/1), brake (6/1), candy (7/2), swamp (3/2), plain (2/2), eager (3/6), burst (2/4), grace (8/3), fever (5/7), spoil (1/1), alley (2/2), light (9/1), layer (3/5), power (10/3)

Experimental pseudo-word items used in Experiment 1. The number of orthographic neighbours is indicated between parentheses.

Cross-language hermit pseudo-words: gaish, leith, imary, ghorf, rasle, pafle, redle, emare, asame, roilt, muzor, umpsy, swufe, faige, orult, sopit, huser, teyal, jeish, cloif, fleap, lerme, prerg, moash, ecose, halic, doolp, exape, togar, irfe

Pseudo-words with only Dutch neighbours: zorf (3), yoos (10), pois (7), etin (2), klig (6), volge (2), frets (5), heish (1), nerst (5), darst (3), sholp (1), hegen (16), lugen (6), garst (4), spuld (1), emmet (1), gleip (1), lilve (1), noret (2), smoog (2), gluit (2), slewe (1), ploag (2), vagel (5), vraig (1), vorg (10), gronc (1), vroog (4), slaip (2), knoog (2)

Pseudo-words with only English neighbours: fosh (9), sish (7), aboke (2), lidge (5), mourt (3), traim (3), roash (2), monch (4), creal (3), redge (5), blusp (1), cheem (3), guare (2), touse (6), cloul (2), launt (6), flage (4), vitch (7), daint (5), tenal (4), hount (5), goast (4), noght (1), dable (5), wheeg (1), sooth (5), douth (5), waish (2), parsh (4), swame (3)

Pseudo-words with English and Dutch neighbours: dosk (6/6), hade (12/9), pilt (13/10), mair (8/6), greel (6/5), dorse (8/4), pleat (3/3), lawer (4/5), haron (2/3), gleep (2/2), groap (3/1), scole (6/2), scade (5/2), prood (3/2), dight (11/1), bover (9/10), metel (4/9), claip (3/1), tonus (2/2), swion (2/1), lavel (6/9), avone (2/1), smoop (5/5), prail (3/1), blear (3/1), vaber (2/2), twiss (2/1), malve (5/2), spoit (5/4), rasel (2/4)

Table 1. Characteristics of the subset of 14 word items.

Stimulus category	Cross-language hermit	Only Dutch neighbours	Only English neighbours	Neighbours in English and Dutch
Length	4.9	4.9	5.0	4.7
Log Frequency	2.78	2.71	2.78	2.89
Log English bigram	8.66	8.43	8.75	8.72
Log Dutch bigram	9.79	9.94	9.91	9.90
Age-of-Acquisition	6.9	7.2	5.7	6.5
Imageability	501	441	543	482
English neighbours	0	0	4.1	4.6
Dutch neighbours	0	2.6	0	3.8

Table 2. Mean RTs (in ms) and their standard deviations between parentheses for the subset of 14 word items.

Stimulus category	English neighbour	Dutch neighbour	RT (SD)	Accuracy (SD)
Cross-language hermit	-	-	611 (69)	91 (.10)
Only Dutch neighbours	-	+	635 (64)	87 (.09)
Only English neighbours	+	-	591 (63)	93 (.07)
Neighbours in English and Dutch	+	+	594 (67)	92 (.08)

Table 3. Mean RTs to the four item categories of Experiment 1 taken from the English Lexicon Project and British lexicon project for lexical decision and word naming.

Lexicon	Stimulus Category	Lexical decision RT	Word naming RT
ELP	Cross-language hermit	631	611
	Only Dutch neighbours	625	609
	Only English neighbours	623	629
	Neighbours in English and Dutch	611	616
BLP	Cross-language hermit	568	-
	Only Dutch neighbours	564	-
	Only English neighbours	550	-
	Neighbours in English and Dutch	541	-

Summary and Discussion

Chapter 6

Summary

This dissertation investigated the interconnectedness of words in the mental lexicon of bilingual language users. More specifically, it considered under which conditions related words from one language become activated and influence the processing of words in another language. In the Introduction of this dissertation (Chapter 1), I explained that words within one language and across languages can be related via relationships that can be formal (orthographic or phonological), semantic, or morphological in nature. In this dissertation, I focussed on two types of relationships: Morphological relatives and orthographic neighbours. A morphological family member is a morphologically related complex word in which a given word occurs as a constituent (e.g., *homework* is morphologically related to *work*). Orthographic neighbours are words that differ from each other in only one letter (e.g., *work* and *cork*). The latter relationship characterizes a purely orthographic connection, while the former is a morphological relationship that is characterized by both orthographic and semantic connections.

Studying effects of orthographic and morphological relatedness in bilingual word processing can provide useful insights into how words in the bilingual lexicon are stored and accessed. In the commonly accepted view of language non-selective access, upon presenting a visual input, related words from the other language can be co-activated based on formal similarity with the input word from the target language. This also holds for morphological family members and orthographic neighbours that share this formal similarity with the input word. However, relatively little is known about how the activation of these specific related words comes about, especially in the case of cross-language morphological family members. Current monolingual and bilingual models of word processing (e.g., MROM-p, Jacobs, Rey, Ziegler & Grainger, 1998; BIMOLA, Léwy & Grosjean, 1997; SOPHIA, Van Heuven & Dijkstra, 2001, 2003; BIA+, Dijkstra & Van Heuven, 2002) generally only distinguish orthographic, phonological, and semantic levels. In these models, morphological effects are generally explained by means of an interaction between orthographic and semantic levels of representation, while it is not clear whether morphological effects are really to be considered as a sum of orthographic and semantic effects.

A further problem with many current models of word processing is that they tend to underestimate the importance of task-related processes. Lexical effects may differ as a function of different task demands. For instance, activation of language membership information of activated word candidates can influence target word processing differently when a given task requires distinguishing stimuli based on their language membership in one language or the other, compared to when the task requires a distinction on the lexical status of stimuli in one language only (cf. Chapter 2). In the first situation, this may lead to response competition between two language responses, while in the latter such response competition is less apparent. Many models do not specify the influence of task-related factors on word processing. In this way, models may be unsuccessful in predicting effects of different types of relationships, such as orthographic and semantic relationships, under particular experimental conditions.

In the present dissertation, I examined and compared morphological family size and orthographic neighbourhood effects in different experimental paradigms. By examining these relationships in different task situations, I aimed to assess how orthographic and semantic connections are activated during word processing, and how task-specific mechanisms interact with more general mechanisms of word processing. The observed findings have their consequences for the further specification of current models of word processing.

Chapters 2-4 addressed morphological family size relationships in bilinguals. Most experiments reported in these chapters made use of cognates to investigate morphological family size effects. Cognates are words that share their form and meaning in two or more languages (e.g., the English-Dutch word *water*). Given their formal overlap in two languages, they allow for cross-language activation to occur, such as the activation of cross-language family members, when these words are visually presented to bilinguals. Until now it was not clear how activation of morphological relationships affects cognate processing.

From research on interlingual homographs (e.g., the Dutch-English word *room*, meaning 'cream' in Dutch), we know that the effects of family size are inhibitory when the activated family members do not belong to the same language as the target word (Dijkstra, Moscoso del Prado Martín, Schulpen, Schreuder, & Baayen, 2005). For cognates, the effects of family size might be different, given that, in contrast to interlingual homographs, cross-language family members are always semantically related to the target cognate (compare *water* – *waterkan* 'water bowl' to *room* – *slag**room***, 'whipped cream'). The direction of cross-language family size effects in cognates could therefore reveal the relative importance of semantic overlap in family size effects in general. An additional benefit of looking at cognates is that the degree of orthographic overlap between cognate representations can be varied (compare *thief* - *tasjes**dief***, 'bag snatcher', and *water* – *waterkan* 'water bowl'). This allowed us to examine the additional contribution of orthographic similarity to the family size effect.

In Chapter 2, we addressed cross-language family size effects in cognates in L2 processing. To be able to observe cross-language family size effects in cognates, the family size of the target language was controlled for, while the cross-language (i.e., non-target language) family size was varied. Investigating family size effects in cognates in different experimental situations might clarify whether the activation of morphological family members is exclusively semantically driven or (also) sensitive to other factors that affect word processing such as task context or stimulus characteristics. We hypothesized that if the family size effect purely reflects semantic activation, semantic similarity between target words and their morphological family should always lead to facilitatory effects regardless of the experimental paradigm. However, if formal aspects of the stimuli are also relevant for word processing in a given task, both the within-language and cross-language family size effect could be sensitive to these aspects.

Cross-language (i.e., Dutch) family size effects were first addressed in an English lexical decision task, in which the within-language (i.e., English) family size was controlled for. As expected, facilitatory Dutch family size effects were observed. Moreover, Dutch family size did not interact with cognate type (form-identical versus form non-identical cognates). In a second experiment, a Dutch-English language decision task, participants had to decide whether or not the presented word was a Dutch or English word, and response competition was experimentally induced. Both English and Dutch family sizes were found to affect word processing, but stronger family size effects were obtained when both family sizes were combined into one family size count. Interestingly, the combined family size count interacted significantly with the cognate type, showing inhibition of combined family size for identical cognates relative other items. For Dutch non-identical cognates, the combined family size effect even turned into facilitation. Apparently, the presence of language-specific orthographic information in these non-identical cognates reduced response competition in these cognates. Participants seemed to adopt a strategy in which their non-native language was the default and they relied on orthographic cues to make the appropriate response. This suggests that cross-language and within-language family size effects in bilingual processing are also sensitive to form aspects of word processing.

These findings led us to reanalyze available English progressive demasking data from Dutch-English bilinguals of Dijkstra, Miwa, Brummelhuis, Sapelli, and Baayen (2010). This task is assumed to tap into early processes in word recognition and is sensitive to formal aspects of processing (Grainger & Jacobs, 1996). Similar to our experiment, the stimuli included both Dutch-English identical and non-identical cognates and English controls. In line with the (monolingual) Dutch experiment of Schreuder and Baayen (1997), no effects of English family size were observed. However, Dutch family size had an inhibitory effect on response latencies to cognates. By means of this re-analysis, we have shown that the family size effect is not only a late post-lexical semantic effect, but can occur earlier during stages of word processing in which form characteristics of the input are relevant.

In Chapter 3, within-language and cross-language family size effects were investigated by means of ERPs. The main aim was to show that the ERP signal is sensitive to the morphological productivity of Dutch words in both L1 and L2 processing. In both Dutch lexical decision with Dutch monolinguals and English lexical decision with Dutch-English bilinguals, we found that words with a high Dutch family size elicited less negative N400 amplitudes than words with a low Dutch family size. Moreover, in both the monolingual and bilingual data, the effects remained present during later time points in the signal, in the 500-800 ms time window, which led us to suggest that these later family size effects are semantic effects induced by resonance between activated family members and the semantic presentation of the target to which they are linked.

Interestingly, in both the monolingual and bilingual data, early family size effects were observed in the ERP signal around 200 ms. In line with what was observed in Chapter 2, these findings show that family size affects also early stages of word processes. The question remains however, to which extent the observed effects indeed reflect early semantic activation of morphological relatives. The possibility that family members are initially activated via a bottom-up orthographic route cannot be fully excluded.

Chapter 4 focussed on the activation of indirect connections between L2 words in the lexicon of Dutch-English bilinguals. More specifically, it was investigated whether during L2 processing, activation could spread beyond directly related items in the L2 (the primary L2 morphologically family), to items that are morphologically related to the primary family (secondary L2 family size). Thus, the question was: Can *work* activate secondary family members such as *horse ride* (via primary family member such as *work horse*)?

Effects of primary and secondary family size were first tested in an English lexical decision task with English monolinguals. The materials included both non-cognate English words and English-Dutch cognates. Note that the English monolinguals had no knowledge of Dutch and were unaware of the cognate status of the cognate items. As expected and in line with the bulk of studies reporting family size in monolinguals, facilitatory effects of English primary family size were observed. Surprisingly, English secondary family size effects had an inhibitory effect on the response latencies to English-Dutch identical cognates but did not affect responses to English controls and English-Dutch non-identical cognates. The data of English-Dutch bilinguals showed the same pattern of results. The reason why an effect of secondary family size emerged only for the identical cognates is unclear. We ruled out that the effect was due to an imbalance in morphological productivity, because the identical cognates, the non-identical cognates, and the controls were carefully matched for primary and secondary productivity (in addition to other variables such as length, and frequency). One alternative and perhaps a bit speculative explanation could be that identical cognates, many of which are of non-germanic origin (e.g., *sultan*, *echo*, *flora*), may have special orthotactics. Because of their 'special' physical form, the processing of these identical cognates may be extra sensitive to the activation of lexical items that are semantically irrelevant (i.e., secondary family members) and produce 'lexical noise'.

This study showed that bilinguals are sensitive to the L2 morphological productivity of words during L2 processing, and that they activate a larger network of morphologically related items that are semantically irrelevant to the task at hand. Moreover, this study suggests that the direction of the family size effects is at least partially determined by the semantic overlap between target word and family member, leading to facilitation when there is semantic overlap (e.g., in the case of activating *work horse* when reading *work*) and inhibition when there is no semantic overlap (e.g., in the case of activating *horse ride* when reading *work*).

Chapter 5 addressed the role of within-language and cross-language activation for words that only share formal overlap but are not semantically related, i.e., orthographic neighbours. Orthographic neighbourhood size effects were investigated in an English lexical decision task with Dutch-English bilinguals. Within-language and cross-language neighbourhood size were manipulated for both English words and English pseudo-words. Importantly, the applied contrast in neighbourhood size was not a gradual 'many versus few' contrast, but we contrasted words and pseudo-words with no neighbours in one or both languages versus words and pseudo-words with some neighbours in one or both languages. Further, note that the word stimuli did not contain any cognates.

Facilitatory effects of English orthographic neighbourhood size were observed on the processing of English words, while the activation of Dutch orthographic neighbours had an inhibitory effect on word processing. The pseudo-word data showed the reverse pattern. Inhibitory effects of English orthographic neighbourhood size and facilitatory effects of Dutch orthographic neighbourhood size were observed on the latencies to English pseudo-words (which required no-responses). This experiment showed that when reading purely English words (i.e., non-cognates) or English pseudo-words, Dutch-English bilinguals activate Dutch form similar words.

On the basis of this experiment, we concluded that cross-language orthographic neighbours can be activated in a purely monolingual task context. Moreover, we concluded that the mechanisms that are put forward by interactive activation accounts of word processing to explain orthographic neighbourhood size effects, namely global lexical activation and lexical competition, may not be sufficient in themselves to account for the complete range of orthographic neighbourhood size effects observed in our study. We proposed an alternative explanation in terms of response competition to account for these effects.

In the following section of this chapter, I reconsider each of the research questions I formulated in the Introduction (Chapter 1) of this dissertation. Where possible, more general issues concerning morphological family size or orthographic neighbourhood size effects are discussed together in order to allow for one single account of bilingual word processing.

Discussion

Cross-language activation of morphological family members and orthographic neighbours

In the Introduction (Chapter 1), I discussed the issue of cross-language lexical activation during bilingual word processing. I posed the question of whether bilinguals activate within-language and cross-language morphological family members and orthographic neighbours during word processing. This question was addressed in Chapter 2-3 for morphological family members, and Chapter 5 for orthographic neighbours. The results of the experiments reported in these chapters show that when Dutch-English bilinguals read words in a purely English task context, such as English lexical decision, they activate Dutch words that are morphologically or orthographically related to the English target words. For morphological family members, this activation is assumed to proceed via the activated Dutch representation of the Dutch-English cognate. For orthographic neighbours, cross-language Dutch neighbours can be activated directly via the English target word based on the orthographic overlap with this word. Both morphological family members and orthographic neighbours have in common that they are not totally visibly present in the input word. As such, they provide strong evidence for language non-selective access in bilingual word processing.

A further question concerning the activation of cross-language morphological family members is under which conditions these family size effects can be observed. Chapter 4 has shown that there were no effects of Dutch morphological family size in English lexical decision when the both the family sizes of the target language (English) and the cross-language (Dutch) family size were varied. In that case, only the effect of English family size remained. We hypothesized that this occurred because the two effects were pointing in the same direction, and the English family size effect was the dominant. In Chapters 2 and 3, in which the family of the target language was controlled for, Dutch family size effects are observed in English lexical decision.

Further, cross-language family size effects were observed across several paradigms, in lexical decision as well as language decision and progressive demasking. Moreover, we showed that even the ERP signal is sensitive to the cross-language morphological productivity of words. This shows that bilinguals activate their network of cross-language morphological relations under many circumstances of word processing and that the cross-language family size effect is a robust effect. The same can be concluded for orthographic neighbourhood size effects. Dutch orthographic neighbourhood size effects even arise in a purely English task context with purely English words and no cognates.

Going deeper into the network: secondary family size effects

Chapter 4 of this dissertation was devoted to the question of how far activation can actually spread within the lexicon of monolinguals and bilinguals. We focussed on within-language secondary family members. An earlier study of Baayen (2010) has shown that monolinguals can activate a deeper network of morphological relations. For bilinguals processing words in their second language, this is not evident. First, the size of the second language vocabulary is probably not as large as that of monolinguals, and links between second language words may be weak. Second, it is not evident that bilinguals need to activate words beyond the primary morphological family. The results of Experiment 2 of Chapter 4 show that both monolinguals and bilinguals activated English secondary family members for identical cognates. Interestingly, the activated secondary family members were not directly morphologically related to the English target words (e.g., *work* and *horse power*), and, as a consequence, their activation was not beneficial to word processing. While it is not clear why secondary family size effects are restricted to identical cognates only, we concluded that the activation of secondary family members, affects monolingual and bilingual processing in a similar way, regardless of the proficiency in English of the participants.

Our observation of secondary family size raises several issues which needs to be further addressed in future research. As a first issue, can/do bilinguals activate Dutch secondary family members in an English task? Because our primary focus was on finding secondary family size effects in word processing in the target language (English), the family size of the target language was varied. As a consequence, this design did not allow for Dutch family size effects to show up. A second issue for further research is: where are the boundaries of spreading activation? For instance, can activated orthographic neighbours activate their orthographic neighbours? This would entail that the target word *good* activates its orthographic neighbour *wood*, which would in turn activate its orthographic neighbour *wool* via their shared letters *w*, *o*, and *o* (mediated co-activation).

Morphological effects: a combination of orthographic and semantic effects?

Another question that was posed in the Introduction is whether the morphological family size effect is a true morphological effect or an effect based on the sum of orthographic and semantic similarity. A large number of studies (discussed in Chapters 2-4) argue that the family size effect is mainly a semantic effect and is unaffected by orthographic similarity. For instance, De Jong, Schreuder, and Baayen (2000) showed that the family size effect did not differ for regular and irregular past participles of which the family members had complete or less complete formal overlap with the target participles.

Further, De Jong, Schreuder, and Baayen (2003) observed that co-activation of family members co-determines the meaning of mono-morphemic target words. They showed that adjectives in different contexts activate different subsets of family members, by means of semantic restrictions. Finally, the finding that family size did not affect response latencies in progressive demasking (Schreuder & Baayen, 1997) suggests that the family size effect is not present during early phases of word processing and support evidence for the assumption that the effect is mainly a semantic effect. The late effects observed in the ERP signal after 500 ms in the experiments of Chapter 3 supports the proposal that a semantic component must be involved.

At the same time, the observed early effects in the ERP signal reported Chapter 3 suggest that the family size effect is also sensitive to formal aspects of word processing.

Moreover, the finding that cross-language family size effects affect response latencies in progressive demasking (Chapter 2) indicates that the family size effect is at least partly orthographic in nature. Thus, although the family size effect might be semantically driven, we have argued that it is not exclusively a semantic effect.

In Chapter 3, we compared ERP effects of cross-language family size to ERP effects of orthographic neighbourhood size and associative neighbourhood size reported by Müller, Duñabeitia, and Carreiras (2010). Orthographic neighbours (e.g., *park* and *part*) are similar in orthography but have no semantic overlap, while semantic associates (e.g., *cat* and *milk*) only share part of their semantic representation and do not bear formal similarities. In contrast to what was observed by Müller et al. for words with many orthographic neighbours and words with many semantic associates, words with a large number of morphological family members elicited smaller negative amplitudes in the N400 time window than words with less morphological relatives. The difference in direction of the family size effect and the effects of orthographic and semantic neighbourhood size suggests that the family size effect is different from effects of orthographic and semantic similarity. Although this evidence indicates that both semantic and orthographic similarity may contribute to the family size effect, it does not allow us to conclude unequivocally that the family size effect requires a morphological representation separate from purely orthographic and semantic representations.

The direction of family size and neighbourhood size effects: Semantic similarity and task demands

The observed family size effect in monolingual studies led us to hypothesize that the direction of the family size effect in both monolingual and bilingual word processing may depend on whether or not the target word and its family members overlap with respect to the semantics they activate. The different direction of the primary (facilitation) and secondary (inhibition) family size effects observed in Chapter 4 support this hypothesis. Secondary family members often do not bear any semantic relationship with the target to which they are linked (e.g., *work* and *horse ride*), while primary family members do (e.g., *work* and *work horse*). Activated semantic representations that are not convergent with the semantic representation of the target will produce irrelevant semantic activation, which will negatively affect the processing of the target word.

In addition, in Chapter 3, we observed that orthographic neighbours and semantic associates produced different ERP patterns in the N400 time window than morphological family members. While activated family members will always co-activate the semantic representation of that of the target (i.e., because they *contain* the target) and increase the activation of the target word, orthographic neighbours activate semantic fields that are different from those of the target. This will generate a large amount of semantically non-convergent activation, which will increase processing load. The same holds for activated semantic associates, which are related in meaning to the target word but activate different semantic representations. Moreover, inhibitory effects of orthographic neighbourhood size observed in behavioural studies, such as the study of Bowers, Davis and Hanley (2005), which are generally taken as evidence of lexical competition, could be explained with this semantic interpretation.

However, semantic convergence does not always lead to facilitatory effects. Especially in tasks in which orthographic information is relevant for completing the task, such as language decision and progressive demasking, semantic overlap between a target word and its morphological family does not lead to facilitatory effects of family size. In language decision, participants need to decide whether or not the presented letter string is a word in one language or the other. Since cognates share form overlap in both languages (e.g., *tent* in English and Dutch), response competition is induced between the activated cognate representations to which morphological family members are linked. This results in inhibitory effects of family size, although family members may still have become activated via the semantic representation of the target word. In progressive demasking, inhibitory effects could be a result of family members being activated via an orthographic route, while resonance between orthography and semantics might be delayed. In that case, the direction of family size effect might not be a result of semantic convergence either.

In similar vein, the observed inhibitory effects of orthographic neighbourhood size in semantic categorisation tasks in behavioural studies (Bowers et al., 2005) and in ERP studies (i.e., more negative N400 amplitudes for words with a large number of orthographic neighbours; Holcomb, Grainger, & O'Rourke, 2002; Midgley, Holcomb, Van

Heuven, & Grainger, 2008), but facilitatory effects in lexical decision (Chapter 5) show that semantic similarity or divergence might only explain the direction of the effect under specific task requirements.

Task-related factors should therefore not be underestimated as a predictor of the direction of lexical effects. In the Introduction of this dissertation, I posed the question of whether the direction of orthographic neighbourhood size effects is dependent on the contrast in neighbourhood size (few versus many, or none versus some). In Chapter 5, we observed facilitatory effects of orthographic neighbourhood size instead of inhibitory effects, as was predicted and observed by Bowers et al. (2005) when applying a 'none versus some' contrast in neighbourhood size. Given these conflicting findings with the same neighbourhood size contrast, we argued that the difference in direction of neighbourhood size effects observed in the literature is probably not due to applying a difference in neighbourhood size contrast, but should be ascribed to other factors. In our study and that of Bowers et al., the different pattern in results can be a result of using of different tasks (lexical decision and semantic categorisation).

This may also hold for conflicting results in ERP studies. For instance, cognates that have been observed to produce smaller N400 amplitudes relative to controls in semantic categorisation (e.g., Midgley, Holcomb, & Grainger, 2011), but not in language specific lexical decision (see Chapter 3). To measure ERP effects of family size and neighbourhood size that are not 'contaminated' by task-related factors, we therefore adviced to conduct task-free ERP measurements.

To conclude, using different experimental tasks may lead to different result patterns for morphological family members and orthographic neighbours. The direction of effects of family size and neighbourhood size cannot uniquely be ascribed to semantic convergence, though the effect, in particular for morphological family members, may have a semantic component.

Processing mechanisms underlying family size and neighbourhood size effects

In the previous sections, I tried to decompose the observed morphological family size and orthographic neighbourhood size effects in terms of the experimental conditions under which they arose and the possible factors that influenced the direction of the effects. In order to build a model, the processing mechanisms underlying these effects need to be reconsidered. I will discuss processing mechanisms that have been put forward to account for family size and orthographic neighbourhood size effects and evaluate these in the light of the effects observed in Chapters 2-5.

Schreuder and Baayen (1997) explained family size effects along the lines of a read-out of global lexical activation (Grainger & Jacobs, 1996). Upon reading a target word, activation is spread to morphologically related items, which then become co-activated. Words that co-activate many other words (lemmas) give rise to more global lexical activation supporting a positive lexicality decision. This will lead to facilitatory effect for words with a large number of morphological relatives.

More recently, De Jong et al. (2003) proposed a computational model, the Morphological Family Resonance Model (MFRM), to simulate observed family size effects. In their model, family size effects are explained by means of resonance between the activated lemmas and the semantic representations to which they are linked at the semantic level. Due to this resonance of activation, the activation of the target level increases exponentially, until a certain threshold is reached. The larger the activated morphological family is, the sooner this threshold will be reached. The simulations of De Jong et al. show that global lexical activation may not be necessary if activation is allowed to resonate between forms, lemmas, and meanings. Their simulations support experimental findings that indicate co-activation of family members reflects semantic activation (e.g., De Jong et al., 2003).

The findings of our ERP experiments reported in Chapter 3 are partially in line with the assumption that the family size effect reflects semantic activation. Especially the late effects of Dutch family size (between 500 and 800 ms) observed in our monolingual and bilingual ERP data are not likely to be due to increased global activation, because at this time point a lexical decision to a word must have been already made. Rather, these effects are more likely to be semantic in nature and reflect resonance in the lexicon.

However, resonance between the semantic level and the lemma level might not play a role during the very first phases of word identification. The effects of family size observed during progressive demasking (Chapter 3) question whether resonance needs to be involved. It is not unthinkable that family members are activated via a bottom-up orthographic route rather than via the semantic representation of the target (i.e., the input *water* could activate *waterproof*). In line with Grainger and Jacobs (1996), facilitatory effects of family size could then arise because of global lexical activation, while inhibitory effects can occur as a result of lexical competition between activated family members and the target. This means that De Jong et al.'s assumption of resonance, and Grainger and Jacob's account of summed lexical activation are not mutually exclusive and can account for different stages of word processing.

Finally, in tasks such as language decision, which require a decision concerning the language membership of the letter string, more general task-related processes can play. We argued that when the activated representations of a cognate activate their language membership information at the language node, the activated family members that map onto the cognate representation to which they are linked increase the activation at the language node. In a task in which cognate representations induce response competition, a large family size in one of the languages would increase the response competition, and produce inhibitory effects on the processing of the cognate.

As for purely orthographic relationships such as orthographic neighbourhood, behavioural studies on orthographic neighbourhood effects generally explain facilitatory effects in terms of global lexical activation following Grainger and Jacobs (1996), while inhibitory effects are a result of lexical competition between activated word candidates.

As an alternative to account for the complete range of orthographic neighbourhood effects observed in the word and pseudo-word data, we proposed an explanation in terms of response competition that was similar to that proposed for family size effects. In English lexical decision, facilitatory effects of Dutch neighbours to English pseudo-words could not be explained solely by global lexical activation feeding a positive response nor by lexical competition between activated word candidates. Rather, these effects to pseudo-words, plus the observed facilitatory effects of English neighbourhood size and inhibitory effects of Dutch neighbourhood size to English words, can be explained by the single mechanism of response competition. The assumption that orthographic neighbours activate their language membership information is necessary. The activated language nodes are linked to a response, which corresponds in English lexical decision to a yes-response for English language activation and a no-response for all other activated languages. In lexical decision, activated English neighbours of word stimuli feed the positive response, and, consequently, produce facilitatory effects, while activate Dutch neighbours map onto a negative response and produce inhibitory effects.

Of course, we acknowledged that response competition by itself is not sufficient to account for lexical effects that occur across paradigms in bilingual word processing. Rather, different mechanisms seem to interact depending on task demands. More research is clearly needed to clarify the role of response competition.

In conclusion, I discussed a number of processing mechanisms (i.e., resonance, global lexical activation, lexical competition, and response competition) that could account for the effects of morphological family size and orthographic neighbourhood size in Chapters 2-5. It seems likely that all of these mechanisms should be included in a model of bilingual word processing. In what follows, I account for the range of observed effects of morphological family size and orthographic neighbourhood size in Chapters 2-5 and effects observed in the literature by considering two theoretical frameworks that incorporate some of these mechanisms. First, I consider the framework of spreading activation. One bilingual model of spreading activation that has proven more than adequate in accounting for different lexical effects in bilingual word processing is the Bilingual Interactive Activation Plus (BIA+) model (Dijkstra & Van Heuven, 2002. I present a further specification of the BIA+ model. Second, I explore the possibilities of the framework of naïve discrimination learning.

A bilingual model for morphological and orthographic effects

The BIA+ model is a connectionist model that extends the original Interactive Activation (IA) model of McClelland & Rumelhart (1981) to account for bilingual word processing. The model assumes an integrated lexicon in which nodes at the word level are interconnected between languages. The model distinguishes a word identification system and a task-decision system (see Figure 6.1 for a graphic representation of the model).

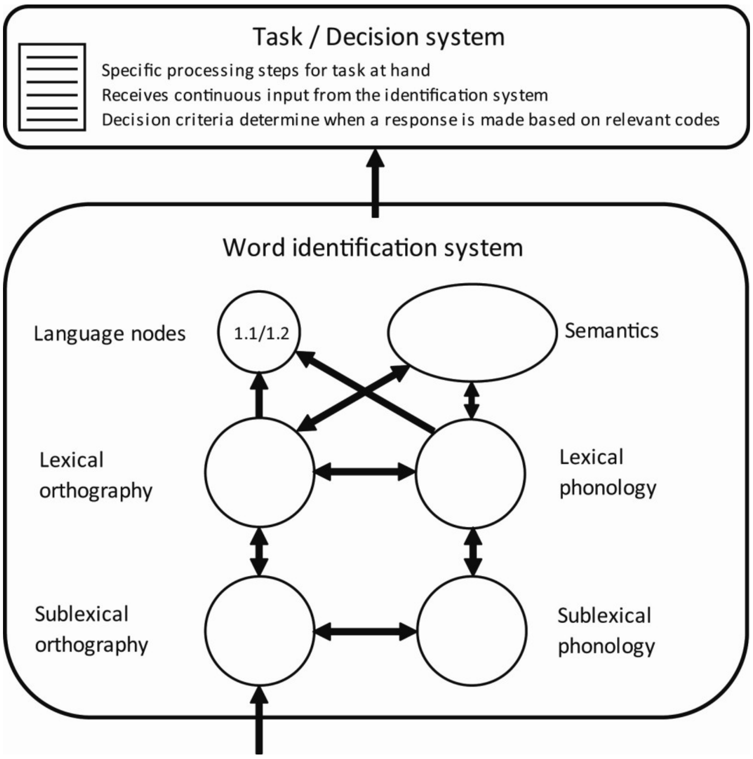

Figure 6.1. Graphical representation of the BIA+ model (reproduced from Dijkstra & Van Heuven, 2002).

The word identification system contains pools of sub-lexical and lexical orthographic and phonological representations, as well as semantic representations. Further, the model contains a language node that specifies the language membership of each word in the lexicon. The task-decision system incorporates task schema specifications of instructions, task demands, and participant expectancies. As such, it accounts for how the task-relevant language is used for responding. The word identification system provides output to the task-decision system, while there is no influence of the task-decision system on the activation state of words. In order to come to a response, the decision mechanism of the task-decision system continuously weighs the different kinds of activation input produced by the word identification system.

According to the BIA+ model, lexical candidates are activated via an initial stream of bottom-up activation. Identification of the appropriate word will occur through a process of activation and inhibition within and between activation levels. The interactive nature of the model assumes the activation of a lexical candidate suppresses the activation of the other activated lexical candidates through lateral inhibition. This would result in inhibitory effects for words that activate a large number of lexical candidates from either the same or a different language than the target word.

In its current form, the BIA+ model offers no specific account for morphological family size effects. It treats morphological effects as purely orthographic effects that always result in inhibitory effects given that the activated related items are competing for selection with the target word. The predicted inhibitory effects are clearly conflicting with the commonly observed facilitatory effects observed in lexical decision. Moreover, mechanisms other than lexical competition are not considered as a source of inhibitory effects. In what follows, I will discuss resonance, lexical competition, and response competition as potential mechanisms to account for family size effects.

De Jong et al. (2003) explained family size effects as a result of resonance of activation. In their model, the MFRM (Morphological Family Resonance Model) model, lemmas that activate the same semantics are linked onto a shared semantic representation. Associated lemmas (family members) of a target word are activated via the semantic representation of that target word. Activation is spread back and forth between this semantic representation and the associated lemmas, gradually increasing the shared semantic activation and the activation level of the target lemma. Resonance of a large amount of activation due to the activation of many family members will thus speed up the rate at which the activation of the target lemma increases, speeding up word recognition.

To account for both within-language and cross-language family size effects, in Chapter 2, we proposed an integration of the MFRM model of De Jong et al. (2003) in the BIA+ model. Integrating the mechanism of resonance in the BIA+ model allows for the top-down activation of morphological family members via the semantic representation of the input word. In the BIA+ model, there is no lemma level, and activation is assumed to resonate between the semantic and orthographic level. This should result in facilitatory effects rather than inhibition effects that are a consequence of lexical competition.

Moreover, resonance between the semantic level and orthographic level allows for an explanation in terms of semantic congruency. The more semantically congruent representations are activated due to the activation of family members, the larger the facilitatory effect of family size. This is in accordance with the findings of Schreuder and Baayen (1997) and Bertram, Baayen, and Schreuder (2000), who observed that correlations between family size and reaction times increased when semantically opaque family members were excluded from the family size count (e.g., *honeymoon* is morphologically but not semantically related to *honey*; exclusion of opaque family members such as *honeymoon* from the family size count increased the correlation of family size with RT).

Important to note is that, in the structure of the new model, completely in accordance with the assumptions of the original BIA+ model, family members can also be activated via an initial bottom-up flow of activation. In this case, family members are activated based on the orthographic overlap they share with the input, similar to the activation of orthographic neighbours. Activation can resonate to and from the semantic level but this is not necessary. With resonance between the orthographic and semantic level, the family size effect on target word processing will be a semantically driven effect and will be facilitatory for cognates. Without resonance to and from the semantic level, a purely orthographic route would logically result in lexical competition between family members and the input word. This is in accordance with the inhibitory effects of cross-language family size observed in progressive demasking in Chapter 2. We argued that in this task that is assumed to tap into early stages of word processing, semantic representations may not yet have been activated and resonance between the semantic level and orthographic level is delayed. The inhibitory family size effect would then be purely orthographic in nature and a result of lexical competition.

The third mechanism that is considered in order to account for family size effects is response competition. Response competition could explain inhibitory effects in language decision (see Chapter 2). In this task, a response conflict arises when activated representations from two languages overlap in form (e.g., cognates such as *norm*) and are linked to a different response. The response competition is directly dependent on language membership of the activated items. Inhibitory effects of family size of both languages can be explained as follows. The target word will activate, besides its morphological family members, also the language membership information of these activated family members. Increased summed activation of the non-target language increases the response conflict. The effect of summed language membership activation on response competition is less strong when the orthographic overlap between the target word and family members is reduced (i.e., less activation is sent to the inappropriate language membership node). Thus, in an interactive activation account, family size effects can be explained via three mechanisms: facilitation through semantic activation, and inhibition though lexical competition or response competition (via summed language membership activation). The mechanisms are illustrated in Figure 6.2.

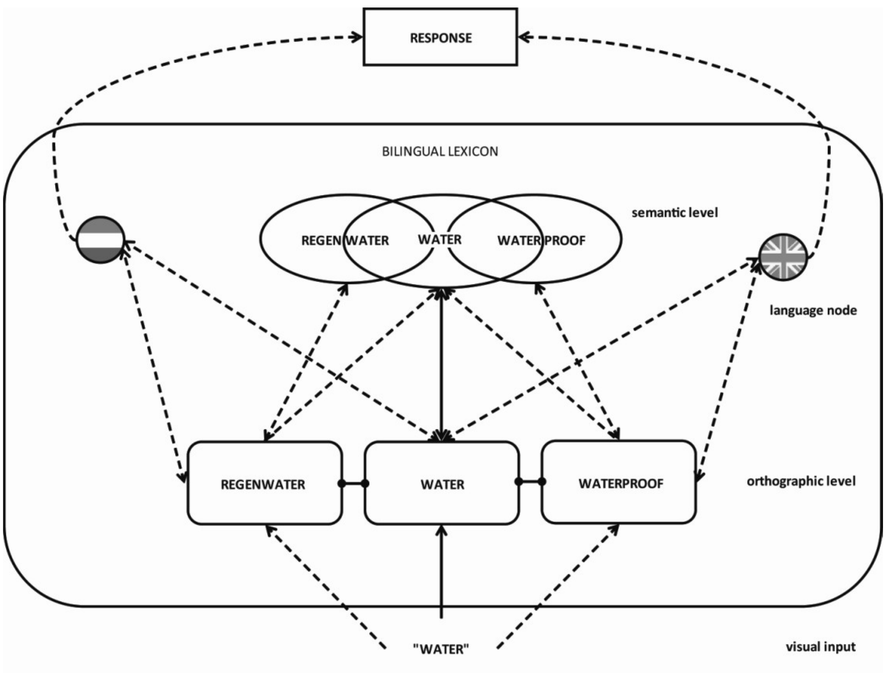

Figure 6.2. Schematic representation of the activation of within-language and cross-language family members with a model based on an integration of the MFRM of De Jong et al. (2003) into the BIA+ model (Dijkstra & Van Heuven, 2002).

The neighbourhood effects of the word stimuli reported in Chapter 5 can also be explained within this model considering the same mechanisms (see Figure 6.3). Assuming that neighbours are activated via a purely orthographic route, inhibition of cross-language orthographic neighbours can occur because of either lexical competition or summed language membership activation that is linked to a different response. Moreover, facilitatory effects can be explained with this same mechanism of summed language membership information: In English lexical decision, activated English neighbours are linked to the appropriate positive response, and increased activation due to the activation of a large number of orthographic neighbours will result in facilitatory effects.

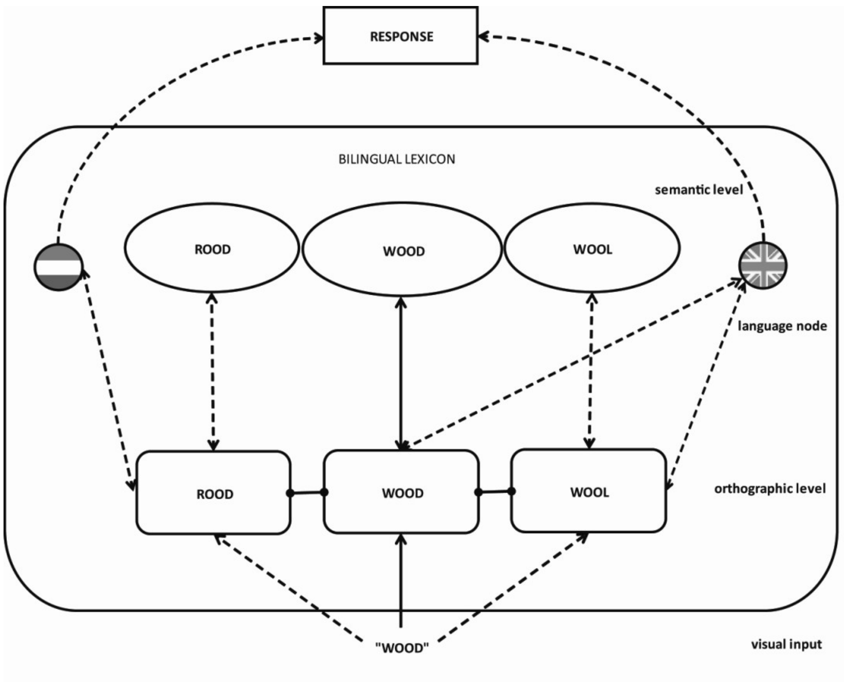

Figure 6.3. Flow of activation for within-language and cross-language orthographic neighbours of the visual input “wood” at the orthographic and semantic level, along with their activated language membership information.

A logical question that follows from Figure 6.3 is whether orthographic neighbourhood size effects can be explained in terms of semantic activation as well. In Chapter 4, it was suggested that the inhibitory ERP effects observed by Müller et al. (2010) for orthographic neighbours might be the result of the activation of semantically incongruent representations. Note that this task was a semantic go/no-go task, in which the orthographic neighbours did not require a button-press. This task required semantic processing, and one might therefore argue that the inhibitory effects of neighbourhood size are a result of resonance between the semantic and orthographic level. In contrast to family members, the activated neighbours do not strengthen the activation of the target word. Rather, the activated semantic representations only spread activation back to the orthographic representation of the neighbour itself, increasing the competition. The hypothesis that the orthographic neighbourhood size effect has a semantic component is not unthinkable (see Müller et al., 2010 for a discussion on this topic). Holcomb, Grainger, and O'Rourke (2002) proposed that the N400 associated with the orthographic neighbourhood size effect reflects semantic activation, even though the neighbourhood manipulation is orthographic in nature. Moreover, several behavioural studies provide evidence that semantic representations of orthographic neighbours are activated (e.g., Duñabeitia, Carreiras, & Perea, 2008; Boot & Pecher, 2008). Whether it is the activation of semantically incongruent representations rather than lexical competition that explains the N400 effect for orthographic neighbours is a topic for further research. It is clear that a full explanation in terms of semantic overlap does not account for the observed effects of orthographic neighbourhood size in behavioural studies. Rather, whether or not the activated semantics of an orthographic neighbour play a role seems to depend heavily on task context.

In sum, I have sketched the contours of a model that could account for within-language and cross-language morphological and orthographic effects. Obviously, this is merely a blueprint of a model and the model has yet to be implemented. Nevertheless, it provides a basis for new studies into the mechanisms underlying morphological and orthographic effects.

As an alternative way to account for the observed family size effects, the framework of Naïve Discrimination Learning (Wagner & Rescorla, 1972; Ramscar, Yarlett, Dye, Denny,

& Thorpe, 2010) was explored in Chapter 4. In this framework, family size effects are a consequence of a dynamic system that learns the distributional pattern of orthographic cues to meanings in the English lexicon. The effects of primary and secondary family size as well as the effects of cognate status that were observed in Experiments 1 and 2 of Chapter 4 were simulated successfully by the Naïve Discriminative Reader (cf. Baayen, Milin, Filipovic Durdjevic, Hendrix, & Marelli 2011). The simulations show that family size and cognate effects can be understood without reference to spreading activation. The simulation studies also integrated the idea of multiple read-out (Grainger & Jacobs, 1996) by including the thresholded summed activation of competitors as a predictor.

In contrast to current interactive activation models, such as BIA or BIA+, the Naïve Discriminative Reader is able to account for family size effects in terms of an explanation of semantic incongruence as was put forward in Chapters 2 and 3. In interactive activation models, the mapping between representations is based on purely formal (i.e., orthographic) information links. In contrast, the Naïve Discriminative Reader works with a direct mapping from orthographic cues to semantic outcomes.

However, one possible drawback of the simulations of the naïve discriminative reader is that the bilingual model that best fits the data is a model based on two separate language-specific lexicons. Although this model is still compatible with the hypothesis of non-selective access, and indicates that the Dutch and English networks are subject to domain-specific learning, it conflicts with the dominant view that words of both languages of a bilingual are stored in one fully integrated lexicon. Of course, we should consider that these simulations were a first attempt to model lexical effects in bilingual word processing and further specification is needed. In addition, the Naïve Discriminative Reader should prove to be able to effectively simulate the range of lexical effects that are simulated by BIA+ before abandoning an explanation of family size effects in terms of spreading activation. Moreover, it should prove to be able to account for task-related effects. Nevertheless, the Naïve Discriminative Reader offers a promising alternative account to interactive activation models of spreading activation, showing that distributional properties of words in the language in interaction with discrimination learner have explanatory power.

Conclusions

In conclusion, I have shown that both monolingual and bilingual word processing can be affected by the activation of other words that are not directly visible in a presented letter string, namely morphological family members and orthographic neighbours. These morphological and orthographic effects not only emphasize the interconnectedness between words in the mental lexicon of language users, they also provide evidence for an integrated lexicon with language-non-selective access.

This dissertation has clarified the nature of morphological family size and orthographic neighbourhood size effects in several ways: First, I have shown that the morphological family size effect in bilingual word processing is sensitive both semantic and orthographic characteristics of the stimuli. Second, I have shown that morphological family size can change as a function of task-related processes. Finally, I have shown that both orthographic neighbourhood size and morphological family size effects can be explained by different processing mechanisms. These findings concerning family size and neighbourhood size effects in bilingual word processing led us to propose a model, based on an integration of the MFRM model of monolingual morphological processing into the BIA+ model for bilingual word processing. The new model is a first attempt to account for the whole range of observed models, by means of including both mechanisms within the word identification system and a processing mechanism tied to the task decision system. Finally, I explored the new theoretical framework of Naïve Discrimination learning by presenting simulations of family size effects with a new model, the Naïve Discriminative Reader.

All in all, I have shown that the mental lexicon is a complex network of words, and the activation of words in the lexicon is affected by several stimulus-related and task-related factors. In sum, there is so much more to word reading than meets the eye.

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Nederlandse samenvatting

We uiten, zien, lezen of schrijven elke dag duizenden woorden en de snelheid en flexibiliteit waarmee we deze woorden kunnen verwerken is opzienbarend. Dit is alleen mogelijk wanneer de woorden die we kennen op een enigszins gestructureerde manier in het geheugen zijn opgeslagen. De opslagplaats voor woorden in ons hoofd, ook wel 'mentale lexicon' genoemd, is geen grote oceaan waarin woorden als geïsoleerde eilandjes drijven. Het mentale lexicon moet eerder beschouwd worden als een complex netwerk of spinnenweb waarin woorden op verschillende manieren met elkaar verbonden zijn. Het overkomt iedereen wel eens dat hij/zij een ander woord leest dan er eigenlijk staat. Dat juist déze niet-bedoelde woorden actief worden is het gevolg van de complexe structuur van ons lexicon.

Dat het lezen van een bepaald woord een ander woord kan activeren heeft vooral te maken met de eigenschappen waarin die woorden overlappen. Zo komen sommige woorden met verschillende betekenissen gedeeltelijk of zelfs geheel overeen in hun schrijfwijze (zoals *muis* en *huis*) of uitspraak (zoals *vier* en *fier)*, terwijl andere woorden juist gedeeltelijk in betekenis overlappen, maar heel verschillend geschreven worden (*bank* en *sofa* verwijzen allebei naar objecten om op te zitten). De twee typen relaties tussen woorden die in dit proefschrift centraal staan zijn morfologische familierelaties en orthografische burenrelaties. Een morfologisch familielid is een complex woord, dat wil zeggen een samenstelling of afgeleid woord, dat een morfeem deelt met een ander woord. Familieleden van het woord *huis* zijn bijvoorbeeld *verhuizing*, *huiselijk* en *tuinhuis*. Het tweede type relatie tussen woorden zijn orthografische burenrelaties. Wanneer woorden in slechts één letter van elkaar verschillen noemen we hen orthografische buren (zoals *huis* en *muis*). Monolinguaal onderzoek naar de verwerking van woorden in isolatie en in zinnen heeft aangetoond dat deze morfologische familieleden en orthografische buren geactiveerd kunnen worden en het woordverwerkingsproces kunnen beïnvloeden (zie bijvoorbeeld Schreuder & Baayen, 1997; Andrews, 1997).

Relaties tussen woorden beperken zich niet tot de woorden van een enkele taal, maar zijn taaloverstijgend. De respectievelijk Engelse en Nederlandse woorden *wood* en *rood* zijn orthografische buren, terwijl het Nederlandse woord *vingerhoed* een morfologisch familielid is van het Engelse woord *finger*. Psycholinguïstisch onderzoek heeft aangetoond dat meertaligen woorden uit een andere taal dan de taal waarin ze op dat moment lezen of luisteren kunnen activeren. Een voorwaarde voor deze activatie is dat de geactiveerde woorden uit de andere taal gedeeltelijk of geheel overlappen in schrijfwijze of uitspraak met het woord uit de doeltaal. Omdat bij zowel orthografische buren als morfologische familieleden uit verschillende talen sprake is van een overlap in schrijfwijze, zijn dergelijke relaties tussen woorden uitermate geschikt om de activatie van woorden in een andere taal te bestuderen.

Hoewel onderzoekers al veel te weten zijn gekomen over hoe ons mentale lexicon in elkaar zit, zijn er nog veel vragen onbeantwoord. Zo is niet geheel duidelijk welke rol specifieke woordeigenschappen en taakafhankelijke processen spelen bij het activeren van woorden uit een andere taal dan de taal waarin je op dat moment woorden verwerkt. Daarnaast is er ook nog vrij weinig onderzoek gedaan naar de effecten van activatie van orthografische buren en morfologische familieleden bij tweetalige woordverwerking en naar de algemene processen die ten grondslag liggen aan de activatie van familieleden en buren. In dit proefschrift is onderzocht of en onder welke condities tweetaligen familieleden en buren uit hun andere taal activeren tijdens het lezen van woorden uit een van hun twee talen. Ook is gekeken naar de invloed die de activatie van deze woorden heeft op het woordverwerkingsproces in een specifieke taakcontext. Of buren of familieleden uit een andere taal actief worden of niet, leidt tot verdere inzichten in de structuur van ons mentale lexicon.

In Hoofdstukken 2 tot en met 4 belichten we de effecten van morfologische familiegrootte. In alle taken met bilinguale proefpersonen is gebruik gemaakt van Nederlands-Engelse cognaten. Cognaten zijn woorden die (nagenoeg) dezelfde betekenis en dezelfde vorm hebben in twee of meerdere talen, zoals de woorden *book* in het Engels en *boek* in het

Nederlands, of het woord *tent* dat identiek is in beide talen. Omdat deze cognaten overlappen in vorm, zouden tweetaligen tijdens het lezen van het Engelse woord *book* Nederlandse morfologische familieleden als *boekenplank* en *luisterboek* kunnen activeren.

In Hoofdstuk 2 hebben we onderzocht of Nederlands-Engelse tweetaligen morfologische familieleden van hun andere taal activeren tijdens het lezen van woorden. Hierbij werden drie verschillende taken benut: lexicale decisie, taaldecisie en progressieve demaskering. In Experiment 1, bij de Engelse lexicale decisietaak, moesten proefpersonen zo snel mogelijk aangeven of de letterreeks die ze zagen een bestaand Engels woord was of niet door op een knop te drukken van een kastje met twee knoppen. Als de letters een Engels woord vormden, moesten ze op de ene knop drukken; als het geen Engels woord was maar een zinloze letterreeks, moesten ze op de andere knop drukken. Proefpersonen zagen in dit experiment Engels-Nederlandse cognaten, puur Engelse woorden zonder enige orthografische overlap met het Nederlands (zoals *bird*) en pseudo-woorden die op Engelse woorden leken (zoals *blear*).

Het experiment liet een significant effect van morfologische familiegrootte zien: reactietijden voor Engels-Nederlandse cognaten waren sneller wanneer deze cognaten een groter aantal Nederlandse familieleden hadden dan wanneer cognaten een kleine morfologische familie hadden. Activatie van de Nederlandse morfologische familie tijdens het lezen versnelde dus de woordherkenning in een Engelse context. Dit faciliterende effect ondersteunt het idee dat het familiegrootte-effect vooral een semantisch effect is: geactiveerde familieleden zoals *soeppan* en *tomatensoep* activeren gedeeltelijk dezelfde betekenissen als het doelwoord *soup*, waardoor de activatie van dit doelwoord versterkt wordt en het woord uiteindelijk sneller geïdentificeerd wordt als bestaand Engels woord. De effecten van het aantal Nederlandse familieleden van een doelwoord en de mate waarin de spelling van het doelwoord overeenkomt met de spelling van de Nederlandse versie van de cognaat bleken elkaar niet te beïnvloeden. Dit suggereert eveneens dat de overlappende betekenis, meer nog dan de overlappende vorm, ten grondslag ligt aan het familiegrootte-effect.

In het taaldecisie-experiment (Experiment 2) moesten proefpersonen bepalen of het woord dat ze zagen een bestaand Engels of Nederlands woord was. Als het woord Engels was, drukten ze op de ene knop van het knoppenkastje en als het Nederlands was op de andere. Er waren geen pseudowoorden in deze taak. Een beslissing of een woord een Engels of Nederlands woord is, is moeilijker te maken bij cognaten dan bij Engelse of Nederlandse controlewoorden (zoals *bird* en *fiets*, respectievelijk), omdat cognaten nagenoeg dezelfde vorm hebben in het Engels en Nederlands. In het taaldecisie-experiment zijn beide representaties van een cognaat zijn gelinkt aan een andere respons. Als beide representaties geactiveerd worden treedt er dus een conflict op tussen het geven van een Engelse en een Nederlandse respons (vanaf nu responscompetitie genoemd), waardoor deze cognaten langzamer worden verwerkt dan Engelse of Nederlandse controlewoorden. Een effect van morfologische familliegrootte op de verwerking van cognaten zou nu twee kanten op kunnen gaan. Enerzijds zou vanwege de overlappende betekenis zowel de Nederlandse als de Engelse morfologische familie van een cognaat faciliterend kunnen werken op de verwerking van een cognaat (zoals we gezien hebben in het lexicale decisie-experiment). Een grote morfologische familie in deze talen zou dan het cognaatinhibitie-effect verkleinen. Anderzijds zouden de geactiveerde morfologische families de responscompetitie tussen de geactiveerde Nederlandse en Engelse representatie van een cognaat kunnen versterken. De resultaten laten zien dat dit laatste het geval is. Een tweede interessante bevinding was dat er geen verband bestaat tussen de gecombineerde familiegrootte in beide talen en de mate van vormoverlap tussen cognaatrepresentaties in beide talen. Dit resultaat laat zien dat het familiegrootte-effect wel degelijk gevoelig is voor vormaspecten.

Dit werd ook gevonden in Experiment 3 voor een Engelse progressieve demaskeringstaak, waarin proefpersonen een Engels doelwoord dat geleidelijk vanachter een masker van ruis te voorschijn komt zo snel mogelijk moesten identificeren. Ook in deze taak, waarvan wordt aangenomen dat het vroege processen van woordverwerking reflecteert en gevoelig is voor vormaspecten van woordverwerking, waren proefpersonen gevoelig voor de Nederlandse (maar niet de Engelse!) familiegrootte van een cognaat. Al met al laten deze experimenten zien dat het familiegrootte-effect niet puur semantisch van aard is, maar ook gevoelig is voor taakspecifieke processen zoals responscompetitie en voor vormaspecten van het doelwoord. Dit laatste lijkt met name van belang in taken waarin orthografische informatie van belang is voor het correct uitvoeren van de taak.

In Hoofdstuk 3 werd het familiegrootte-effect bestudeerd in een elektro-encefalografische (EEG) studie met Nederlandse eentaligen en Nederlands-Engelse tweetaligen. In de EEG-experimenten moesten proefpersonen op een knop drukken wanneer de letterreeks die ze zagen geen bestaand woord was in de doeltaal (het Nederlands voor de eentaligen en het Engels voor de tweetaligen) maar niet reageren in het geval van een bestaand woord. Het voornaamste doel van deze studie was om effecten van familiegrootte van de doeltaal en niet-doeltaal aan te tonen in het EEG-signaal en te verhelderen wanneer deze effecten optreden tijdens de woordverwerking. Omdat aangenomen wordt dat het familiegrootte-effect voornamelijk een semantisch effect is, verwachtten we dergelijke effecten te zien op de N400, een EEG-component die gevoelig is voor lexico-semantische effecten (Kutas & Hillyard, 1980; Kutas & Federmeier, 2000). Onze hypothese was dat woorden met een grote morfologische familie minder negatieve N400 amplitudes zouden genereren dan woorden die een kleinere morfologische familie hebben. Morfologische familieleden overlappen immers in betekenis met het doelwoord en ze zouden daarom de activatie van het doelwoord moeten versterken. Deze richting van het N400-effect zou tegenovergesteld zijn aan de eerder gevonden meer negatieve N400 amplitudes bij woorden met een groot aantal orthografische buren of groot aantal semantisch verwante woorden, waarbij coactivatie van woorden het woordverwerkingsprocess van het doelwoord juist blijkt te vertragen.

Zoals verwacht laat het EEG-signaal voor beide groepen proefpersonen significante N400-effecten van Nederlandse familiegrootte zien. Zowel bij Nederlandse doelwoorden (in de eentalige taak) als bij Engelse cognaten (in de tweetalige taak) met een grote Nederlandse familiegrootte vinden we minder negatieve N400-amplitudes dan bij woorden met een kleine Nederlandse familiegrootte. Daarnaast vinden we bij beide groepen in het EEG-signaal ook latere familiegrootte-effecten (tussen 500 en 800 milliseconden na het verschijnen van het woord). Dit suggereert dat resonantie tussen de geactiveerde familieleden en de semantische representatie van het doelwoord nog doorwerkt nadat een lexicale decisie al genomen zou moeten zijn. Tenslotte blijken familiegrootte-effecten ook een rol te spelen tijdens vroege stadia van woordverwerking (tussen 100 en 300 ms), wat zou kunnen aantonen dat het familegrootte-effect deels een vormeffect is, of anders zou kunnen wijzen op zeer vroege activatie van semantiek.

Hoofdstuk 4 belicht de vraag of gedurende het verwerken van woorden activatie in de niet-doeltaal zich verder kan verspreiden dan naar direct gerelateerde wooden, zoals primaire morfologische familieleden. Meer specifiek hebben we gekeken we of *secundaire* morfologische familieleden uit de doeltaal geactiveerd kunnen worden. Een voorbeeld van een secundair morfologisch familielid van het doelwoord *work* is *horse ride*, dat bereikt wordt via *work horse*. Secundaire morfologische familieleden zijn alleen indirect gerelateerd aan het doelwoord via de primaire morfologische familie. De effecten van Engelse en secundaire familiegrootte werden onderzocht in een Engelse lexicale decisietaak met Engelse eentaligen en Nederlands-Engelse tweetaligen. De selectie van bestaande doelwoorden bevatte zowel puur Engelse (niet-cognate) woorden als Engelse-Nederlandse cognaten. Merk op dat de cognaatstatus van de laatste categorie woorden voor de Engelse eentaligen irrelevant was omdat deze proefpersonen geen kennis van het Nederlands hadden.

Zoals verwacht had de Engelse primaire familiegrootte een faciliterend effect op de woordverwerking bij zowel de eentaligen als de tweetaligen. Verder vonden we in beide groepen een inhiberend effect van Engelse secundaire familiegrootte op de verwerking van identieke cognaten, maar niet op de niet-identieke cognaten en Engelse controlewoorden. Waarom effecten van secundaire familliegrootte alleen in identieke cognaten gevonden worden en niet bij de andere woordtypes vereist verder onderzoek, maar lijkt voort te komen uit de distributionele eigenschappen van de Engelse taal. Identieke cognaten met hun speciale orthografische eigenschappen zijn wellicht extra gevoelig voor de activatie van items die semantisch irrelevant zijn. Simulaties met het NDR (naïve discriminative reader) model ondersteunen dit idee. Binnen het kader van naïef discriminatief leren worden familiegrootte-effecten gezien als een consequentie van een dynamisch systeem dat het distributionele patroon van orthografische cues naar betekenissen in het Engelse lexicon leert.

Onze bevindingen met betrekking tot de effecten van primaire en secundaire familiegrootte ondersteunen de hypothese dat het familiegrootte-effect voornamelijk een semantisch effect is en dat de richting van familiegrootte-effecten tenminste voor een deel bepaald wordt door de aanwezigheid van semantische overlap tussen morfologisch familielid en doelwoord. Secundaire familieleden zijn niet semantisch gerelateerd aan het doelwoord (*horse ride* heeft niets met *work* te maken), terwijl dit bij primaire familieleden vaak wel het geval is (zoals *work* en *work horse*). Activatie van secundaire familieleden zorgt dus voor activatie van irrelevante semantische informatie; daardoor vertragen ze het verwerkingsproces van het doelwoord.

In Hoofdstuk 5 hebben we gekeken naar de effecten van activatie van orthografische buren in de doeltaal en niet-doeltaal. Nederlands-Engelse tweetaligen werden getest in een Engelse lexicale decisietaak, waarin we zowel de doelwoorden als de pseudowoorden hebben gemanipuleerd met betrekking tot de aanwezigheid van orthografische buren in de doeltaal en niet-doeltaal. De doelwoorden en pseudowoorden hadden ofwel helemaal geen buren in het Engels en Nederlands (ze worden dan wel 'kluizenaarwoorden' genoemd), één of meerdere buren in één van de twee talen, of buren in beide talen. De resultaten van het experiment laten bij woorden een faciliterend effect van de aanwezigheid van Engelse buurwoorden zien, terwijl de aanwezigheid van Nederlandse buren juist vertragend werkt. Bij de pseudowoorden vonden we het omgekeerde effect: langzamere reactietijden op pseudowoorden met Engelse buren ten opzichte van pseudowoorden zonder Engelse buren, en snelle reactietijden voor pseudowoorden met Nederlandse buren ten opzichte van pseudowoorden zonder Nederlandse buren. Op basis van de resultaten van het experiment kunnen we concluderen dat tweetaligen orthografische buren uit hun moedertaal activeren wanneer ze Engelse woorden en pseudowoorden lezen.

De woorddata werden vervolgens gesimuleerd met het BIA+model (Dijkstra & Van Heuven, 2002). Interactieve activatiemodellen zoals dit model voorspellen dat in beginsel geactiveerde woorden in competitie zijn met het doelwoord en daardoor het verwerkingsproces van het doelwoord vertragen. De simulatie laat inhibitie-effecten zien voor doelwoorden met buren in één of beide talen ten opzichte van woorden zonder buren in beide talen. Het model bleek de gevonden facilitatie in het lexicale decisie-experiment niet te kunnen simuleren.

Volgens interactieve activatiemodellen kunnen faciliterende effecten optreden op basis van globale lexicale activatie. Hierbij zou de totale activiteit die in het lexicon wordt gegenereerd door de woordkandidaten, een positieve lexicale decisie op het doelwoord bevorderen (er is dan immers meer evidentie dat het doelwoord een bestaand woord is).

Hoewel dit mechanisme inderdaad het faciliterende effect van Engelse buren op de woorddata zou kunnen verklaren, geeft het geen verklaring voor het faciliterende effect bij de pseudowoorden. Immers, veel evidentie voor een positieve respons door de activatie van Nederlandse woordkandidaten zou moeten leiden tot een tragere respons op Engelse pseudowoorden die juist een negatieve respons moeten uitlokken.

We concluderen daarom dat verklaringen die steunen op lexicale competitie en globale lexicale activatie niet toereikend zijn om het complete patroon van effecten van de aanwezigheid van buren in doeltaal en niet-doeltaal te beschrijven. We stellen dat een verklaring op basis van responsbinding een beter alternatief is: wanneer de geactiveerde buren verbonden zijn met een respons die overeenkomt met de respons die de stimulus vereist, zal deze faciliterend werken. Met andere woorden, Engelse buren activeren een positieve respons bij bestaande Engelse woorden en versnellen daardoor de verwerking van het Engelse doelwoord. Op dezelfde manier voeden geactiveerde Nederlandse buren een negatieve respons op Engelse non-woorden (meer evidentie dat de stimulus geen bestaand Engels woord is).

Het onderzoek naar morfologische familiegrootte-effecten en orthografische bureneffecten dat gepresenteerd wordt in dit proefschrift leidt tot verschillende interessante inzichten. Uit eerder onderzoek weten we al dat woorden uit één taal geactiveerd kunnen worden tijdens het lezen van woorden in een andere taal. De experimenten uit dit proefschrift tonen aan dat deze activatie gevoelig is voor een aantal factoren, zoals eigenschappen van de stimulus en taakspecifieke verwerkingsprocessen zoals responscompetitie. Dit heeft gevolgen voor zowel tweetalige als eentalige modellen voor woordverwerking. Veel woordverwerkingsmodellen onderschatten de rol van taakspecifieke processen in het woordverwerkingsproces. De resultaten uit dit proefschrift benadrukken dat taakspecifieke processen in bestaande modellen en theorieën moeten worden meegenomen om effecten van morfologische familiegrootte te kunnen verdisconteren. In Hoofdstuk 6 presenteren we een voorstel voor uitwerking van zo’n model (gebaseerd op het BIA+model).

Het proefschrift laat verder zien dat visuele woordverwerking niet altijd volledig ‘bottom-up’ (op basis van enkel het signaal) verloopt, maar dat er sprake is van wisselwerking tussen verschillende typen representaties in het lexicon. Zo lijken familiegrootte-effecten vooral een gevolg van resonantie tussen semantische en orthografische lexicale representaties.

Tenslotte heeft dit proefschrift aangetoond dat de structuur van het tweetalige lexicon gekenmerkt wordt door een grote mate van interconnectiviteit. We hebben laten zien dat activatie zich kan verspreiden naar woorden die niet altijd direct in het doelwoord visueel aanwezig zijn. De bevinding dat een Engels woord zoals *work* andere Engelse woorden zoals *horse ride*, *cork* en Nederlandse woorden zoals *huiswerk* en *worm* kan activeren en dat deze woorden de herkenning van dit woord kunnen beïnvloeden is niet alleen fascinerend, maar roept verdere interessante vragen op. Hoe ver kan activatie zich uiteindelijk verspreiden? Onder welke omstandigheden worden verschillende relaties tussen woorden geactiveerd? En in hoeverre hangt de activatie van bepaalde woordrelaties af van de structuur van de talen die de spreker beheerst? Kortom, dit proefschrift heeft laten zien dat visuele woordherkenning meer behelst dan wat het oog daadwerkelijk waarneemt.

Curriculum Vitae

Kimberley Mulder was born in 1982 in Amsterdam, The Netherlands. In 2005, she obtained a Master's degree in French language and culture (cum laude), with a specialization in linguistics from the University of Amsterdam. In 2009, she obtained a Master's degree in Linguistics (cum laude), with a specialization in psycholinguistics and second language acquisition from the same university. In that same year, she received a Language Learning Small Grant to continue the research of her Master's at the University of Amsterdam for six months. In October 2009, she started her PhD research as an IMPRS fellow at the Donders Institute for Brain, Cognition, and Behaviour in Nijmegen. In July 2013, she will start as a post-doctoral researcher in the ERC project 'Foreign Casual Speech' at the Radboud University, Nijmegen.

264

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