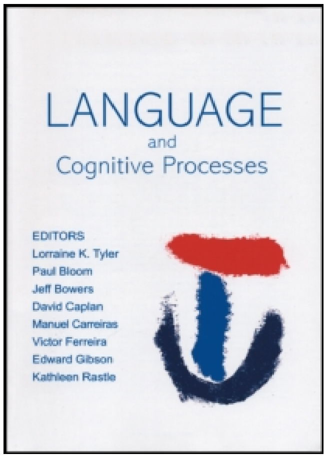

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A roommate in cream: Morphological family size effects on interlingual homograph recognition

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A roommate in cream: Morphological family size effects on interlingual homograph recognition

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In monolingual studies, target word recognition is affected by the number of words that are morphologically related to the target. Larger morphological families lead to faster recognition. We investigated the role of the morphological family size (MFS) effect in bilingual word recognition. First, re-analysis of available English lexical decision data from Dutch–English bilinguals reported by Schulpen, Dijkstra, and Schriefers (2003) revealed a facilitatory English MFS effect in purely English words and in Dutch–English interlingual homographs (such as ROOM, a word that exists both in English and in Dutch, where it means 'cream'). For interlingual homographs, the Dutch MFS simultaneously induced inhibitory effects, supporting a language non-selective access process. The MFS effect was independent of the relative frequency of the two readings of the homographs. Task-dependence of the MFS effect was demonstrated in generalized Dutch–English lexical decision data, which led to facilitatory effects of both families. Finally, the pervasiveness of the MFS effect was demonstrated in a Dutch lexical decision task performed by the same type of bilinguals. Facilitatory effects of Dutch MFS were found for Dutch monolingual words and interlingual homographs, which were also affected by inhibitory effects of English MFS. The results are discussed in relation to the task-sensitive BIA+ model of bilingual word recognition.

INTRODUCTION

A large number of reaction time (RT) studies in the last decade have provided evidence that the recognition of visually presented words by bilinguals proceeds in a language non-selective way. Thus, Dutch–English bilinguals reading a book in their second language (L2), English, will be affected by the lexical knowledge of their first language (L1), Dutch, even when they are not aware of it (Van Heuven, Dijkstra, & Grainger, 1998; Van Hell & Dijkstra, 2002). To the extent that Dutch words are orthographically similar to the English words that the bilinguals are reading, they will be coactivated and may affect item selection. More surprisingly, the bilinguals will even be affected by the knowledge of similar English words when they are reading in Dutch (Van Hell & Dijkstra, 2002). This indicates that the architecture of the lexical processing system is fundamentally non-selective in nature, although the actual effects of course depend on the degree of cross-language similarity of the involved items. A consequence of this theoretical position is that word recognition in L1 and L2 is open to effects of a variety of variables found to affect monolingual word recognition. In this paper, we will argue that this is indeed the case for a recently discovered independent variable in monolingual word recognition, morphological family size (MFS).

So far, the available evidence supporting language non-selective access has been collected in studies basically manipulating the degree of cross-language similarity of items in one of two ways (see Dijkstra & Van Heuven, 2002, for a review of studies). A first type of item manipulation has been to compare the RTs to words existing in one language only to words that share their orthographic, phonological, and/or semantic characteristics across languages. For instance, an item like LIST shares its orthography but not its meaning across Dutch and English (in Dutch, LIST means 'trick'). In contrast to such interlingual homographs, cognates like FILM share (most of) their meaning and orthography across languages. Studies have generally found facilitatory effects for cognates relative to one-language control items under various circumstances (Lemhöfer, Dijkstra, & Michel, 2004). The direction and size of RT effects for interlingual homographs appears to be dependent on task demands, stimulus list composition, and the relative frequency of the homograph readings in the two languages (e.g., Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998). Most studies have focused on homograph effects for bilinguals reading in their L2, but significant (inhibitory) effects have also been obtained in the L1 (De Groot et al., 2000). Note that interlingual homographs are words in two languages, even though they differ in meaning across these languages.

In a second type of manipulation, the number of orthographically or phonologically similar items to the target word from the same and the other language has been varied. As an example, words that are orthographically similar to WORK (called neighbours) are CORK and WORD in English, and VORK and WERK in Dutch. Intralingual and interlingual neighbourhood density have been found to affect the RT patterns observed for target words in a number of tasks (Van Heuven et al., 1998). For lexical decision, inhibitory effects of neighbourhood density have often been reported, but the mechanisms underlying the effects are not well understood and may be sensitive to a variety of factors (such as differences between languages, participants, and stimulus materials; Carreiras, Perea, & Grainger, 1997). Nevertheless, the manipulation of interlingual neighbourhood density provides convincing evidence in support of language non-selective access into an integrated lexicon, because it is concerned with 'on-line' effects for 'normal' words existing in only one language, in contrast to 'special' words like homographs and cognates.

The effects of neighbourhood density were first reported in monolingual studies before they were also demonstrated in bilingual studies. Recent monolingual studies have shown that the RTs in various word identification tasks are affected by yet another variable, called a word's 'morphological family size' (MFS; Baayen, Lieber, & Schreuder, 1997b; Bertram, Baayen, & Schreuder, 2000; de Jong, 2002; Schreuder & Baayen, 1997). For instance, a Dutch word like WERK (meaning 'work') is a constituent of many morphologically complex words, among which are HUISWERK ('homework'), WERKBAAR ('workable'), and VERWERKEN ('to process'). Experiments have revealed that words with larger morphological families are processed faster and more accurately than those with smaller families. This effect is independent of other lexical effects such as word frequency or length (De Jong, Schreuder, & Baayen, 2000), and available evidence indicates that it is at least partially semantic in nature. First, the effect of MFS appears for both regular and irregular past participles (e.g., GEROEID, 'rowed' vs. GEVOCHTEN, 'fought'), even though the irregular past participles do not share the exact orthographic or phonological form across family members (e.g., ROEIER, 'rower', vs. VECHTER, 'fighter'). This suggests that morphological and/or semantic sources underlie the MFS effect. Second, only morphologically related words that are also semantically related contribute to the MFS (Bertram et al., 2000; Schreuder & Baayen, 1997). For instance, GEMEENTE ('municipality') is morphologically but not semantically related to GEMEEN ('nasty') and the correlation between RTs and family size decreases if GEMEENTE is included in the MFS count for GEMEEN.

Moscoso del Prado Martín, Deutsch, Frost, Schreuder, De Jong, and Baayen (2004) report an additional semantic characteristic of the MFS effect in Hebrew. The MFS of Hebrew words for which the morphological root is active in two semantic fields needs to be split into two different subfamilies, one for each semantic field. Both subfamilies show effects of a similar magnitude on the RTs to a particular Hebrew word. However, the direction of the effect is reversed for the subfamily that contains the words that are in a semantic field different from that of the target. For instance, the Hebrew root R-G-L can form words whose meaning is related to 'foot' (REGEL), and words whose meaning is related to 'spy' (MERAGGEL). Response latencies to REGEL are facilitated by the MFS containing those members of the family of R-G-L that are more related in meaning to 'foot' and inhibited by the MFS containing the members of the R-G-L family that are more related in meaning to 'spy'.

It is likely that bilinguals acquiring a second language will start to develop the morphological and semantic relations between words from their second language as well. Of course, the MFS in L2 may initially be smaller than in L1, but it should develop with vocabulary size. Therefore, just like an effect of interlingual neighbours can arise in bilingual word recognition (in spite of a smaller number of known L2 words), the MFS of a word would be expected to start playing a role in L2 as well. In other words, English word recognition in Dutch–English bilinguals should be affected by the English MFS of the target item. Even more interestingly, both the English and the Dutch MFS should play a role in the recognition of interlingual homographs, because these items belong to both English and Dutch families. Additionally, one might expect to find inhibition effects akin to those reported by Moscoso del Prado Martín et al. (2004) for Hebrew. For interlingual homographs, participants performing a lexical decision task in L2 might show a facilitatory effect of the MFS of the target in L2, and an inhibition effect of the MFS of the target in L1. Conversely, participants making lexical decisions in their L1 might show facilitation of the MFS of the word in L1, and for interlingual homographs, they might also show inhibition caused by the MFS of the word in L2.

These predictions follow straightforwardly from the basic assumptions of a recent model for bilingual word recognition, the BIA+ model (Dijkstra & Van Heuven, 2002). According to this language non-selective access model, word recognition entails parallel activation of words from different languages in an integrated word identification system. A task/decision system monitors lexical activity and uses it in accordance with the demands of the task at hand, allowing for context sensitive performance patterns. For instance, let us assume that a Dutch–English bilingual is performing an English (L2) lexical decision task, in which an English word must be accepted ('yes' response), while other words and nonwords must be rejected ('no' response). According to the model, interlingual homographs are represented by means of two orthographic lexical representations, one for each reading of the homograph (e.g., ROOM has one orthographic representation linked to the phonological and semantic characteristics of the English item, and another linked to those of its Dutch counterpart). In the task situation at hand, recognising an interlingual homograph involves a 'race to recognition' between its two readings, with an ensuing response competition (one reading is connected to a 'yes' response, the other to the 'no' response). This whole process is modulated by the relative frequencies of the two readings of the interlingual homograph (because in the model a word's resting level activation depends on its frequency). When a homograph has a higher word frequency in the non-target language (Dutch) than in the target language (English), this induces extra competition resulting in inhibition relative to a one-language (English) control word (Dijkstra et al., 1998).

If the MFS behaves like word frequency, a large English MFS of the homograph should also exert a facilitatory effect in English lexical decision, because in this task it would support the selection of the target item and be indirectly linked to the correct response. At the same time, a large Dutch MFS, associated with the competitor item, should exert an inhibitory effect. This prediction can be contrasted to that for generalised lexical decision, in which participants give a 'yes' response to both English and Dutch words. In this task situation, both English and Dutch MFS should have a facilitatory effect on the RTs.

In sum, in the present study we will investigate a number of issues with respect to morphological families in L1 and L2. First, we will search for the expected MFS effects in the L1 and L2 of bilinguals. Second, we will test if in L2 MFS effects of both L1 and L2 occur for interlingual homographs differing in their relative frequency in L1 and L2. More specifically, we will test the prediction of BIA+ that in an English lexical decision task the MFS effects of Dutch (L1) on English (L2) are inhibitory in nature, while in a generalised lexical decision task they are facilitatory. Finally, we will go even further and try to demonstrate effects of the English (L2) morphological family size of interlingual homographs in a Dutch (L1) lexical decision task. Finding MFS effects would provide additional independent evidence supporting the language non-selective access hypothesis, because it would demonstrate that it is not just the stronger L1 that is affecting the weaker L2, but that there is a mutual effect between the two languages.

These predictions will be tested in two steps. In the first part of the paper, we will test the first two predictions by re-analysing some recent experiments reported by Schulpen et al. (2003). As part of a larger study, these authors conducted two lexical decision experiments with Dutch–English bilingual university students. In the first experiment, the participants responded by pressing a 'yes' or a 'no' button depending on whether they encountered English target words or non-words (English lexical decision task). No Dutch words were present in the experiment. Reaction times for interlingual homographs were compared to those for English control words, revealing only small non-significant latency differences (as observed in earlier studies by Dijkstra et al., 1998; and De Groot et al., 2000). In the second experiment, they pressed a 'yes' button when they encountered a word from English or Dutch, and a 'no' button otherwise (generalised Dutch–English lexical decision task). Now interlingual homographs were recognised faster than English control words. We will investigate if the difference in RT patterns between the two experiments is accompanied by a difference in the MFS effect.

In the second part, we will conduct a new Dutch lexical decision experiment with Dutch–English bilinguals involving largely the same test materials to test the third prediction, i.e., the presence of L2 on L1 effects in the interlingual homographs. This experiment is similar to that by De Groot et al. (2000, Experiment 2), who observed slower RTs to interlingual homographs than to purely Dutch control words. Note that the effects of morphological family size were examined in neither of the earlier studies.

PART I: REANALYSES OF TWO EARLIER STUDIES

Experiment 1: English Visual Lexical Decision

Method

Participants. Nineteen students of the University of Nijmegen (mean age: 22.5 years) were paid to participate in the experiment. All were native speakers of Dutch. All had begun to acquire English at school when they were 11 or 12 years old.

Materials. In total, the stimulus set consisted of 420 items of which 210 were words and 210 nonwords. All word items were selected from the CELEX database (Baayen, Piepenbrock, & Van Rijn, 1993) and had a length of 3–6 letters. Table 1 describes the characteristics of the relevant words in the three experiments of our study. The actual test words can be found in Appendices A and B. Experiments 1 and 2 correspond with Experiments 1 and 2 in Schulpen et al. (2003), while Experiment 3 refers to the present study only. The experiment included 42 interlingual homographs, i.e., words that are legal both in Dutch and English. Homographs were chosen from three frequency categories (high English frequency—high Dutch frequency, high English frequency—low Dutch frequency, and low English frequency—high Dutch frequency). The experiment also included 84 monolingual English words (note that the 84 Dutch words mentioned in Table 1 were only included in Experiments 2 and 3). These monolingual words were divided in four groups. Three groups of 14 words each (English Controls) were matched in English frequency with the three groups of interlingual homographs. The fourth group consisted of 42 words (English Open Range), chosen from English low, middle, and high frequency ranges (14 of each). Finally, 294 filler items (84 words and 210 nonwords with a legal English orthography) were included that do not concern us here.

Procedure. The design consisted of item blocks that were rotated across participants. The presentation order of items within a block was randomised individually with the restriction that no more than three words or nonwords were presented in a row. Each participant was tested individually. The presentation of the visual stimuli and the recordings of the RTs were controlled by an Apple Powerbook G3 400 MHz with 128 megabytes of working memory, with an external Multiplescan 15AV Display and using experimentation software was developed by the technical group of the University in Nijmegen. The participants were seated at a table with the computer monitor at a 60 cm distance. The visual stimuli were presented in capital letters (24 points) in font New Courier in

TABLE 1
Materials present in Experiments 1, 2, and 3

Materials	*Frequency range*	*Number of words*	*Dutch freq.*	*English freq.*	*Experiment*	*Appendix*
English-Dutch homographs	HF English–HF Dutch	14	104	233	1, 2, 3	A
	HF English–LF Dutch	14	9	244		
	LF English–HF Dutch	14	114	32		
English monolingual words	HF English (HF Dutch)	14	–	233	1, 2	B
	HF English (LF Dutch)	14	–	244		
	LF English (HF Dutch)	14	–	32		
	Open range	42	–	5, 48, 415		
Dutch monolingual words	(HF English) HF Dutch	14	104	–	2, 3	C
	(HF English) LF Dutch	14	9	–		
	(LF English) HF Dutch	14	114	–		
	Open range	42	5, 40, 489	–		

The word frequency counts are in occurrences per million. The frequency conditions shown in parentheses in the monolingual words indicate the homograph frequency condition to which each group was matched. The three numbers in the frequency column of the Dutch and English open range monolingual words indicate the average frequency of the low, middle, and high frequency words in the group.

the middle of the screen on a white background. The participants performed an English visual lexical decision task. They first read an English instruction, telling them that they would see a letter string to which they were supposed to react by pressing the 'yes' button when it was an English word or the 'no' button when the letter string was a nonword. The participants were told to react as quickly as possible without making too many errors. Each trial started with the visual presentation of a fixation dot for 500 ms followed after 150 ms by the target letter string in the middle of the screen. The target letter string remained on the screen until the participant responded or until a maximum of 2000 ms. When the button was pressed, the visual target stimulus disappeared and a new trial was triggered immediately.

The experiment was divided in three parts of equal length. The first part was preceded by 24 practice trials. After the practice set the participant could ask questions. All communication between participant and experimentator was conducted in Dutch. After the experiment, the participants were asked to fill out two questionnaires, one on paper about their level of proficiency in the English language, and one on the computer evaluating their knowledge of the stimulus words used in the experiment on a 7-point scale. In total, each experimental session lasted about 45 minutes.

Results and discussion

Data cleaning procedures were based on error rates for items and participants. All incorrect responses were removed from the data (8.14% of all trials). All participants performed with an error rate of less than 20%. Eleven items elicited errors in more than 30% of the trials, and were removed from the analyses. After removing these, 74 trials with RTs that were outside the range of two standard deviations from the mean RT were considered as outliers and were discarded (3.56% of the remaining trials). Note here that our procedure for determining outliers is slightly different than the one reported by Schulpen et al. (2003) for this dataset (and also for the dataset in Experiment 2). Schulpen and colleagues also provide analyses of the monolingual English or Dutch fillers, which they analyse together with the English and Dutch open range words and controls. In our case, the analyses of the monolingual words is restricted to the controls and the open range monolingual words.

Table 2 provides the means, standard deviations, and ranges of the frequency counts, family size counts, and RTs after the data cleaning procedures had been applied.

For this dataset, Schulpen et al. (2003) report results using the traditional ANOVAs on different frequency conditions from a factorial design contrasting high and low Dutch and English frequency. However,

TABLE 2
Means, standard deviations, and ranges for the different counts in the data set from Experiment 1 (EVLD), and in the subsets of interlingual homographs and English monolingual words (after removing outliers)

	Total 115 items		*Interlingual homographs 37 items*		*English monolingual words 78 items*	
English frequency	179.63 ± 312.06	[1, 1981]	190.13 ± 297.78	[3, 1351]	174.65 ± 320.38	[1, 1981]
English family size	16.41 ± 21.76	[0, 112]	12.27 ± 14.99	[1, 70]	18.37 ± 24.16	[0, 112]
Dutch frequency	26.17 ± 85.23	[0, 724]	81.32 ± 135.62	[2, 724]	–	–
Dutch family size	10.45 ± 25.11	[0, 134]	32.49 ± 35.50	[0, 134]	–	–
Response latency (ms)	590 ± 65	[481, 875]	585 ± 48	[500, 710]	591 ± 72	[481, 875]

The word frequency counts are in occurrences per million.

we intend to assess the influence of an additional variable (morphological family size) that the original experimental design did not control for. Furthermore, the word frequency and morphological family size variables for both languages in this dataset follow smooth lognormal distributions according to Shapiro–Wilk normality tests (Royston, 1982) of the log counts ($W = 0.99$, $p = .40$, for English frequency, $W = 0.98$, $p = .13$ for English family size, $W = 0.98$, $p = .58$ for Dutch frequency of the homographs, and $W = 0.95$, $p = .08$ for Dutch family size of the homographs). Given these considerations, we decided to report regression analyses on the experimental results, which are more adequate for analysing this sort of data. In all cases, we report sequential analyses of variance on stepwise multilevel linear regression models (Alegre & Gordon, 1999; Baayen, Tweedie, & Schreuder, 2002; Lorch & Myers, 1990; Pinheiro & Bates, 2000).

We begin by assessing whether English word frequency and morphological family size have a significant influence on the response latencies to the remaining 76 English monolingual words in our dataset. A stepwise multilevel regression model with RT as the dependent variable and English word frequency and English morphological family size as independent variables showed facilitatory main effects of English word frequency, $F(1, 1313) = 112.28$, $p < .001$, and English morphological family size, $F(1, 1313) = 7.80$, $p < .01$, after having partialled out the effect of English word frequency), with the interaction between frequency and family size approaching but not reaching significance, $F(1, 1312) = 3.62$, $p = .06$.

In order to analyse the results for the interlingual homographs in this experiment, we investigate the possible influences of the different variables on the response latencies by means of correlations. As all variables are lognormally distributed, we will report correlations on their logarithms. Both English counts show negative correlation coefficients with RTs ($r = -.21$, $p = .21$ for English word frequency, and $r = -.36$, $p = .03$ for English morphological family size), for which we note that the correlation is not significant for English word frequency. In contrast, both Dutch counts show significant positive correlations with the response latencies ($r = .38$, $p = .02$ for Dutch frequency, and $r = .36$, $p = .03$ for Dutch family size). This indicates that while English word frequency and English family size exert more or less facilitatory influences, Dutch frequency and Dutch family size have inhibitory effects on the response latencies. This is in line with Schulpen et al. (2003) who report opposite effects of English frequency and Dutch frequency for this dataset in an ANOVA on the factorial design.

Note that the magnitude of the correlation coefficient of both family size counts is similar, differing mainly in the direction of the effect. This is reminiscent of the pattern reported by Moscoso del Prado Martín et al. (2004) for Hebrew, in which the semantically close and semantically distant family sizes appear to have effects that are equal in magnitude but different in direction. Moscoso del Prado Martín and colleagues operationalised this in their analyses by taking the difference between the two logarithmic counts as the predictor variable. Note here that a difference in logarithmic scale is equivalent to the logarithm of the ratio (in non-logarithmic scale). This log-transformed ratio, henceforth the family size ratio, turned out to be the crucial predictor for the Hebrew data.

In our regression analyses, we will make use of a similar approach, by which we consider the English counts to have a facilitatory effect on the task (given that English was the relevant language in the experiment), and the Dutch counts to have an inhibitory effect of the same magnitude as their English counterparts. More specifically, we will use two ratio variables for the interlingual homographs: the English–Dutch frequency ratio, i.e., the difference between the log of the English frequency and the log of the Dutch frequency, and the English–Dutch family size ratio, i.e., the difference between the logarithm of the English family size and the logarithm of the Dutch family size. The usage of these ratios allows us to jointly analyse the effects of these four highly correlated variables, and it significantly reduces the collinearity in the data matrix.

A stepwise multilevel regression analysis with the RTs as the dependent variable and the English–Dutch frequency ratio and the English–Dutch family size ratio as independent variables revealed facilitatory main effects for the frequency ratio, $F(1, 612) = 18.47$, $p < .001$, and the family size ratio, $F(1, 612) = 5.95$, $p = .02$, after having partialled out the effect of the frequency ratio, and no significant interaction, $F(1, 611) = 1.45$, $p = .23$.

Taken together, the analyses reported here clearly show effects of word frequency for both the English monolingual words and the English–Dutch interlingual homographs. In the later case, as illustrated by the effect of the frequency ratio, the effect of word frequency seems to be a composite effect, which consists of a facilitation effect caused by English word frequency (words with a high frequency in English are recognised faster), and an equivalent inhibitory effect due to the Dutch frequency count (homographs with a high Dutch frequency are recognised slower). These frequency effects confirm the results reported by Schulpen et al. (2003). Additionally, the regression analyses reveal an MFS effect for both the English monolingual words and the interlingual homographs. This effect shows characteristics similar to that of frequency, in that the size of the morphological paradigm of a word in the relevant language (i.e., English) facilitates the recognition of the word. Thus, words from large English morphological paradigms are recognised faster, while at the same time, the size of the morphological paradigm in the language that is not relevant for the task inhibits target recognition. In the next experiment, we will examine if the size and/or direction of MFS effects changes if the task is modified into a Generalised Lexical Decision task.

Experiment 2: Generalised Visual Lexical Decision

Method

Participants. Eighteen students of the University of Nijmegen (mean age: 22.5 years) were paid to participate in the experiment. All were native speakers of Dutch who began to acquire English when they were 11 or 12 years old.

Materials. The stimulus set consisted of 420 items of which 210 were words and 210 nonwords. The current experiment included the same 42 interlingual homographs and the 84 monolingual English words from Experiment 1. Additionally, the 84 monolingual Dutch words characterised in Table 1 were included in the experiment. Appendices A–C contain the test words themselves. As was the case for the English words, the set of monolingual Dutch words consisted of three groups of 14 words, each matched in frequency to one of the groups of interlingual homographs (Dutch Controls), plus 42 words in the low, medium, and high Dutch frequency ranges (Dutch Open Range). The experiment further contained 126 nonwords with a legal English orthography and 84 nonwords obtained by changing a letter in low and middle frequency Dutch words.

Procedure. The procedure was identical to that of Experiment 1, except that this time participants were instructed to react by pressing the 'yes' button when the stimulus on the screen was either a legal English word or a legal Dutch word, and the 'no' button when the letter string was not a word in Dutch or English. All communication between participant and experimentator was conducted in Dutch. In total, each experimental session lasted about 60 minutes.

Results and discussion

All participants performed with an error rate of less than 20%. Ten items elicited errors in more than 30% of the trials, and were removed from further analyses. All incorrect responses were removed from the data (7.57% of all trials). After removing the errors, 166 trials with RTs that were outside the range of 2.5 standard deviations from the mean RT were considered as outliers and were thus discarded (4.75% of the remaining trials). Table 3 provides the means, standard deviations, and ranges of the frequency counts, family size counts, and RTs after the data cleaning procedures had been applied.

As in the previous experiment, the word frequency and morphological family size variables in this dataset followed smooth lognormal distributions according to conservative Shapiro–Wilk normality tests of the log counts ($W = 0.99$, $p = .27$, for frequency, $W = 0.98$, $p = .14$ for family size in the English words, and $W = 0.98$, $p = .12$ for Dutch family size of the Dutch words).[1] Therefore, we report once more analyses of variance on stepwise multilevel linear regression models.

We first assessed whether word frequency and morphological family size have a significant influence on the response latencies to the monolingual English and Dutch words in our dataset. A stepwise multilevel regression model with RT as the dependent variable and English word frequency and English morphological family size as independent variables showed main facilitatory effects of English word frequency, $F(1, 1166) = 98.22$, $p < .001$, and English morphological family size, $F(1, 1166) = 18.51$, $p < .001$, after having partialled out the effect of English word frequency, as well as a significant interaction between frequency and family size, $F(1, 1166) = 4.11$, $p = .04$.

With respect to the monolingual Dutch words, a stepwise multilevel regression model with RT as the dependent variable, and Dutch word frequency and Dutch morphological family size as independent variables showed a main facilitatory effect of Dutch word frequency, $F(1, 1412) = 74.40$, $p < .001$, but no significant effect of Dutch morphological family size, $F(1, 1410) = 2.29$, $p = .13$, after having partialled out the effect of Dutch word frequency, nor any interaction between frequency and family size ($F < 1$).

As for the English visual lexical decision experiment, we analysed the results for the interlingual homographs by using correlations on the log counts to provide an overview of the influences of the different variables on the response latencies. Both English counts showed significant negative correlation coefficients with RTs ($r = -.41$, $p < .001$ for English word frequency, and $r = -.30$, $p < .001$ for English morphological family size). In contrast to what we observed in English lexical decision, both Dutch counts in the present generalised lexical decision experiment show significant correlations with the response latencies ($r = -.38$, $p < .001$

[1] Dutch frequency appeared to be significantly non-lognormally distributed according to the very conservative Shapiro–Wilk test ($W = 0.97$, $p = .02$). However, inspection of a quantile-quantile plot showed that this deviation was quite small.

TABLE 3

Means, standard deviations, and ranges for the different counts in the data set from Experiment 2 (GVLD), and in the subsets of interlingual homographs and English monolingual words (after removing outliers)

	Total 200 items		*Interlingual homographs 42 items*		*English monolingual words 74 items*		*Dutch monolingual words 84 items*	
English frequency	103.52 ± 252.33	[0, 1981]	169.78 ± 284.63	[3, 1351]	183.43 ± 326.71	[1, 1981]	–	–
English family size	9.42 ± 18.33	[0, 112]	11.40 ± 14.28	[1, 70]	18.99 ± 24.58	[0, 112]	–	–
Dutch frequency	69.27 ± 177.22	[0, 1370]	75.90 ± 128.39	[2, 724]	–	–	126.97 ± 243.90	[1, 1370]
Dutch family size	22.80 ± 40.23	[0, 283]	31.71 ± 34.12	[0, 134]	–	–	38.43 ± 51.87	[0, 283]
Response latency (ms)	542 ± 48	[454, 716]	525 ± 29	[472, 598]	574 ± 49	[484, 716]	522 ± 37	[454, 606]

The word frequency counts are in occurrences per million.

for Dutch frequency, and $r = -.40$, $p < .001$ for Dutch family size), which are now also negative. This indicates that both English and Dutch word frequency and family size counts have facilitatory influences on the response latencies. This finding was predicted by the BIA+ model, which assumes that the two readings of an interlingual homograph are activated and processed in parallel. In other words, the English and Dutch readings are engaged in a 'race' to recognition and the fastest of them to be recognised in a particular trial determines the 'yes' response in the Generalised Lexical Decision task. We can operationalise this account by taking as independent variables in our regression analyses the maximum frequency of a word, i.e., the largest of the Dutch and the English frequency counts for a homograph, and the maximum family size of a word, i.e., the largest of the Dutch and the English family size counts for a given word, all of them in logarithmic scale. This operationalisation allows us to keep the collinearity in the data matrix under control while at the same time testing the predictions of the BIA+ model.

A stepwise multilevel regression analysis with the RTs as the dependent variable and the maximum logarithmic frequency and maximum logarithmic family size as independent variables revealed facilitatory main effects for the maximum frequency, $F(1, 690) = 11.28$, $p < .001$, and the maximum family size, $F(1, 690) = 5.23$, $p = .02$, after having partialled out the effect of the maximum frequency, and no significant interaction, $F < 1$. The effects of the maximum frequency and family size are consistent with the predictions of the BIA+ model. However, other analyses also reveal a similar pattern. For instance, the summed frequencies and summed family sizes of both readings of a homograph are also excellent predictors of the RTs, just as the maximum frequency and family size are. This shows that the pattern in the data is robust and independent of the specific theoretical framework of the BIA+ model.

These analyses showed effects of word frequency, for both the English and Dutch monolingual words, while in the case of the English-Dutch interlingual homographs it was the maximum of the frequency of the Dutch reading and the frequency of the English reading of the homograph that predicts response latencies. This effect of the maximum frequency confirms the predictions of models of bilingual word recognition that postulate the existence of a race between the two readings of a homograph in this task. Additionally, the analyses reveal the presence of family size effects for the English monolingual words and the interlingual homographs. Again, in line with the predictions of the BIA+ model, it is the maximum of the two family size counts that exerts an influence on the response latencies.

Discussion of Experiments 1 and 2

Our reanalyses of the two earlier experiments confirm and extend the original results of Schulpen et al. (2003). In bilingual participants, the frequency of the L1 reading of an interlingual homograph can affect the response latencies in a visual lexical decision task where L2 is the target language. This supports the predictions of the BIA+ model that both readings of the homograph are activated simultaneously. The presence of a 'race' between both readings of the homograph entails that, in cases of words with a high L1 frequency, it is the L1 reading of the homograph that 'wins' the race. This results in inhibition relative to an English control condition when the L1 reading of the homograph is not relevant for the task (English visual lexical decision), and in facilitation when either of the two readings represents a valid word and can be used for responding (generalised visual lexical decision).

The regression analyses document for the first time the presence of a morphological family size effect in the processing of L2. This is an indication that the family size effect is a fundamental characteristic of human lexical processing that is already present quickly after a morphological paradigm or group of paradigms is acquired. Crucially, the morphological family size effect in L2 shows very similar characteristics to its counterpart in L1. The analyses have shown that the morphologically related words that are related in meaning to the target provide facilitation, while those of which the meanings are not related to a relevant possible reading of the target for a given task produce inhibition. This inhibitory effect is very similar to the inhibitory effect caused by semantically opaque Hebrew words (Moscoso del Prado Martín et al., 2004).

PART II: A NEW EXPERIMENT

The finding of cross-lingual effects of MFS, reported in the previous section, provides new and independent evidence that during the processing of interlingual homographs, both their L1 and L2 readings are activated. As in earlier papers, this finding can be interpreted as evidence for language non-selective access. However, in the English lexical decision task, the response must be based upon the English reading of the homograph, so the evidence relates only to the effect of the strong L1 on the weaker L2. Furthermore, the bilingual participants are Dutch native speakers immersed in a Dutch environment. It is therefore possible that, although there are L1 effects of morphological family size in L2 processing, the opposite is not true. This would be the case, for instance, if L1, being the participant's native language, has a special status relative to L2. In other words, language non-selective access would not be general, but restricted to the native language. To investigate this possibility, we conducted an additional experiment testing if the contrasting effects of frequency and family size of the L2 (English) reading of a homograph also arise when participants make visual lexical decisions in their L1 (Dutch). We tested this in the strongest way possible by ensuring that the participants were not aware of the relevance of their second language while they were performing in their native language: the data from all participants who noticed the bilingual nature of interlingual homographs were excluded from analysis.

Experiment 3: Dutch Visual Lexical Decision

Method

Participants. Twenty-nine students of the University of Nijmegen (mean age: 22.5 years) were paid to participate in the experiment. All were native speakers of Dutch who learned English from age 11 or 12 onwards.

Materials. The stimulus set consisted of 252 items of which 126 were Dutch words and 126 were nonwords. As specified in Table 1, this experiment included the same 42 interlingual homographs used in Experiments 1 and 2, and the 84 monolingual Dutch words from Experiment 2. Appendices A and C contain the test words themselves. As nonwords we included the 84 Dutch nonwords from Experiment 2, and 42 nonwords with a pattern valid both in English and Dutch that were used in Experiments 1 and 2.

Procedure. The procedure was very similar to that employed in Experiments 1 and 2. Participants received their instructions in Dutch and were instructed to react by pressing the 'yes' button when the stimulus on the screen was a legal Dutch word, and the 'no' button when the letter string was not a word in Dutch. Words were presented on a NEC Multisync color monitor in white lowercase 24 point Arial letters. After the experiment, the participants were asked if they had noticed anything special about the experiment. Five participants reported having noticed the presence of some English words in the experiment and their data were excluded from the analyses to ensure that the results were not affected by any conscious strategies of the participants. In total, the experimental session lasted about 45 minutes.

Results and discussion

The remaining 24 participants performed with an error rate of less than 20%. Two items elicited errors in more than 30% of the trials and were removed from the analyses. All incorrect responses were removed from the data (3.72% of all trials). After removing the errors, 24 trials with RTs that were outside the range of 2.5 standard deviations from the mean RT were considered as outliers and were discarded (0.82% of the remaining trials). Table 4 provides the means, standard deviations, and ranges of the frequency counts, family size counts, and RTs after the data cleaning procedures had been applied.

In order to compare our results with those reported by Schulpen et al. (2003), we begin by analysing the results of the interlingual homographs and their frequency matched Dutch controls (excluding the Dutch open frequency range items) in terms of the original orthogonal design contrasting the English and Dutch frequencies of the homographs. Table 5 describes the reaction times, standard deviations, and errors in each frequency condition after applying the data cleaning procedures. By-participant and by-item analyses of variance revealed significant effects of Frequency Category: High English–High Dutch, High English–Low Dutch, or Low English–High Dutch; $F_1(2, 46) = 25.24$, $p < .001$; $F_2(2, 76) = 6.81$, $p < .01$; a less clear effect of Type of Target: Interlingual homograph vs. Dutch control, $F_1(1, 23) = 4.77$, $p = .04$; $F_2(1, 76) = 2.80$, $p = .09$; and an interaction reaching significance in the by-participant analysis, $F_1(2, 46) = 5.15$, $p < .01$; $F_2(2, 76) = 1.41$, $p = .25$. When we analysed the effect of Frequency Category in more detail, only the words in the High English frequency–Low Dutch frequency condition were significantly slower than the rest ($t = 2.17$, $p = .03$).

A logistic regression[2] on the ratio of incorrect to correct responses revealed significant effects of both Type of Target, $\chi^2(1, 80) = 28.76$, $p < .001$, and Frequency Category, $\chi^2(1, 78) = 20.37$, $p < .001$, with no significant interaction, $\chi^2(2, 76) = 0.83$, $p = .66$. As in the analyses of RTs, the only frequency category that differed from the rest was the high English frequency–low Dutch frequency category that gave rise to significantly more errors ($Z = 3.17$, $p < .01$).

On the whole, interlingual homographs were processed significantly slower and with more errors than their frequency matched controls. Table 5 and the reported t-test show that this was mostly due to the slow RT to homographs that had a low Dutch frequency and a high English frequency. The result pattern replicates that by De Groot et al. (2000, Experiment 2) in a directly comparable study. Thus, one might expect an interaction between Type of Target and Frequency Category, such that homographs

[2] Error data from lexical decision experiments are strongly non-normally distributed, due to the very small numbers of incorrect responses provided by participants. This violates the normality precondition for a traditional ANOVA. Instead, we use a logistic regression analysis which is less sensitive to the deviation from normality.

TABLE 4

Means, standard deviations, and ranges for the different counts in the data set from Experiment 3 (DVLD), and in the subsets of interlingual homographs and English monolingual words (after removing outliers)

	Total *124 items*		*Interlingual homographs* *40 items*		*Dutch monolingual words* *84 items*	
English frequency	55.63 ± 182.71	[0, 1351]	172.45 ± 290.90	[3, 1351]	–	–
English family size	3.57 ± 9.70	[0, 70]	11.07 ± 14.53	[1, 70]	–	–
Dutch frequency	111.35 ± 214.71	[0, 1370]	78.52 ± 131.00	[2, 724]	126.98 ± 243.90	[0, 1370]
Dutch family size	36.77 ± 46.83	[0, 283]	33.27 ± 34.22	[0, 134]	38.43 ± 51.87	[0, 283]
Response latency (ms)	530 ± 36	[460, 657]	537 ± 41	[460, 657]	527 ± 33	[469, 636]

The word frequency counts are in occurrences per million.

TABLE 5
Means and standard deviations of the reaction times, and error percentages for the different frequency categories of interlingual homographs and their frequency matched Dutch controls from Experiment 3 (DVLD), after applying data cleaning procedures

	RT (ms)		*SD (ms)*		*Errors (per cent)*	
	Homographs	*Controls*	*Homographs*	*Controls*	*Homographs*	*Controls*
HFE-HFD	535	526	43	28	3.66	1.20
LFE-HFD	514	515	29	24	2.61	0.60
HFE-LFD	562	534	41	31	10.34	1.84

with a higher English frequency (or a lower Dutch to English frequency ratio) would show more inhibition than their corresponding Dutch controls. This interaction was indeed found in the by-participant analysis, but did not become significant in the by-item analysis. This suggests that the inhibition effect depends on both the English and the Dutch frequency of the homographs.

Having completed the factorial analysis of the frequency effects, we now turn to correlational and regression analysis of the data, including family size as independent variable. As in the previous experiments, the word frequency and morphological family size variables for both languages in this dataset follow lognormal distributions ($W = 0.96$, $p = .14$, for English frequency of the homographs, $W = 0.95$, $p = .08$ for English family size of the homographs, $W = 0.97$, $p = .02$ for Dutch frequency,[3] and $W = 0.99$, $p = .23$ for Dutch family size).

Both Dutch counts showed negative correlation coefficients with RTs ($r = -.40$, $p < .001$ for Dutch word frequency, and $r = -.43$, $p < .001$ for Dutch morphological family size). In contrast, both English counts showed positive correlations with the response latencies ($r = .29$, $p = .07$ for English frequency, and $r = .45$,[4] $p < .01$ for English family size). This pattern is precisely the opposite of that observed in the English visual lexical decision task. While Dutch word frequency and Dutch family size have facilitatory influences on the response latencies, English frequency and English family size exert inhibitory influences on the response latencies. Note that the correlation coefficients for English and Dutch are again similar.

[3] Although Dutch frequency appeared to be significantly non-lognormally distributed, visual inspection of a quantile-quantile plot showed that the deviation from lognormality was very small. Moreover, separate normality tests revealed that neither the subset of interlingual homographs ($W = 0.97$, $p > .05$), nor the subset of Dutch monolingual words ($W = 0.98$, $p = .60$), deviated significantly from lognormality.

[4] Although this correlation was only marginally significant, it reached full significance by a non-parametric Spearman correlation ($r_s = .37$, $p = .02$).

The correlation analyses indicate that there is an effect of the English frequency of the homographs. Figure 1 provides further evidence for this English frequency effect, using non-parametric regression (robust locally weighted regression; Cleveland, 1979). The horizontal axis displays log frequency. The vertical axis plots the pairwise difference in the response latencies for the homographs and their controls. The solid line represents the effect of English frequency on this difference, the dashed line the effect of Dutch frequency. Note that as the English frequency increases, the difference in response latency between homograph and control word increases as well, with perhaps a ceiling effect for the highest frequencies. Conversely, the difference in response latency decreases steadily with increasing Dutch frequency. The crossover of the two regression lines bears elegant witness to the inverse effects of English and Dutch frequency for interlingual homographs in Dutch visual lexical decision.

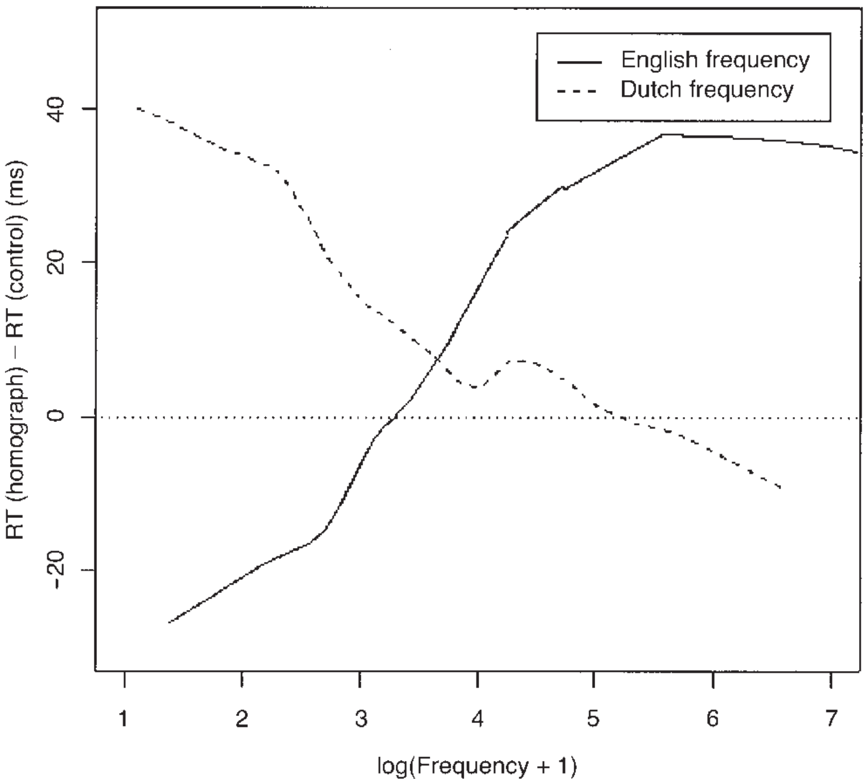

Figure 1. Nonparametric regression lines showing the effects of English word frequency (solid line) and Dutch word frequency (dashed line) on the average difference in RT between a homograph and its frequency-matched control. Frequency counts are in logarithmic scale.

Figure 2 shows a similar crossover between the effects of Dutch and English family size counts on the difference of RTs between homographs and controls. The horizontal axis now plots the logarithm of the family size counts, the vertical axis again displays the difference between the response latencies to a homograph and its control. The solid line representing the correlation between English family size and the difference in response latencies increases steadily with increasing family size. The greater the English family size is, the more time it takes to respond to a homograph relative to its control. The dashed line representing the correlation for Dutch family size suggests a floor effect for the words with larger families.

Having studied the correlations between frequency and family size with the difference in response latencies between the homographs and their controls, we now return to the response latencies to the homographs by themselves. As a first step, we fitted a stepwise multilevel regression model

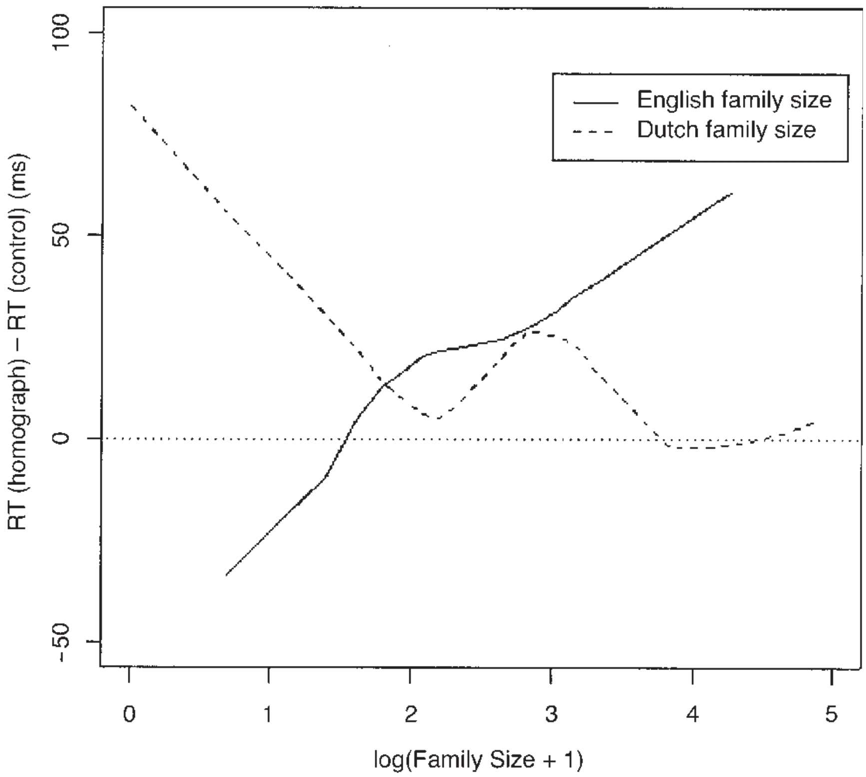

Figure 2. Nonparametric regression lines showing the effects of English morphological family size (solid line) and Dutch morphological family size (dashed line) on the average difference in RT between a homograph and its frequency-matched control. Family size counts are in logarithmic scale.

to the Dutch monolingual words with RT as the dependent variable, and log Dutch word frequency and log Dutch morphological family size as independent variables. We obtained facilitatory main effects of Dutch word frequency, $F(1, 1925) = 48.87$, $p < .001$, and Dutch morphological family size, $F(1, 1925) = 8.42$, $p < .01$, after having partialled out the effect of Dutch word frequency, with a small inhibitory interaction, $F(1, 1925) = 8.05$, $p < .01$.

As in the preceding analyses, we extend the model to take account of English frequency and family size by means of frequency and family size ratios. The Dutch–English frequency ratio captures the difference between the log of the Dutch frequency and the log of the English frequency. Similarly, the Dutch–English family size ratio accounts for the difference between the logarithm of the Dutch family size and the logarithm of the English family size. A stepwise multilevel regression analysis with the RTs of the interlingual homographs as the dependent variable and the Dutch–English frequency ratio and the Dutch–English family size ratio as independent variables revealed facilitatory main effects for the frequency ratio, $F(1, 847) = 43.06$, $p < .001$, and the family size ratio, $F(1, 847) = 20.20$, $p < .001$, after having partialled out the effect of the frequency ratio, and no significant interaction ($F < 1$).

The effects of the frequency and family size ratios can be graphically depicted by comparing the RTs to homographs with those to controls. In Figure 3, the horizontal axis plots the two types of ratios on a logarithmic scale that positions them on a range from -4 to $+4$. The vertical axis plots the observed difference in RTs between a homograph and its control. The solid line in the figure thus visualizes the correlation between the latency difference and the frequency ratio, whereas the dashed line represents this correlation for the family size ratio. Note that for both ratios, the relation with latency difference is roughly linear with a negative slope that is perhaps slightly larger for the family size ratio. A linear regression with the average difference between RTs to the homographs and RTs to their control, and the Dutch–English frequency ratio and the Dutch–English family size ratio as independent variables, confirmed this linear relation. The frequency ratio had a significant effect on the magnitude of this difference, $F(1, 37) = 5.19$, $p = .03$, and so did the family size ratio, $F(1, 37) = 4.16$, $p < .05$, after partialling out the effect of the frequency ratio, with no significant interaction between them ($F < 1$).

The pattern of results obtained for the Dutch visual lexical decision data is consistent with that obtained for the English visual lexical decision data of Experiment 1. In both experiments, the frequency and family size ratios are key predictors of the response latencies for interlingual homographs. Crucially, however, the ratios are defined with the English measures in the numerator and the Dutch measures in the denominator for Experiment 1,

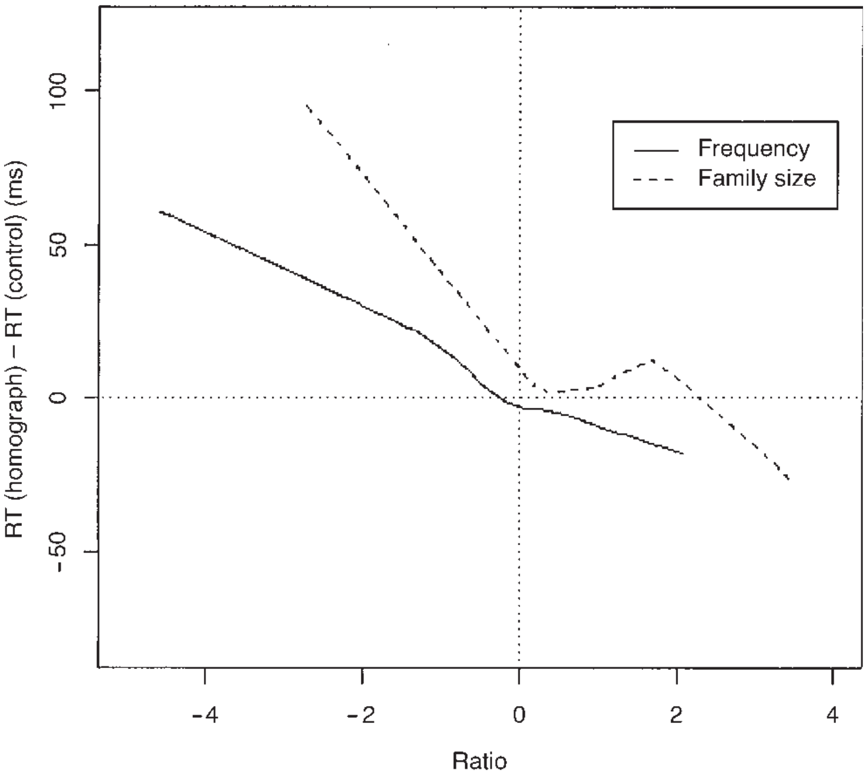

Figure 3. Nonparametric regression lines showing the combined effects of Dutch and English frequency (solid line), and Dutch and English morphological family size (dashed line) on the average difference in RT between a homograph and its frequency-matched control. English and Dutch counts are combined using the Dutch–English frequency and family size ratios.

while for Experiment 3, the Dutch measures are in the numerator and the English measures in the denominator. In other words, the effects are reversed when the task is changed from English lexical decision to Dutch lexical decision.

GENERAL DISCUSSION

The present study shows that neither words nor languages as a whole should be considered as isolated building blocks in the organisation of the mental lexicon. The recognition of words does not just depend on the characteristics of the items themselves (e.g., their frequency, length, or language membership), but also on lexical context, in our case the number of morphologically complex words that the word is related to. For words that exist in two languages, the morphological family sizes (MFS) in both languages play a role.

The experiments we presented led to several important new findings. First, in bilinguals, the MFS in L1 and L2 both affect lexical processing. Second, for interlingual homographs, (partially semantic) MFS effects from both languages are present simultaneously. This does not only indicate that lexical access is language non-selective, but also that the effects must arise in an integrated lexicon. Third, the direction of these effects is task dependent. In the English-specific lexical decision experiment, English family size was facilitatory for homographs, whereas Dutch family size was inhibitory. In contrast, in the generalised (Dutch–English) lexical decision task, both English and Dutch family size had a facilitatory effect.

The pervasiveness of the MFS was revealed by a Dutch lexical decision task. Participants performing in their native language, and unaware of the importance of their second language (English), nevertheless suffered from inhibitory effects of the non-target language MFS on the RTs to the target language reading of interlingual homographs.

A striking finding is that the direction of the MFS effects is in line with that of word frequency effects. In accordance with earlier studies by Dijkstra et al. (1998) and Schulpen et al. (2003), we reported that in the present English specific lexical decision study (Experiment 1), the RTs to interlingual homographs were inhibited to an extent that depended on the relative frequency of the two readings of these items. If the items had a low word frequency in English and a high word frequency in Dutch, RTs were slower than in a one-language control condition consisting of purely English words. In contrast, in the generalised Dutch–English lexical decision experiment (Experiment 2), word frequency in both languages exerted a facilitatory effect on the RTs.

Analogously to the English specific lexical decision experiment, in Experiment 3 (Dutch lexical decision) the RTs to the Dutch reading of interlingual homographs were faster when word frequency was higher in Dutch (LFE–HFD condition), and slower when it was higher in English (HFE–HFD and HFE–LFD conditions). These findings are in agreement with the data from the Dutch lexical decision experiment (Experiment 2) by De Groot et al. (2000).

Although the direction of MFS and word frequency effects was generally the same, the MFS effect in our data was not a mere frequency effect. The effects of the MFS remained significant after partialling out the word frequency effects. Still, the origin of both types of effects may to some extent be comparable. Word frequency effects have been attributed to both orthographic and conceptually semantic levels (e.g., Bradley and Forster, 1987, Morton, 1969, attribute frequency effects to the orthographic level, while Becker, 1979, Stanovich & West, 1981, Borowsky &

Besner, 1993, Plaut & Booth, 2001, argue for it being a conceptual-semantic effect), and the same may hold for MFS effects. In the introduction, we already reviewed the empirical evidence supporting the view that the MFS effect has a strong semantic component (Bertram et al., 2000; De Jong et al., 2000; Moscoso del Prado Martín, Bertram, Häikiö, Schreuder, & Baayen, in press; Moscoso del Prado Martín et al., 2004).

These findings and conclusions are compatible with both the monolingual model for the recognition of morphologically complex words that has been proposed to account for MFS effects by De Jong, Schreuder, & Baayen (2003) and with the BIA+ model of bilingual word recognition (Dijkstra & Van Heuven, 2002). Indeed, they suggest that an optimal integration of both models can easily be established.

The model accounting for morphological family size effects proposed by De Jong et al. (2003), the morphological family resonance model (FMRM), is an interactive activation (IA) model in which there is a cumulative build-up of activation resonating between lemmas (Levelt, 1989; Schreuder & Baayen, 1995) and the semantic and syntactic representations to which these lemmas are linked. If a lemma is linked to a semantic representation that itself is linked to a great many other lemmas, as is the case for a word with a large morphological family, this semantic representation will co-activate its associated lemmas, which in turn will contribute to the activation level of this semantic representation. Over time, this resonance within the morphological family speeds up the rate at which the activation of the target lemma increases. The greater the morphological family, the greater the rate will be with which the target lemma is activated. In the FMRM, a lexical decision response is initiated once a lemma has reached a threshold activation level. For a formal definition of the FMRM and some simulation studies, the reader is referred to De Jong et al. (2003).

The MFS effects documented for the bilingual lexicon can be explained in the MFRM framework along the following lines. Given a homograph as orthographic input, e.g., ROOM, two lemmas are activated in parallel: the English lemma 'room' (meaning 'chamber'), and the Dutch lemma 'room' (meaning 'cream'). Both lemmas activate their families simultaneously through the resonance mechanism. Consequently, depending on their respective family sizes, the activation levels of the two lemmas increase exponentially over time. If the task is language-specific visual lexical decision, the appropriate lemma has to be selected. This might be accomplished by means of, for instance, the Luce choice rule. If the task is generalised visual lexical decision, the lexical decision can be made at the time the first representation reaches the threshold activation level. Extended in this way, the MFRM becomes very similar in spirit to the BIA+ model.

The BIA+ model is also an IA model assuming interactive links between orthography and meaning levels within the lexicon, but it has focused on the bilingual recognition of monomorphemic words. The BIA+ model has successfully modelled a range of word frequency and neighbourhood effects in the bilingual lexicon, an area that the MFRM has not addressed at all. By assuming the more complex linkage system between lemmas and meaning that the MFRM proposes, the BIA+ model can be extended to account for the findings of the present study with respect to the MFS effects.

By incorporating the MFRM within the BIA+ architecture, a richer modelling framework is obtained that has interesting consequences for the processing of those interlingual homographs that share their meaning across languages, namely the homographs known as 'cognates'. An example of a form-identical cognate is the word FILM that shares its orthography, and to a large extent its semantics and phonology across languages. Non-identical cognates such as TOMAAT (Dutch)–TOMATO (English) also exist.

In the past, researchers such as Kirsner (e.g., Lalor & Kirsner, 2000) and Sánchez-Casas (e.g., Sánchez-Casas, Davis, & García-Albea, 1992) have proposed that cognates can be considered as morphological representations that are shared between languages. The extended BIA+ model provides a clear account of how this could work. The members of word pairs such as FILM/FILM and TOMATO/TOMAAT share most of their links to conceptual, semantic, and (partially) orthographic representations across languages. Given the process of morphological resonance we discussed above, the overlap may lead to the 'semantic' facilitation effects that are so often observed for these types of items (e.g., due to shared MF members; Van Hell & Dijkstra, 2002). As in the monolingual domain, the strength of the effect will depend on the transparency of the mappings between orthography and meaning within and across languages. It follows that cross-linguistic morphological priming effects should be obtained for items such as REGENACHTIG (Dutch for 'rainy') and RAIN (REGEN in Dutch).

To conclude, starting from the strong assumption of language non-selective lexical access into an integrated lexicon and the recent findings of morphological family size effects in the monolingual domain, we predicted analogous within-language and between-language effects with respect to bilingual word recognition. We did not only find the expected effects in a reanalysis of two experiments that had been performed with a completely different aim, but also in a new study that specifically investigated the effect of the L2 family size on L1 homograph recognition under circumstances where the participants were processing in their strongest language and were unaware of the bilingual nature of the experiment. Stated differently, the word recognition process of bilinguals is different from that of monolinguals, even when they are processing in their L1 and are unaware of the relevance of their L2 (Brysbaert, 2003). It further turned out that these empirically innovative data could be interpreted in an interesting theoretical integration of a monolingual model for the recognition of morphologically complex words and a bilingual model for monomorphemic word recognition. The new modelling framework, furthermore, allows a reinterpretation of earlier proposals about the representation of cross-linguistically ambiguous words such as interlingual homographs and cognates.

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Appendix A: Interlingual Homographs

The superscript numbers indicate in which experiments a word has been excluded from the analyses for eliciting more than 30% errors.

	Frequency		*Family Size*		
Item	*English*	*Dutch*	*English*	*Dutch*	*Frequency condition*
angel[3]	24	5	4	1	HELD
arts[1]	38	93	3	55	LEHD
bad	332	24	6	59	HELD
beer	51	23	1	14	HEHD
big	397	3	9	0	HELD
boom	27	137	2	96	LEHD
brand	16	45	4	123	LEHD
breed	26	131	9	32	LEHD
brief	54	200	7	77	LEHD
even	1351	724	13	38	HEHD
glad	64	37	3	13	HEHD
last	684	72	8	102	HEHD
lever	11	13	2	40	HEHD
list	114	6	20	4	HELD
long	1052	20	70	26	HELD
loom[1]	12	8	5	2	HEHD
lot	290	55	3	16	HEHD
map	45	9	4	6	HELD
mate	30	155	14	0	LEHD
nut	24	26	22	15	HEHD
peer	41	10	6	9	HELD
pet	22	19	4	5	HEHD
pink	52	6	3	4	HELD
pool[3]	49	29	4	23	HEHD
rest	263	115	16	8	HEHD
roof	60	2	6	39	HELD
room	542	5	63	21	HELD
rose	29	43	14	0	LEHD
rot[1]	16	14	7	21	HEHD
slang	3	27	4	26	LEHD
slap[1]	21	27	9	7	HEHD
slim	14	26	4	6	LEHD
slot	8	72	2	50	LEHD
spot	79	11	16	25	HELD
star	110	12	27	7	HELD
trap	51	116	16	49	LEHD
tree	204	4	22	1	HELD
vast	69	332	2	74	LEHD
vet[1]	9	37	1	45	LEHD
war	369	14	24	14	HELD
week	408	294	15	45	HEHD
wet	70	187	5	134	LEHD

Appendix B: English Monolingual Words
The superscript numbers indicate in which experiments a word has been excluded from the analyses for eliciting more than 30% errors

Item	*Frequency*	*Family size*	*Frequency condition*
aid	70	3	LE(HD)
area	333	1	HE(LD)
army	125	2	Open Range
attic[1,2]	8	0	Open Range
bike	11	0	HE(HD)
bird	108	32	HE(LD)
bless	19	0	Open Range
book	424	60	HE(HD)
candy	8	4	Open Range
cave	40	6	HE(LD)
chair	145	15	Open Range
chest	51	6	LE(HD)
child	1097	16	HE(LD)
chord[1,2]	5	0	Open Range
cloud	59	11	Open Range
coat	65	23	Open Range
cough	24	2	HE(HD)
cream	38	9	LE(HD)
crow	9	8	Open Range
doll	27	2	LE(HD)
duck	14	9	Open Range
eagle	10	5	Open Range
face	486	53	Open Range
far	687	16	HE(HD)
fear	155	8	Open Range
fish	204	37	HE(LD)
food	312	3	Open Range
foot	344	65	HE(LD)
force	191	18	Open Range
giant	47	1	HE(HD)
glue	7	2	Open Range
hate	111	4	HE(LD)
hiker	1	4	Open Range
hood	7	28	Open Range
horse	139	42	Open Range
house	616	112	Open Range
isle[1,2]	14	1	Open Range
itch[1,2]	1	4	Open Range
judge	98	7	Open Range
king	104	11	Open Range
kite[1,2]	5	2	Open Range
knife	49	16	HE(HD)
lawn	29	1	LE(HD)

Appendix B: *(continued)*

Item	*Frequency*	*Family size*	*Frequency condition*
liar	9	11	LE(HD)
lion	25	6	HE(LD)
lyric[2]	3	5	Open Range
mill[2]	22	21	Open Range
mind	401	69	HE(LD)
money	390	21	Open Range
movie	47	0	Open Range
nuts	1	1	Open Range
owner	64	12	HE(HD)
peace	92	19	Open Range
peach	6	2	Open Range
pig	46	28	HE(LD)
play	538	48	HE(LD)
proof	36	16	Open Range
quake	2	4	Open Range
razor[1,2]	9	6	Open Range
sail	26	11	LE(HD)
seed	52	16	HE(LD)
shark	21	1	HE(HD)
shift	79	11	HE(LD)
ship	80	110	Open Range
sir	284	1	HE(HD)
skin	113	32	Open Range
skirt	30	4	Open Range
smile	262	1	HE(HD)
snow	68	23	LE(HD)
soul	57	10	Open Range
spoon	16	9	HE(HD)
steam	30	14	LE(HD)
sugar	60	15	HE(LD)
tail	38	27	Open Range
theft[2]	8	0	Open Range
thief	12	6	HE(HD)
time	1981	77	Open Range
towel	24	5	Open Range
value	172	18	Open Range
way	1310	83	HE(HD)
weird	8	4	LE(HD)
whine[2]	16	2	Open Range
woman	876	46	Open Range
wound	54	2	LE(HD)

Appendix C: Dutch Monolingual Words

Item	*Frequency*	*Family size*	*Frequency condition*
berg	55	73	(HE)HD
bijl	10	4	(HE)LD
blauw	133	55	(LE)HD
bloem	94	102	(LE)HD
boog	46	29	Open Range
bril	36	17	Open Range
broer	128	6	Open Range
bron	64	43	Open Range
buis	9	30	Open Range
buurt	109	18	Open Range
darm	14	30	(HE)HD
deuk	3	4	Open Range
dier	188	100	(LE)HD
ding	365	15	Open Range
doel	165	40	Open Range
dorp	137	38	(LE)HD
dorst	14	11	(HE)LD
duif	19	13	(HE)HD
enkel	596	9	Open Range
feest	60	67	Open Range
fiets	48	37	Open Range
fooi	6	1	(HE)LD
fout	71	30	(HE)HD
geit	11	17	(HE)LD
gids	22	8	Open Range
gil	8	5	(HE)HD
gips	5	8	(HE)LD
grap	24	5	(HE)LD
griep	7	7	Open Range
haas	9	16	(HE)LD
hagel	4	12	Open Range
hitte	30	15	Open Range
hoofd	544	283	Open Range
hulp	116	92	(LE)HD
jaar	1143	190	Open Range
jacht	26	40	(LE)HD
kans	202	34	(LE)HD
kant	294	50	(HE)HD
kat	72	35	(LE)HD
kern	43	65	(LE)HD
kleur	155	118	(LE)HD
klok	37	39	(LE)HD
klomp	13	11	(HE)HD
kooi	23	11	(HE)HD
korst	13	6	Open Range
krat	4	1	(HE)LD

Appendix C: *(continued)*

Item	*Frequency*	*Family size*	*Frequency condition*
kust	52	24	Open Range
kwal	2	1	(HE)LD
laat	735	63	(HE)HD
maal	115	60	(HE)HD
mens	1370	103	Open Range
mond	228	39	Open Range
moord	45	42	(LE)HD
niets	864	8	Open Range
pand	11	17	Open Range
pijl	16	7	Open Range
reep	6	1	Open Range
rijst	6	20	Open Range
roet	3	5	(HE)LD
rund	5	6	Open Range
schep	2	37	Open Range
sfeer	65	42	Open Range
slok	26	5	(HE)HD
smoes	6	2	(HE)LD
snik	5	5	(HE)LD
snoek	2	3	Open Range
speld	5	14	Open Range
spuit	3	24	Open Range
stuk	282	135	Open Range
taak	147	12	Open Range
traan	77	14	Open Range
trui	20	5	(HE)LD
uier	1	0	Open Range
verf	27	34	(LE)HD
vlag	29	12	(HE)HD
vlek	27	30	(HE)HD
vlieg	18	130	Open Range
vork	12	7	(HE)LD
vorm	332	255	(LE)HD
vraag	475	85	Open Range
vuist	37	7	(HE)HD
wrok	8	2	Open Range
zaak	423	117	Open Range
zwaai	4	15	Open Range