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Orthographic Neighborhood Effects in Bilingual Word Recognition

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A series of progressive demasking and lexical decision experiments investigated how the recognition of target words exclusively belonging to one language is affected by the existence of orthographic neighbors from the same or the other language of bilingual participants. Increasing the number of orthographic neighbors in Dutch systematically slowed response times to English target words in Dutch/English bilinguals, while an increase in target language neighbors consistently produced inhibitory effects for Dutch and facilitatory effects for English target words. Monolingual English speakers also showed facilitation due to English neighbors, but no effect of Dutch neighbors. The experiments provide evidence for parallel activation of words in an integrated Dutch/English lexicon. An implemented version of such a model making these assumptions, the Bilingual Interactive Activation (BIA) model, is shown to account for the overall pattern of results.

One of the striking features of bilingual language performance is the apparent ease with which the bilingual manages to keep interference from the non-target language at a minimal level. The fact remains, however, that interference from one language to the other does occur and is observable with respect to both language structure and linguistic processing. For example, in language production, interference from the first language can be noticed both at the phonological level (foreign accents) and at the sentence level (borrowed syntax), as well as in intrusions of words from the other language (accidental lexical borrowings).

In the area of language comprehension research, there has been a debate for several decades about how exactly cross-language interference effects relate to the way words from different languages are stored and processed. With respect to lexical storage, a distinction has been made between the hypotheses of language independent and language dependent lexica. The first hypothesis proposes that bilinguals possess one integrated lexicon for both their languages, while the second assumes two separate lexica, one for each language. With respect to on-line processing, an analogous contrast has been made between language selective and nonselective access views. Given that all contemporary models of visual word recognition assume a one-to-many mapping from input representation to lexical representations in memory (e.g., Forster, 1976; McClelland & Rumelhart, 1981; Paap et al., 1982), the issue is whether words of both languages are activated (or considered as candidates) during word rec-

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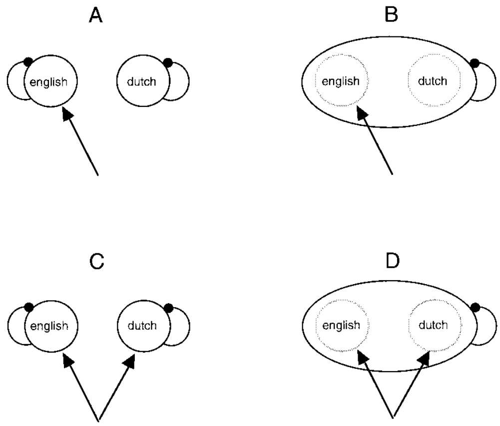

FIG. 1. Four theoretical viewpoints on bilingual word recognition models: (A) language-selective access, independent lexica; (B) selective access, integrated lexicon; (C) language non-selective access, independent lexica; (D) non-selective access, integrated lexicon. Black filled circles indicate inhibitory connections.

ognition, or only words belonging to the targeted language.

Restricting ourselves to those stages of bilingual word recognition involved in word-form access, four basic hypotheses can be distinguished with respect to lexical organization and on-line processing. These are represented in Figure 1.

Early work in this field provided support for hypothesis A in Figure 1, which combines the independent-lexica hypothesis with that of language selective access determined by language mode information (Macnamara & Kushnir, 1971; Scarborough, Gerard, & Cortese, 1984; Soares & Grosjean, 1984). According to this viewpoint, a selection mechanism, called an ‘input switch‘, guides all incoming auditory or visual information to the English lexical system of the bilingual while (s)he is performing an English monolingual task. The high selectivity of the system implies that the linguistic input initially (i.e., at the orthographic or phonological level) only contacts representations in one language. If the lexical representation corresponding to the input is not found in the active lexicon, contact is established with the other lexical system. A typical description of this type of model is in terms of self-terminating search procedures examining first the representations in one lexicon followed by those in the other. The second hypothesis, represented in Figure 1B, that of selective access to an integrated lexicon, is functionally equivalent to hypothesis A. Since words of the non-selected language are never activated, they can have no influence on how words in the selected language are processed. This amounts to having independent lexica.

According to hypotheses C and D, words from both languages that are partially compatible with the stimulus are activated in parallel. These two hypotheses are distinguished in the extent to which words from different languages interact once activated. Within the framework of search models of lexical access (e.g., Forster, 1976), this is determined by whether or not search is organized by language. Hypothesis C states that search is organized by language, with words of one language being checked before those of the other language. Hypothesis D states that search is language independent, words from both languages being examined as a function of their relative frequency. In an interactive activation framework (McClelland & Rumelhart, 1981), the integrated lexicon hypothesis postulates the existence of inhibitory connections between words from different languages. The separate lexica hypothesis, on the other hand, limits inhibitory connectivity to within languages.

The discussion in the literature has focused on testing between the selective-access, independent-lexica and the non-selective-access, integrated-lexicon views (hypotheses A and D in Figure 1). Early evidence for a selective access position came from research comparing pure-language and mixed-language sentence comprehension in bilinguals. Macnamara and Kushnir (1971) asked bilinguals to judge the truth of written and spoken English and French mixed-language sentences. They observed that switching languages within a sentence takes time compared to monolingual passages. More recently, Soares and Grosjean (1984), using a phoneme-triggered lexical decision task, demonstrated that bilinguals responded slower than monolinguals to nonwords in monolingual and bilingual speech. Furthermore, they found that bilinguals responded slower to code-switched words in bilingual speech than to the same words in monolingual speech. They concluded that, when operating in a bilingual speech mode, participants search the base-language lexicon first, which induces longer recognition times for code-switched words. A similar conclusion was reached by Scarborough, Gerard, and Cortese (1984), who demonstrated that English/Spanish bilinguals responded to non-target (Spanish) words in an English lexical decision task as if they were nonwords (i.e., at approximately the same speed as nonwords and without exhibiting frequency effects). The bilingual participants thus seemed to be capable of operating in an entirely language-specific manner without any influence from their knowledge of the other language. In a similar vein, Gerard and Scarborough (1989) found that the reaction times (RTs) of English/Spanish bilinguals in an English lexical decision task were not affected by their knowledge of form-identical Spanish words, suggesting that the bilinguals were in fact functioning as English monolinguals. This result, as well as the finding that word latencies were primarily determined by frequency of usage in the target language, was considered to be consistent with the predictions of a language-specific access and separate-lexica model.

Evidence for non-selective access, on the other hand, has been collected in research using interference paradigms such as the Stroop color–word task (Dyer, 1971), the picture–word interference task (Ehri & Bouchard-Ryan, 1980), or the flanker task (Guttentag, Haith, & Goodman, 1984), all of which provide evidence that between-language interference can be just as great as within-language effects. Between-language interference has been repeatedly observed in the time to reject nonwords in a lexical decision task. Altenberg and Cairns (1983) found that the nonword rejection latencies of bilinguals performing an English lexical decision task were affected by the legality of the nonword in German (e.g., *pflok*) just as much as its legality in English (e.g., *twoul*). Furthermore, Nas (1983) observed that Dutch/English bilinguals took longer to reject nonwords that were orthographically but not phonologically identical to real Dutch words than nonwords without resemblance to Dutch words. Examples of the first kind of nonwords are *beeld* (image, statue) or *mank* (crippled). In the second experiment, similar results were obtained for nonwords that were phonologically but not orthographically similar to real Dutch words, such as *snay*, which according to English spelling-to-sound rules is pronounced like the Dutch word *snee* (*cut*), or *spailer,* pronounced approximately like the Dutch word *speler* (*player*).

The studies by Altenberg and Cairns (1983) and Nas (1983) provide evidence that non-target language representations are activated during word recognition in bilinguals. Nevertheless, their results only concerned correct negative responses to nonword stimuli. Only a few studies have investigated cross-language interference effects in positive responses to word stimuli in non-primed recognition paradigms such as lexical decision (Grainger & Dijkstra, 1992; Beauvillain, 1992). In the present series of experiments we will add to the latter type of studies.

The main aim of the current set of experiments was to test both processing and organizational accounts of the bilingual mental lexicon by manipulating both within- and across-language neighborhood density. Target words belonged only to one language (i.e., there were no cross-language homographs, homophones, or cognates). Cross-language interference on target word recognition was examined by varying the number of orthographic neighbors of the target word in the non-target language (cf. Grainger & Dijkstra, 1992; Beauvillain, 1992). An orthographic neighbor is any word differing by a single letter from the target word, respecting length and letter position (Coltheart et al., 1977). Our study builds upon the empirical finding that among the set of lexical candidates that are activated during visual word recognition, orthographic neighbors take a prominent position. Target word identification and target word naming have been shown to be sensitive to the number of neighbors (neighborhood density) and the frequency of such orthographically similar words (e.g., Andrews, 1989, 1992; Carreiras, Perea, & Grainger, 1997; Grainger et al., 1989; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Snodgrass & Mintzer, 1993; Ziegler, Rey, & Jacobs, in press). The present experiments use effects of number of orthographic neighbors as an index of the relative influence of non-target language words on target word recognition in different experimental tasks and conditions.

Returning to the bilingual situation, language-selective and non-selective access models differ in their predictions about neighborhood effects across languages. As described above, in a selective access model, only words from the target language are activated (or considered) on a given trial. If, in an experiment, target word presentation is blocked by language and participants are informed of this blocking, we expect the input switch of the selective access model to always be set on the appropriate lexicon. In this case, the selective access model predicts that recognition of a target word is determined by the neighborhood characteristics of the target language only. In a non-selective access model, on the other hand, sensory input activates words from both languages simultaneously, and it therefore predicts neighborhood effects of both languages during the word recognition process. It has recently been argued that such a language non-selective explanation is more flexible than a selective access hypothesis because it allows for different degrees of activation in the two languages, dependent on experimental circumstances (Grosjean, 1997; Li, 1996). This view suggests that a neighborhood density manipulation could yield evidence for non-selective access but that the degree of effect observed might be task-dependent.

With respect to the organization of the bilingual lexicon, non-selective access could occur with either separate or integrated lexica (hypotheses C and D in Figure 1). Because neighborhood density effects are assumed to arise during word identification, cross-language manipulation of neighbors allows us to examine this structural issue as well. According to an integrated lexicon hypothesis, recognition of a target word will be affected by the presence of both target and non-target language neighbors in situations where both languages are active (bilingual language mode, Grosjean, 1997). According to an independent lexicon hypothesis, recognition of the target word should not be affected by interlexical neighborhood density, since there are no direct interaction effects between the two lexica. In fact, manipulation of neighborhood density may be one of the very few experimental means of testing the integrated vs independent lexica hypotheses.

Thus, only a non-selective-access integrated-lexicon model predicts that target word recognition will be influenced by orthographic neighbors from both the target and the non-target languages. All other types of models described here predict no effects of non-target language neighborhood density on target word recognition. Of course, we cannot exclude that more complex model variants could be formulated that would make different predictions. Finally, we may consider whether orthographic neighbors from the same or different language as the target word will exert a facilitatory or an inhibitory effect on target recognition. Because the examination of neighborhood effects in bilinguals is uncharted territory, the answer to this question is unknown. However, whether any neighborhood density effects observed will be facilitatory (as observed in the monolingual English lexical decision task, by Andrews, 1989, 1992) or inhibitory (as in the fragmentation task of Snodgrass & Mintzer, 1993) is not directly relevant for the present purposes of setting constraints on possible bilingual model types in terms of lexical access and structure. Most relevant is the general agreement that effects of number of orthographic neighbors in a given language, whether they be inhibitory or facilitatory, reflect the influence of simultaneously activated word representations from that language.

Four experiments were carried out using the same stimulus materials in different tasks. This provided us with a means of assessing cross-experimental transitions in RT-patterns resulting from task and instruction differences. The first two experiments involved a word identification paradigm, that of progressive demasking. While in the first experiment Dutch/English bilingual participants were presented with blocks of English or Dutch target words, the second presentation involved a mixed presentation of English and Dutch words. Next, two visual lexical decision experiments were run. In the third experiment, bilingual participants performed a generalized lexical decision (say 'yes' to any string that is either a Dutch or an English word). In the fourth experiment, two groups of participants (Dutch/English bilinguals and English monolinguals) made a lexical decision in response to English words and English-like nonwords only. With respect to these last two experiments, not only the cross-language orthographic similarity of the word stimuli was considered, but that of the nonword stimuli was as well.

STIMULUS SELECTION

Since all experiments to be reported use the same set of stimulus words, it is convenient to first describe how the stimuli were selected. First, a list of English and Dutch four-letter words was extracted from the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). Only nouns, adjectives, verbs, and adverbs with a printed frequency of at least 2 occurrences per million (o.p.m.) were selected. This resulted in a list of 1,323 English words and a list of 982 Dutch words. For each target word, the number of neighbors in each language and their frequency were calculated (following Coltheart et al., 1977). Four conditions of items from each language were defined by orthogonally varying the number of neighbors in English (English N) and Dutch (Dutch N): (1) words with many neighbors in the target language and many in the non-target language (large English N and large Dutch N), (2) words with many neighbors in the target language (large English N or Dutch N, depending on target language) and few in the non-target language (small Dutch N or English N, respectively), (3) words with few neighbors in the target language (small English N or Dutch N) and many neighbors in the non-target language (large Dutch N or English N, respectively), and (4) with few neighbors in both languages (small English N and small Dutch N). Each condition consisted of 20 words, mostly nouns and adjectives. All selected items were purely monolingual (no cross-language homographs or cognates were selected). Within each language, the target items in the four conditions were matched for word frequency.

In addition, for both English and Dutch target items, the word frequency of the neighbors was matched as closely as possible over conditions. To realize this, the neighbors of the target words were divided into three word frequency categories: low frequency (LF), neighbors with a frequency of less than 20 o.p.m.; medium frequency (MF), neighbors with a frequency between 20 and 50 o.p.m.; and high frequency (HF), neighbors with a frequency of at least 50 o.p.m. The number of neighbors of each frequency category was approximately equal for each test condition.[1]

We selected only English and Dutch words expected to be known to the participant population that we intended to use for experimentation. To check the list of potential English test words, 11 students from a Dutch participant population with low proficiency in English were asked to examine the list and mark unknown items. This resulted in a set of test stimuli in which the English words were about three times as frequent as the Dutch words, reflecting the fact that the Dutch participants in Experiments 1–4 were not perfectly balanced bilinguals. The subjective frequency of English words for these Dutch participants is expected to be much lower than for English native speakers, on which the frequency statistics in the written CELEX-corpus are based. The descriptive statistics for the word stimuli in each condition are summarized in Table 1, and the complete list of stimuli can be found in the Appendix.

[1] The mean number of *higher* frequency neighbors across conditions was not explicitly matched. However, the number of higher frequency neighbors correlated very highly with the total number of neighbors. For Dutch targets a correlation of 0.94 ($N = 8$) was obtained, and for English targets 0.97 ($N = 8$). A further attempt was made to match the test conditions within and across languages with respect to bigram frequency, but, given the other matching criteria (target frequency, frequency, and number of neighbors) and due to the correlation between neighborhood density and bigram frequency, this match was not perfect.

TABLE 1

Descriptive Statistics for the Stimuli Used in the Experiments

	Neighbors			Number of neighbors		
	Dutch N	English N	Word frequency	Dutch	English	Total
Dutch[a]	large	large	18.6	3.50	3.50	7.00
	large	small	18.7	3.50	1.00	4.50
	small	large	18.6	1.00	3.50	4.50
	small	small	18.6	1.00	1.00	2.00
English[a]	large	large	51.8	3.50	3.60	7.10
	large	small	54.1	3.50	1.15	4.65
	small	large	55.2	0.95	3.50	4.50
	small	small	55.5	1.00	1.20	2.20

Note. Word frequency per million.
[a] $n = 20$ for each condition.

EXPERIMENT 1: PROGRESSIVE DEMASKING (BLOCKED PRESENTATION)

Prior work using progressive demasking (PDM) and related techniques in the monolingual domain (Grainger & Segui, 1990; Grainger & Jacobs, 1996; Snodgrass & Mintzer, 1993; Carreiras et al., 1997) has demonstrated the sensitivity of the paradigm to the influence of orthographic neighbors on target word recognition. In the PDM task, the presentation of the target word is alternated with that of a mask. During this process of alternation, the target presentation time slowly increases while that of the mask decreases. The participant's task is to push a button as soon as the target word is identified. Compared to other paradigms (such as lexical decision), PDM reduces the rate of presenting the sensory information to the participant, thus effectively slowing the target identification process.

In the present experiment, two masks were used which covered the entire word matrix. One mask consisted of black and white blocks (checkerboard pattern), and the other was the inverse of it (black became white and white became black). The two masks were presented in turn. The mask presented on the first cycle of each trial was changed for each participant. Extensive pre-testing with various mask types indicated that this alternating checkerboard pattern was preferable to the usual row of hash marks (####), since the former type of mask resulted in fewer identification biases for particular letters and features (Jacobs & Grainger, 1991).

Method

Participants. Forty-two Dutch students with normal or corrected-to-normal vision participated. Two groups of participants were selected, differing in their proficiency in English. Students in the High Proficiency (HP) group were mainly students of English or students who had visited an English speaking country for a short period (6–12 months), while those in the Low Proficiency (LP) group consisted of students of Dutch or other disciplines. The allocation of students to these two groups was checked by the results of a questionnaire that examined their proficiency in more detail. All students were native speakers of Dutch.

Stimuli and design. Participants saw two blocks of items, one for each language. Stimulus selection was described above and can be summarized as follows. Each language block consisted of 80 items, 20 for each of the four conditions defined by the factorial combination of neighborhood density in Dutch and English (see Table 1). One group of participants was presented with the Dutch block first, followed by the English block, and the other group saw the English block first and then the Dutch block. Each block was preceded by 25 practice trials, and five dummy trials were placed at the beginning of each test block. Each participant saw a different randomized order of test items within a block.

Procedure. Presentation of the visual stimuli and recording of the RTs was controlled by an Apple Macintosh IIcx microcomputer connected to an Apple 14″ Trinitron monitor. RTs were measured at a 1 ms accuracy by a button box connected to the computer. This box and the experimentation software were developed in collaboration with the Technical Group of the Nijmegen Institute for Cognition and Information. The words consisted of black Courier capital letters (18 points or approximately 8 mm on screen) presented at the center of the computer screen on a white background. The monitor was placed 60 cm from the participant, in order to provide projection within the fovea of the eye.

Participants were tested individually. They were told that they had to identify four-letter target words that would gradually appear on the computer screen out of a background of visual noise. They were further informed that the experiment consisted of two blocks, first one with Dutch words and then one with English words (or vice versa). Before each block started, the participants were given written instructions in the language of the subsequent trials. They were instructed to react as soon as they identified a target word but without making errors.

At the beginning of each trial the words ‘‘NEXT WORD’’ (in the English block) or ‘‘VOLGEND WOORD’’ (in the Dutch block) were presented. After the participant pressed a button two small lines appeared, 6.6 mm (15 pixels) above and below the center of the screen. After 1500 ms, the screen was cleared and one of the two checkerboard masks was presented at the center of the screen. Next, the target word appeared at the same position, followed by the other mask, and so on. In the first cycle the mask appeared for 300 ms and was followed by the target word, which was presented for 15 ms. Then the other mask was presented, but now for 285 ms, followed again by the target word for 30 ms, and so on. The time that the mask was visible decreased, while the time that the target word was visible increased until the mask presentation time was zero. The PDM-cycling process continued until the participant pushed the response button or a time-out period of 6 seconds was reached.

Immediately after the participants had pressed the button to indicate that they had identified the target word, this word was replaced by a checkerboard backward mask. At the same time, a dialog box appeared with the words ‘‘Enter the word’’ (in the English block) or ‘‘Tik het woord in’’ (in the Dutch block). After the participants entered the word that they had identified, the next trial started. Before the second block began the participants read the instructions again, now written in the other language. After the experiment, the participant filled out a questionnaire concerning his or her knowledge about and experience with the English language, in order to check the allocation of participants to the two proficiency groups. The session lasted about thirty minutes.

Results

Mean RTs were computed for each participant and for all test conditions in each language separately. Erroneous responses (2.3%) and RTs that were outside the range of two standard deviations from the participant and item mean (0.8%) were omitted from the latency analysis. The results are presented separately for each language in Tables 2 and 3.

An analysis of variance (ANOVA) was carried out for each language separately. The number of neighbors in Dutch (Dutch N, large or small) and English (English N, large or small) were treated as within-participant factors, while Proficiency of the participant (high or low) and Order of Presentation (Dutch followed by English or English followed by Dutch) were between-participant factors.

Reaction time data. For Dutch items, a significant effect of Dutch N was obtained [$F_1(1,38) = 38.64$, $p < .001$; $F_2(1,76) = 7.71$, $p < .01$]. Dutch words with many Dutch neighbors were responded to 59 ms slower than words with few Dutch neighbors (see Table 7 for summary data from this experiment and the

TABLE 2

Mean Identification Latencies of Experiment 1 (in Milliseconds) of Participants Presented with Dutch Words in the First Block or the Second Block (Standard Deviation and Percentage of Errors Are Presented in Parentheses.)

		Low proficiency		High proficiency		
Dutch N	English N	Block 1	Block 2	Block 1	Block 2	Mean
Large	large	1681 (310, 2.7)	1659 (182, 3.5)	1739 (166, 2.7)	1674 (219, 3.5)	1689
Large	small	1684 (329, 1.8)	1634 (170, 3.0)	1675 (229, 3.6)	1672 (180, 5.5)	1667
Small	large	1614 (275, 1.8)	1600 (179, 3.0)	1707 (163, 1.4)	1595 (186, 4.5)	1630
Small	small	1586 (258, 4.5)	1529 (135, 1.5)	1639 (217, 3.2)	1599 (217, 2.5)	1589

following experiments). The effect of English N on Dutch items was also inhibitory (41 ms), but significant only in the participant analysis [$F_1(1,38) = 7.07, p < .05$; $F_2(1,76) = 1.67, p = .20$]. The interaction between Dutch N and English N was not significant [both *F*s < 1]. No main effects were found for Proficiency [$F_1(1,38) < 1$; $F_2(1,76) = 19.69, p < .001$] or Order of Presentation [$F_1(1,38) < 1$; $F_2(1,76) = 21.34, p < .001$]. However, in combination these two factors interacted with English N [$F_1(1,38) = 4.67, p < .05$; $F_2(1,76) = 5.06, p < .05$]. No other interactions were significant in both participant and item analyses.

Further analysis of the interaction between Proficiency, Order of Presentation, and English N revealed that high proficiency participants showed a marginally significant interaction between Order of Presentation and English N [$F_1(1,19) = 3.11, p = .09$; $F_2(1,78) = 6.48, p < .05$], while low proficiency participants did not [$F_1(1,19) = 1.49, p = .24$; $F_2(1,78) < 1$]. The latencies of high proficiency participants were affected by English N only in the first block [66 ms inhibition effect; $F_1(1,10) = 6.62, p < .05$; $F_2(1,78) = 4.42, p < .05$] and not in the second block [1 ms inhibition; both *F*s < 1].

The latencies of English words showed a significant inhibitory effect of Dutch N [$F_1(1,38) = 23.86, p < .001$; $F_2(1,76) = 4.84, p < .05$]. In contrast with the Dutch items, however, the effect of English N on English words was facilitatory, but this effect was only significant by participant [$F_1(1,38) = 13.70, p < .01$; $F_2(1,76) = 1.45, p = .23$]. The interaction between Dutch N and English N was only marginally significant [$F_1(1,38) = 23.23, p < .001$; $F_2(1,76) = 2.92, p = .09$]. Similar to the Dutch items, no significant effects were found for Proficiency [$F_1(1,38) < 1$; $F_2(1,76) = 7.52, p < .01$] or Order of Presentation [$F_1(1,38) = 2.08, p = .16$; $F_2(1,76) = 88.86, p < .001$]. Furthermore, no significant interactions were obtained.

Error data. An analysis of variance run on the error data for each language separately

TABLE 3

Mean Identification Latencies of Experiment 1 (in Milliseconds) of Participants Presented with English Words in the First Block or the Second Block (Standard Deviation and Percentage of Errors Are Presented in Parentheses.)

		Low proficiency		High proficiency		
Dutch N	English N	Block 1	Block 2	Block 1	Block 2	Mean
Large	large	1784 (185, 2.0)	1616 (309, 3.2)	1669 (152, 2.5)	1604 (174, 2.7)	1666
Large	small	1751 (212, 2.5)	1588 (285, 3.2)	1670 (158, 3.0)	1609 (183, 3.6)	1652
Small	large	1630 (150, 4.0)	1513 (259, 5.5)	1581 (183, 2.5)	1517 (206, 3.6)	1558
Small	small	1689 (170, 5.0)	1598 (314, 3.6)	1648 (200, 3.0)	1631 (202, 1.4)	1640

showed no significant main effects and only one significant interaction for Dutch items between Order of Presentation, Dutch N, and English N [$F_1(1,38) = 6.59$, $p < .05$; $F_2(1,76) = 5.92$, $p < .05$].

Discussion

The most important result of Experiment 1 is that target word recognition was significantly influenced by the number of orthographic neighbors in the non-target language. For English (L2), a significant inhibitory effect of Dutch N was found in both the participant and item analysis, while for Dutch (L1), the inhibitory effect of English N was significant only in the participant analysis. These findings represent a further demonstration of effects of orthographic neighborhood across languages in bilingual participants, adding to the work of Beauvillain (1992), Grainger and Dijkstra (1992), and Bijeljac-Babic, Biardeau, and Grainger (1997). As previously argued by Grainger and Dijkstra (1992) and Grainger (1993), such results cannot be accommodated by a serial search model of bilingual lexical access in which language context determines the order in which L1 and L2 representations are examined. Only a model that allows simultaneous activation of word representations in both languages (i.e., a non-selective access model) can account for such results. Furthermore, the inhibitory nature of these between-language neighborhood effects suggests that word units in both languages are interconnected via inhibitory links (see also Bijeljac-Babic, Biardeau, & Grainger, 1997). Thus, these results support the hypothesis of non-selective access to an integrated lexicon.

The within-language neighborhood effects showed a more complex pattern of neighborhood effects. Dutch words showed clear inhibitory effects of increasing number of Dutch neighbors (59 ms). English words showed a 34 ms facilitation effect when the number of English neighbors increased, but this effect was only significant in the participant analysis. Because perceptual identification paradigms typically show inhibitory effects of neighborhood density (Carreiras et al., 1997; Grainger & Jacobs, 1996; Ziegler et al., in press; Snodgrass & Mintzer, 1993), it is the facilitatory pattern obtained with English target words that requires an explanation here. We will return to this point in the General Discussion.

Next, we must consider the manipulation of second-language proficiency in the experiment. The two groups of participants were assumed to differ with respect to their second-language proficiency. However, the results suggest that the proficiency manipulation was not very effective, since Proficiency neither yielded a significant main effect nor interacted with the neighborhood density factors. However, Proficiency did interact with the combination of presentation order of the Dutch items and number of English neighbors. Latencies of high proficiency participants to Dutch target words showed more interference from English neighbors when the Dutch block was presented before the English block than vice versa. This interesting result suggests that our high proficiency participants in some way controlled the effects of non-target language neighbors depending on their expectations. Their English lexicon may have been more active when they expected the English language to be relevant (at the beginning of the experiment), and less so when it was considered less relevant (in the Dutch block after the English block had occurred). Note that the participants were aware that their knowledge of English was potentially relevant because they were explicitly asked to perform in a bilingual experiment. This suggestion is in agreement with the language mode (or relative language activation) hypothesis proposed by Grosjean (1997).

We tried to obtain extra support for this view by carrying out an additional ANOVA over the Dutch response times of the high proficiency participants in which each Dutch block, preceding the English block or following it, was divided into two parts. Apart from Condition and Order of Presentation (the Dutch block followed by the English block or vice versa), this analysis included as an extra within-participant factor Part of Block (first or second part). Due to the post hoc nature of this analysis, the items in each condition were not counterbalanced, since items were randomized for each participant. The analysis showed a significant effect of Order of Presentation [$F_2(1,156) = 13.54$, $p < .001$] and a significant interaction between English N and Order of Presentation [$F_2(1,156) = 6.63$, $p < .05$]. The interaction reflects a gradual change over the experiment in the response time difference between large and small English N conditions from inhibition towards facilitation (see Dijkstra & Van Heuven, 1998). The interaction between English N, Order of Presentation, and Part of Block was not significant [$F_2(1,156) < 1$]. To conclude, the hypothesis that high proficiency participants are able to exert a certain degree of control over the relative activity of their lexica clearly deserves further investigation (also see Dijkstra, Van Jaarsveld & Ten Brinke, 1998).

Experiment 2 provided a further examination of within- and between-language neighborhood effects in the progressive demasking task, this time using a mixed language presentation. In this situation, we expected an even stronger effect from non-target neighbors on target identification because both languages must be kept active during the experiment. In addition, we attempted to replicate the facilitatory effect of number of English neighbors on English word identification.

EXPERIMENT 2: PROGRESSIVE DEMASKING (MIXED PRESENTATION)

Method

Participants. Forty Dutch students with Dutch as their native language and with normal or corrected-to-normal vision participated in this experiment. Participants were paid for their participation.

Stimuli and design. The same materials and task were used as in Experiment 1. The only difference was that Experiment 2 consisted of only one block of items in which both English and Dutch words were presented in a random order. The language of instruction and feedback in the experiment was counterbalanced. One group of participants received instruction and feedback in Dutch, while a second group received them in English.

TABLE 4

Mean Identification Latencies of Experiment 2 (in Milliseconds) (Standard Deviation and Percentage of Errors Are Presented in Parentheses.)

Dutch N	English N	English	Dutch
Large	large	1777 (247, 4.8)	1756 (249, 7.0)
Large	small	1761 (245, 5.5)	1710 (205, 5.1)
Small	large	1660 (233, 3.1)	1689 (229, 4.4)
Small	small	1739 (240, 3.0)	1637 (189, 4.0)

Procedure. The participants started with a practice session of 25 trials. Next, all 160 test items were presented in a random order in one block, starting with five dummy items. The procedure, presentation, and recording were the same as in Experiment 1. The experiment took about 20 minutes.

Results

For items of both languages, erroneous responses (3.0%) and RTs which were outside the range of two standard deviations from the participant and item mean (1.4%) were excluded from the latency analyses. The mean RTs and error rates for items of each language are presented in Table 4. Separate ANOVAs were carried out on the latency data of each language in which the number of neighbors in Dutch (Dutch N) or English (English N) were treated as within-participant factors.

Reaction time data. For Dutch words, the analysis showed, as in Experiment 1, a significant inhibitory effect of Dutch N [$F_1(1,39) = 49.51$, $p < .001$; $F_2(1,76) = 9.23$, $p < .01$]. RTs to Dutch words with a larger number of Dutch neighbors were 70 ms slower than to Dutch words with only a few Dutch neighbors. The effect of English N on Dutch items was now significant in both participant and item analyses [$F_1(1,39) = 16.52$, $p < .001$; $F_2(1,76) = 4.24$, $p < .05$], indicating that Dutch words with many English neighbors were responded to more slowly than words with few English neighbors. No interaction was observed between Dutch N and English N [both Fs < 1].

The analysis of the RTs to English words revealed a pattern similar to Experiment 1.

There was a significant inhibitory effect of Dutch N [$F_1(1,39) = 49.90$, $p < .001$; $F_2(1,76) = 6.58$, $p < .05$]. The facilitatory effect of English N again was only significant in the participant analysis [$F_1(1,39) = 7.13$, $p < .01$; $F_2(1,76) = 1.01$, $p = .32$]. The interaction between Dutch N and English N was not significant [$F_1(1,39) = 21.15$, $p < .001$; $F_2(1,76) = 2.48$, $p = .12$].

Error data. An ANOVA on the error data for Dutch items showed a marginally significant inhibitory effect of Dutch N [$F_1(1,39) = 7.11$, $p < .01$; $F_2(1,76) = 3.14$, $p = .08$] but no effect of English N [$F_1(1,39) = 3.36$, $p = .07$; $F_2(1,76) = 1.13$, $p = .29$], and no interaction between Dutch N and English N [$F_1(1,39) = 1.49$, $p = .23$; $F_2(1,76) < 1$]. For English items, there was a significant inhibitory effect of Dutch N [$F_1(1,39) = 6.33$, $p < .05$; $F_2(1,76) = 4.46$, $p < .05$], but no effect of English N [both Fs < 1], and no interaction between the two factors [both Fs < 1].

Discussion

The results of Experiment 2 show a significant inhibitory effect of increasing the number of non-target language neighbors for both English and Dutch target items. This effect confirms that non-target language neighbors influence the identification of targets in the progressive demasking task. Again, the hypothesis of non-selective access to an integrated lexicon is supported.

Comparing the results of Experiments 1 and 2, there appears to be an increase in the effect of non-target language neighbors when going from a blocked (Experiment 1) to a mixed (Experiment 2) experimental design. This can be illustrated by the inhibition effect of large English N on the latencies to Dutch words. This effect is nonsignificant (by items) in Experiment 1, but becomes significant in Experiment 2. Though the difference in size of effect across the experiments is admittedly only 8 ms, it might be that the effect of the non-target language on target identification is strengthened when the non-target language also becomes relevant for task performance and/or target items from another language occur in the same list as the target item.

The pattern of within-language neighborhood effects was the same as in Experiment 1. In both experiments, a facilitatory effect was obtained to the English target words (only significant in the participant analysis). Dutch words continued to show an significant inhibition effect.

EXPERIMENT 3: GENERALIZED LEXICAL DECISION

The main aim of Experiment 3 was to test whether the results obtained with the progressive demasking technique generalize to another experimental technique, widely used in studies of visual word recognition, the lexical decision task. Exactly the same word conditions as in Experiment 2 (i.e., mixed language presentation) were tested in the lexical decision task.

In addition, four nonword conditions, also varying in terms of number of orthographic neighbors in Dutch and English, were added to the experiment. In lexical decision experiments, not only the positive reaction to words has been shown to be sensitive to neighborhood characteristics but the negative reaction towards nonwords has as well (Andrews, 1989, 1992; Carreiras et al., 1997; Coltheart et al., 1977; Sears, Hino, & Lupker, 1995). We therefore investigated the effect of both English and Dutch neighborhood density on responses to word and nonword stimuli in the same experiment.

Method

Participants. Forty-eight Dutch students from the same population as Experiment 2 participated in this experiment. None of them had participated in the previous experiments. All students were native speakers of Dutch.

Stimuli and design. All 160 words (80 Dutch and 80 English words) of the previous experiments were included in this experiment along with 160 nonwords. Each nonword was constructed by changing one letter in a Dutch or English word (not a target word in the experiments) in such a way that it formed an orthographically and phonologically legal letter string in both languages (bigram analysis ensured that only legal combinations were included).

Analogous to the word conditions, four experimental nonword conditions were defined with respect to the number of neighbors in Dutch and in English, each consisting of 40 nonwords: (1) nonwords with many neighbors in both English and Dutch (large English N, mean 3.5, and large Dutch N, mean 3.5), (2) nonwords with many neighbors in English (large English N, mean 3.5) and few in Dutch (small Dutch N, mean 1.0), (3) nonwords with few neighbors in English (small English N, mean 1.0) and many in Dutch (large Dutch N, mean 3.5), and (4) nonwords with few word neighbors in either language (small English N, mean 1.0, and small Dutch N, mean 1.0). The four nonword conditions were matched as closely as possible with respect to the number of high frequency (larger than 50 o.p.m.) neighbors and positional bigram frequency. The latter was computed as the summed frequency of words containing the bigram of the nonword at the specified position, averaged over the number of bigrams in the nonword.

Procedure. Presentation of the visual stimuli was controlled by an Apple Macintosh Quadra connected to a 67-Hz Trinitron monitor and to the same type of button box as used in earlier experiments. Before the experiment, participants were informed about their task by means of written instructions. They were told that a series of letter strings would appear on the screen, one after the other, and that they had to decide as quickly and as accurately as possible whether each of the presented items was a word (Dutch or English) or not. Responses were made by pressing one of two buttons on the response box. Half of the participants were asked to respond with their left finger when the stimulus was a Dutch or English word and with their right finger when it was a nonword. The other half of participants received the reversed instruction. Language of instruction and feedback (Dutch or English) was counterbalanced by a similar, further subdivision of participants.

When the participants had read the instructions, the experiment began with the 24 practice trials. Next, the 320 experimental stimuli were presented to each participant in a pseudo-random order. Participants received no more than four words or four nonwords in sequence. The participant took a short break after 164 trials. Four dummy trials were inserted at the beginning of the experiment and 2 dummy items were inserted after the break. Prior to the presentation of each stimulus word, two horizontal fixation lines were presented at the center of the screen where the stimulus word was to appear. These fixation lines disappeared after 800 ms and were immediately followed by the stimulus. The stimulus remained on the screen until a deadline of 1500 ms was reached, or until the participant had pressed one of the response buttons. The interval between two successive trials was 500 ms. The experiment lasted about thirty minutes.

Results

Erroneous responses (6.6%) and RTs which were outside the range of two standard deviations from the participant and item mean (1.7%) were excluded from the latency analyses (total 8.5%). The mean RTs and error rates are presented in Table 5. Separate ANOVAs were carried out on the latency and error data of words from each language and for the nonwords, in which the number of neighbors in Dutch (Dutch N) or English (English N) were treated as within-participant factors.

Reaction time data. The analysis of Dutch word latencies revealed that responses were again slower for words with many Dutch neighbors than for words with few Dutch neighbors, but this effect was now only significant by participants [$F_1(1,47) = 20.81$, $p < .001$; $F_2(1,76) = 1.87$, $p = .18$]. Also, the inhibitory effect of English N was again only significant in the participant analysis [$F_1(1,47) = 4.85$, $p < .05$; $F_2(1,76) < 1$]. As in Experiments 1 and 2, no interaction was found between these factors [$F_1(1,47) = 3.58$, $p = .07$; $F_2(1,76) < 1$].

The analysis for English words revealed a significant inhibition effect (27 ms, see Table 7) of Dutch N [$F_1(1,47) = 32.13$, $p < .001$; $F_2(1,76) = 7.07$, $p < .05$]. Again, we obtained

TABLE 5

Mean Identification Latencies of Experiment 3 (in Milliseconds) (Standard Deviation and Percentage of Errors Are Presented in Parentheses.)

Dutch N	English N	English	Dutch	Nonwords
Large	large	621 (69, 13.3)	581 (59, 7.6)	675 (75, 9.7)
Large	small	642 (85, 12.6)	566 (60, 7.5)	672 (78, 9.7)
Small	large	590 (62, 6.6)	561 (58, 6.6)	647 (79, 6.7)
Small	small	619 (73, 8.7)	560 (56, 6.4)	649 (73, 6.4)

a facilitation effect of English N, which was significant in both item and participant analyses [$F_1(1,47) = 29.49$, $p < .001$; $F_2(1,76) = 5.46$, $p < .05$]. The interaction between Dutch N and English N was not significant [both Fs < 1].

The analysis of the nonword latency data revealed a significant inhibition effect of Dutch N [$F_1(1,47) = 78.40$, $p < .001$; $F_2(1,156) = 11.55$, $p < .01$]. There was no effect of English N [both Fs < 1], and no interaction between Dutch N and English N [$F_1(1,47) = 1.01$, $p = .32$; $F_2(1,156) < 1$].

Error data. An ANOVA on the error data for Dutch items showed no effect of Dutch N [$F_1(1,47) = 1.61$, $p = .21$; $F_2(1,76) < 1$], English N [both Fs < 1], or Dutch N and English N together [both Fs < 1]. Similar to Experiment 2, errors on English items showed a significant effect of Dutch N [$F_1(1,47) = 24.42$, $p < .001$; $F_2(1,76) = 5.70$, $p < .05$]. Again, no effect was found of English N [both Fs < 1], and the errors showed no interaction of Dutch N and English N [$F_1(1,47) = 2.69$, $p = .11$; $F_2(1,76) < 1$].

For nonword items, a significant inhibitory effect of Dutch N was found [$F_1(1,47) = 20.66$, $p < .001$; $F_2(1,156) = 6.59$, $p < .001$]. There was no effect of English N [both Fs < 1] and no interaction of Dutch N and English N [both Fs < 1].

Discussion

The results of Experiment 3 extend those obtained in the two previous experiments with a new group of bilingual participants and a different experimental task. Once again, significant inhibition from Dutch neighbors on English target items was observed. And once again, the effect of within-language neighbors was facilitatory with English stimuli tested in the same experiment. However, in contrast with the previous experiments, the effects of Dutch and English neighbors on Dutch target items failed to be significant in both participant and item analyses. As seen in Table 7, the lexical decision task of Experiment 3 generally led to smaller neighborhood density effects than the progressive demasking task of Experiments 1 and 2.

In this generalized lexical decision experiment, the latencies for the nonwords were significantly affected by the neighborhood size of their Dutch neighbors, and not by their English neighbors.[2] It would appear that in this experimental situation, although both English and Dutch were relevant target languages, the dominant language exerted the major influence on performance to nonword stimuli. Being the mother tongue (L1) of the bilingual participants, Dutch exerted the strongest effect on rejection times to nonwords. This should not, however, be the case when only English (L2) words and nonwords are presented to Dutch/English bilinguals in a ‘monolingual‘ lexical decision task.

[2] Recently, we replicated the neighborhood density effects for nonwords in a generalized lexical decision task involving Dutch/English cross-language homographs (Experiment 3 in Dijkstra, Van Jaarsveld, & Ten Brinke, 1998). Nonwords derived from Dutch or English words revealed (inhibitory) effects of about 11 ms for English N and 37 ms for Dutch N.

In this situation, responses to nonword stimuli should be sensitive to their neighborhood size in English. Testing this hypothesis was one of the aims of Experiment 4.

Experiment 4 also tested the English words used in the previous experiments with a new group of Dutch/English bilingual participants and an English monolingual control group. We expected effects of Dutch neighbors to appear only in the bilingual participants' performance, while effects of English neighbors should be present in both groups of participants.

EXPERIMENT 4: ENGLISH LEXICAL DECISION

Method

Participants. Twenty English and twenty-one Dutch right-handed participants with normal or corrected-to-normal vision participated in this experiment. The English participants were all monolingual native speakers of English, who were tested in Cambridge (UK). The Dutch participants were all native speakers of Dutch. They were tested in Nijmegen (Netherlands). None of the participants participated in earlier experiments.

Stimuli and design. The English set of 80 stimulus words described above was used in the experiment, together with a matched selection of 80 of the 160 nonwords used in Experiment 3. Both words and nonwords consisted of 20 items for each of the four conditions described earlier (small or large neighborhoods in English or Dutch).

Procedure. Presentation of the stimuli was controlled by an Apple Power Macintosh computer (Cambridge, PowerMac 8500; Nijmegen, PowerMac 7200). Latencies were recorded by means of a button box (the same as in previous experiments) connected to the computer. Words and nonwords consisted of black Courier capital letters (28 points) presented at the center of a Apple monitor (Cambridge, 20″ Trinitron; Nijmegen, 15″ Multiscan) on a white background. The monitor was placed at a distance of approximately 60 cm from the participant. Each trial started with a fixation marker, · , which was presented for 500 ms before the screen was cleared. After 500 ms, the target item was presented until the participant responded. The next trial started 800 ms after the participant responded or after 2000 ms if the participant did not respond.

Before the experimental block began, the participant started with a practice session of 24 items. At the beginning of the experimental block and after the break, four dummy items were inserted. Each participant saw a different randomized order of the test items.

Participants read written instructions in English explaining that strings of four letters would appear at the middle of the computer screen. They were instructed to give a speeded response by pressing the right response button of the two-button response box with their right index finger if the string was a English word, and by pressing the left button with their left index finger if the string was not a English word.

After the experiment, each participant filled out a questionnaire concerning his or her knowledge about and experience with other languages, in order to check to which extent the participant could be considered as a pure English monolingual or Dutch/English bilingual participant. The session lasted about 20 minutes.

Results

First, the data were removed for five words (BIAS, BUTT, ATOM, MYTH, JERK) that had a mean RT of more than two standard deviations above the mean of their test condition in the English monolingual group. Also, the data for four nonwords (GONK, KNAT, FRIG, BOUL) were removed since some of the English participants considered them to be low-frequency English words (e.g., a GONK was said to be an English toy).[3] Overall, monolingual and bilingual participants made 4.7% erroneous responses. The errors and the RTs which were outside the range of two standard deviations from the participant and item mean (1.8%)

[3] We reanalyzed the data of our bilingual Experiments 1–3 with these five word and four nonword items removed. This procedure did not change the pattern of results in any substantial way, nor did it affect the significance of effects to any relevant extent.

TABLE 6

Mean Identification Latencies of Experiment 4 (in Milliseconds) of Monolingual and Bilingual Participants (Standard Deviation and Percentage of Errors Are Presented in Parentheses.)

		Monolinguals		Bilinguals	
Dutch N	English N	Words	Nonwords	Words	Nonwords
Large	large	488 (58, 4.0)	575 (86, 8.8)	585 (69, 12.1)	651 (94, 9.5)
Large	small	507 (71, 5.0)	558 (74, 4.5)	583 (74, 12.1)	635 (94, 4.0)
Small	large	484 (57, 3.0)	581 (87, 5.8)	561 (70, 4.8)	642 (99, 8.1)
Small	small	503 (53, 5.3)	560 (65, 6.1)	564 (73, 9.5)	626 (93, 3.5)

were excluded from the latency analyses. The resulting mean RTs and error rates are presented in Table 6.

Separate ANOVAs were carried out on the latency and error data of the English words and nonwords in which the number of neighbors in Dutch (Dutch N, large vs small) and English (English N, large vs small) were treated as within-participant factors, and the Language Status of the participants (monolingual or bilingual) as a between-participant factor.

Reaction time data. The analysis of the word latencies showed again a facilitatory effect of English N which was significant in the participant analysis but not in the item analysis [$F_1(1,39) = 10.13$, $p < .01$; $F_2(1,71) = 2.09$, $p = .15$]. The interaction between Dutch N and English N was not significant [$F_1(1,39) = 1.07$, $p = .31$; $F_2(1,71) < 1$]. Not surprisingly, monolingual English participants were significantly faster than Dutch/English bilingual participants [$F_1(1,39) = 14.15$, $p < .001$; $F_2(1,71) = 213.61$, $p < .001$]. There was also a marginally significant inhibition effect of Dutch N [$F_1(1,39) = 9.41$, $p < .01$; $F_2(1,71) = 3.00$, $p = .09$].

More importantly, the monolingual participants showed no effect of Dutch N while the bilinguals did. This interaction between Language Status of the participant (monolingual, bilingual) and Dutch N was significant [$F_1(1,39) = 4.70$, $p < .05$; $F_2(1,71) = 4.10$, $p < .05$]. Language Status did not interact with English N [$F_1(1,39) = 5.02$, $p < .05$; $F_2(1,71) = 2.06$, $p = .16$], and also showed no interaction with both Dutch N and English N [$F_1(1,39) = 1.31$, $p = .26$; $F_2(1,71) < 1$].

The analysis of the nonword latencies showed a significant inhibitory effect of English N [$F_1(1,39) = 26.49$, $p < .001$; $F_2(1,72) = 5.73$, $p < .05$]. The effect of Dutch N was not significant [both *F*s < 1]. There was no interaction between Dutch N and English N [both *F*s < 1]. Again, monolingual participants were significantly faster than bilingual participants [$F_1(1,39) = 8.03$, $p < .01$; $F_2(1,72) = 170.33$, $p < .001$]. The Language Status of the participant did not interact with Dutch N [$F_1(1,39) = 2.06$, $p = .16$; $F_2(1,72) = 1.23$, $p = .27$], English N [both *F*s < 1], or Dutch N and English N [both *F*s < 1].

Error data. For English items, error scores showed no effect of Dutch N [$F_1(1,39) = 13.45$, $p < .01$; $F_2(1,71) = 2.60$, $p = .11$], English N [$F_1(1,39) = 4.44$, $p < .05$; $F_2(1,71) = 1.44$, $p = .24$], and no interaction between Dutch N and English N [$F_1(1,39) = 2.89$, $p = .10$; $F_2(1,71) < 1$]. Bilinguals produced more errors than monolinguals [$F_1(1,39) = 28.48$, $p < .001$; $F_2(1,76) = 14.84$, $p < .001$]. Language Status showed a marginally significant interaction with Dutch N [$F_1(1,39) = 9.93$, $p < .01$; $F_2(1,76) = 2.77$, $p = .10$], but not with English N [$F_1(1,39) < 1$; $F_2(1,76) < 1$], and not with both English N and Dutch N [$F_1(1,39) = 1.00$, $p = .32$; $F_2(1,76) < .1$].

The error scores for nonwords showed no significant main effect of Dutch N [$F_1(1,39) = 1.46$, $p = .24$; $F_2(1,76) < 1$]. In contrast with the error scores of the English words, those for nonwords were affected by English N [$F_1(1,39) = 15.48$, $p < .001$; $F_2(1,76) = 7.46$, $p < .01$]. No interaction was found between Dutch N and English N [$F_1(1,39) = 3.43$, $p = .07$; $F_2(1,76) = 1.14$, $p = .29$]. Furthermore, monolinguals and bilinguals did not differ in their error scores [both Fs < 1], and this factor did not interact with Dutch N [both Fs < 1], or English N [$F_1(1,39) = 2.85$, $p = .10$; $F_2(1,76) = 2.75$, $p = .10$], nor with both English N and Dutch N [$F_1(1,39) = 1.57$, $p = .22$; $F_2(1,76) = 1.05$, $p = .31$].

Discussion

The results of Experiment 4 show that responses of English monolingual participants to English target words were not influenced by the number of Dutch word neighbors of these targets. However, this factor did significantly influence the responses of the Dutch/English bilinguals. This is particularly interesting because in this experiment (in contrast to the earlier ones) the bilinguals were not using their Dutch language at any time during the experiment. The observed pattern of results strongly suggests that it is knowledge of the non-target language (in this case the mother tongue) that produces the between-language neighborhood effects in the bilingual participants, not some uncontrolled variable. As in the previous experiments, increasing the number of English neighbors resulted in facilitation.

With respect to the nonwords, the monolingual and bilingual participant groups showed the same type of effect, slower RTs when the number of English neighbors of the nonword targets increased. It is interesting to note that in the generalized lexical decision task of Experiment 3, the RT pattern for the nonwords was especially affected by the number of Dutch neighbors. Apparently, the presence in that experiment of target items from the mother tongue of the bilingual participants had a pervasive effect on nonword responses. This pattern of neighborhood effects on responses to nonword stimuli will be discussed more fully below.

GENERAL DISCUSSION

In the experiments presented in this paper we tested whether bilingual word recognition involves language selective or non-selective lexical access and whether this access is to language-dependent (separate) or integrated lexical systems. It was argued that target word identification in bilingual participants will be influenced by orthographic neighbors from the non-target language only if bilingual word recognition involves non-selective access to an integrated lexicon. In accordance with this hypothesis, both within- and between-language manipulations of orthographic neighborhood density influenced performance in bilingual participants on words and nonwords presented in two experimental paradigms, progressive demasking and lexical decision. The between-language effect (from Dutch neighbors on English target words) disappeared in an English monolingual control group tested in Experiment 4 (see Table 7). These data provide clear evidence that stimulus items automatically activate orthographically similar words in both the target language and the other language of the bilingual participant. The effects of between-language neighborhood were further obtained in conditions where stimuli were blocked by language or presented in mixed language lists. Numerically larger effects appeared in the latter condition.

The observed effects of number of neighbors from the non-target language stand in clear contradiction with the predictions of models assuming selective access and/or independent lexica. Only models assuming non-selective access and integrated lexica may provide a viable account for all results reported here. However, the effect of non-target language neighbors depended to some extent on the experimental paradigm and stimulus list context (cf. Table 7). For instance, effects were generally smaller in lexical decision than in progressive demasking. Furthermore, in the blocked progressive demasking task of Experiment 1, response times of high proficiency participants to Dutch items were significantly affected by English neighborhood density when the Dutch words were presented

TABLE 7

Neighborhood Density Effects (in Milliseconds) of Number of English (English N) and Dutch Neighbors (English N) for Experiments 1–4 (Effect Size is Calculated by Subtracting RTs in Conditions with a Large Number of Neighbors from Those in Conditions with a Small Number of Neighbors. A Minus Sign Indicates a Facilitatory, and a Plus Sign an Inhibitory Effect.)

		Exp 1	Exp 2	Exp 3	Exp 4	
		Progressive demasking	Progressive demasking	Generalized lexical decision	English lexical decision	
		Blocked	Mixed		Monolinguals	Bilinguals
English	English N	−34	−32	−25	−19	−3
	Dutch N	57	70	27	2	22
Dutch	English N	41	49	8		
	Dutch N	59	70	13		
Nonwords	English N			1	19	19
	Dutch N			26	−5	6

before the English words. In order to account for the pattern of data across experiments, a language non-selective integrated-lexica model is required which allows some control over the relative activation of the two languages. Below we will examine an implemented model of this kind, the BIA model. However, we will first discuss how the task-dependence of the observed cross-language interference effects may have come about.

Task-Dependence of Cross-Language Interference Effects

Examination of Table 7 suggests that there may be differences in cross-language neighborhood density effects depending on task requirements. For instance, it may be observed that density effects are generally smaller in the lexical decision task than in the progressive demasking task (especially for Dutch stimuli). Such task dependence has been observed in the monolingual domain by Carreiras, Perea, and Grainger (1997), who found that the effect of neighborhood density changed from an inhibitory trend in progressive demasking to nonsignificant facilitation in lexical decision and significant facilitation in word naming. If the size and perhaps the direction of the bilingual neighborhood density effects also depend on task demands, any bilingual processing model (such as the Bilingual Interactive Activation [BIA] model) must be extended with a ‘‘meta-account’’ that specifies how a particular task is performed (Dijkstra et al., 1998).

For instance, it could be assumed, following Grainger and Jacobs (1996), that identification latencies in progressive demasking depend on a criterion set on the activation levels of individual word representations, while participants in a lexical decision task may apply several criteria to generate their response. First, as in the progressive demasking task, they may base their positive responses on a criterion set on individual word activation. This type of criterion could be extended to the bilingual domain by applying the criterion to all words in an integrated lexicon. A second criterion proposed by Grainger and Jacobs is one set on summed lexical activity. Words with more orthographic neighbors generate higher levels of summed lexical activity, thus leading to faster positive lexical decision responses. This type of criterion would not apply to progressive demasking, in which participants need to uniquely identify one lexical candidate. For the bilingual variants of lexical decision, it is highly relevant whether summed lexical activity is calculated across both lexica or across each lexicon separately, because the results would be very different for the two options.

The third criterion proposed by Grainger and Jacobs (1996) applies specifically to nonword performance. Following Coltheart et al. (1977), they assumed that correct responses to nonword stimuli are governed by a criterion set on time from stimulus onset. The value of this criterion also varies as a function of summed lexical activity. The greater the summed activity, the higher the criterion. Nonwords with many word neighbors generate higher levels of summed lexical activity and therefore a higher negative response criterion and longer RTs (this effect of neighborhood density on correct reject RTs to nonword stimuli has been reported many times in the literature, e.g., Coltheart et al., 1977). The results of Experiments 3 and 4 suggest that summed lexical activity in the most activated lexicon, rather than the sum of activity across languages, is the critical factor determining RTs to nonword stimuli. In generalized lexical decision (Experiment 3) only L1 (Dutch) neighbors affected RTs to nonwords. In the English lexical decision task of Experiment 4, on the other hand, only L2 (English) word neighbors affected RTs to nonword stimuli. Such an account of the nonword data is not incompatible with the integrated lexicon hypothesis, since we assume that summed lexical activity can be calculated language-specifically. This language-specific summation of lexical activity is carried out by the ''language nodes'' of the BIA model to be described below.

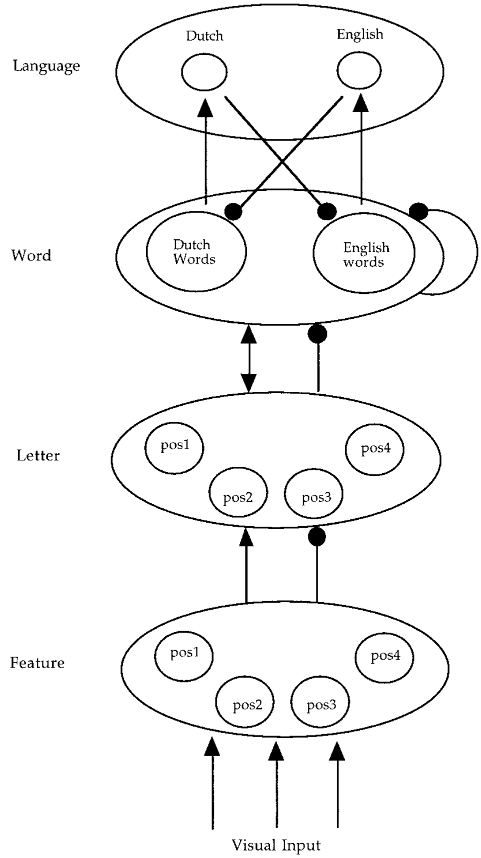

FIG. 2. The Bilingual Interactive Activation (BIA) model. Arrowheads indicate excitatory connections; black filled circles indicate inhibitory connections. Though only four positions for features and letters are represented, the model is not limited to the recognition of four-letter words.

The Bilingual Interactive Activation (BIA) Model

The BIA model (Dijkstra & Van Heuven, 1998; Grainger & Dijkstra, 1992) is an algorithmic model of bilingual word recognition that implements non-selective bottom-up processing (letters activate words from both languages in an integrated lexicon) and language-specific top-down processing (language nodes selectively inhibit activity in words of the other language). By using this language-specific top-down control mechanism, the BIA model can handle both selective and non-selective results (similar mechanisms have been proposed for bilingual language production by Green, 1986, and Monsell, Matthews, & Miller, 1992). To examine to what extent the current pattern of results can be simulated by the model, we first need to discuss the model in more detail.

The BIA model, illustrated in Figure 2, shares the basic architecture and parameter settings of the monolingual Interactive Activation model (McClelland & Rumelhart, 1981, 1988). It has two major extensions: (1) an integrated Dutch and English lexicon, and (2) an extra representational layer containing two 'language nodes' that are connected to all the word nodes in both lexica. A verbal (and slightly different) version of this model has been described elsewhere (Grainger & Dijkstra, 1992; Grainger, 1993).

When a string of letters is presented to the BIA model, this visual input affects particular features at each letter position, which subsequently excite letters that contain these features and at the same time inhibit letters for which the features are absent. The activated letters next excite words in both languages for which the activated letter occurs at the position in question, while all other words are inhibited. At the word level, all words inhibit each other, irrespective of the language to which they belong. Activated word nodes send excitatory feedback to their constituent letters. Activated word nodes from the same language also send activation on to the corresponding language node, while activated language nodes send inhibitory feedback to all word nodes in the other language. The main function of the language nodes is to collect activation from words in the language they represent and inhibit active words of the other language. The activation of the language nodes reflects the amount of activity in each lexicon. They also represent a simple means of storing knowledge about the language to which a particular word form belongs (Grainger & Dijkstra, 1992). A more extensive description of the implemented model and of simulation work involving the language nodes is given in Dijkstra and Van Heuven (1998).

Figure 3 presents the simulation results of the BIA model with a reduced English frequency range and limited asymmetric top-down inhibition (from the Dutch language node on all English words only), along with the results of Experiment 2. Since the patterns of results for Experiments 1 and 2 were similar, the model captures the general pattern of results across both progressive demasking experiments.[4] As can be seen, the BIA model captures the within-language neighborhood effects in both Dutch (inhibition) and English (facilitation). How is the model able to simulate these effects that differ in direction? The inhibitory effect of large Dutch N on Dutch target words can be accounted for by the presence of lateral inhibition between lexical candidates. The facilitation effect of large English N on English target words requires a more complex explanation.

In the BIA model, an English target word also activates Dutch neighbors. These Dutch neighbors activate the Dutch language node, which in turn inhibits all English words. Also, due to the reduced English frequencies, Dutch words will be activated earlier in the recognition process than English words. Thus, top-down inhibition and reduced English frequencies lead to an extra inhibitory effect from the Dutch to the English lexicon. This effect is stronger for English words that have only a small English N than for those with a large English N. Thus, a relative facilitation effect arises of large versus small English N conditions. Simulation studies show that the capability of the model to simulate the facilitatory effect of English neighborhood density on English target words depends on the setting of the top-down inhibition parameter. When this parameter is set to zero, the facilitatory effect of English neighborhood density disappears while the effect of Dutch neighborhood remains inhibitory (see Dijkstra, Van Heuven, & Grainger, in press). In sum, simulations suggest that, at least for the progressive demasking experiments with bilinguals, the facilitatory effect of English N can be explained by the relative activation of the two languages dependent on word frequency in combination with asymetric top-down inhibition.[5]

With respect to the monolingual participants in Experiment 4, the facilitatory effect of large English N observed in lexical decision may also

[4] The quantitative fit of the model to the empirical data can be computed by means of a chi-square procedure (see Footnote 2 of Baayen, Dijkstra, & Schreuder, 1997). Since in the mixed stimulus presentation in Experiment 2 the overall activation state of English and Dutch should be more comparable than in the blocked Experiment 1, the BIA model was fitted to the data of Experiment 2. After linearly transforming the cycle times produced by the model into milliseconds, a chi-square test was performed on the eight pairs of empirical and predicted RTs of Experiment 2. For six degrees of freedom (eight minus two free parameters, EFR and ATD), the resulting chi-square of 12.15 was not significant ($p > .05$), indicating that the model data do not differ substantially from the empirical data in this experiment.

[5] The relevance of the top-down feedback parameter also becomes clear when it is used to simulate the transition effect of English neighbors on Dutch target words that was observed over the experimental parts for high-proficiency participants in Experiment 1. Manipulation of this parameter alone results in a simulation pattern that correlates .99 with the eight empirical data means represented in Figure 6.3 of Dijkstra and Van Heuven (1998).

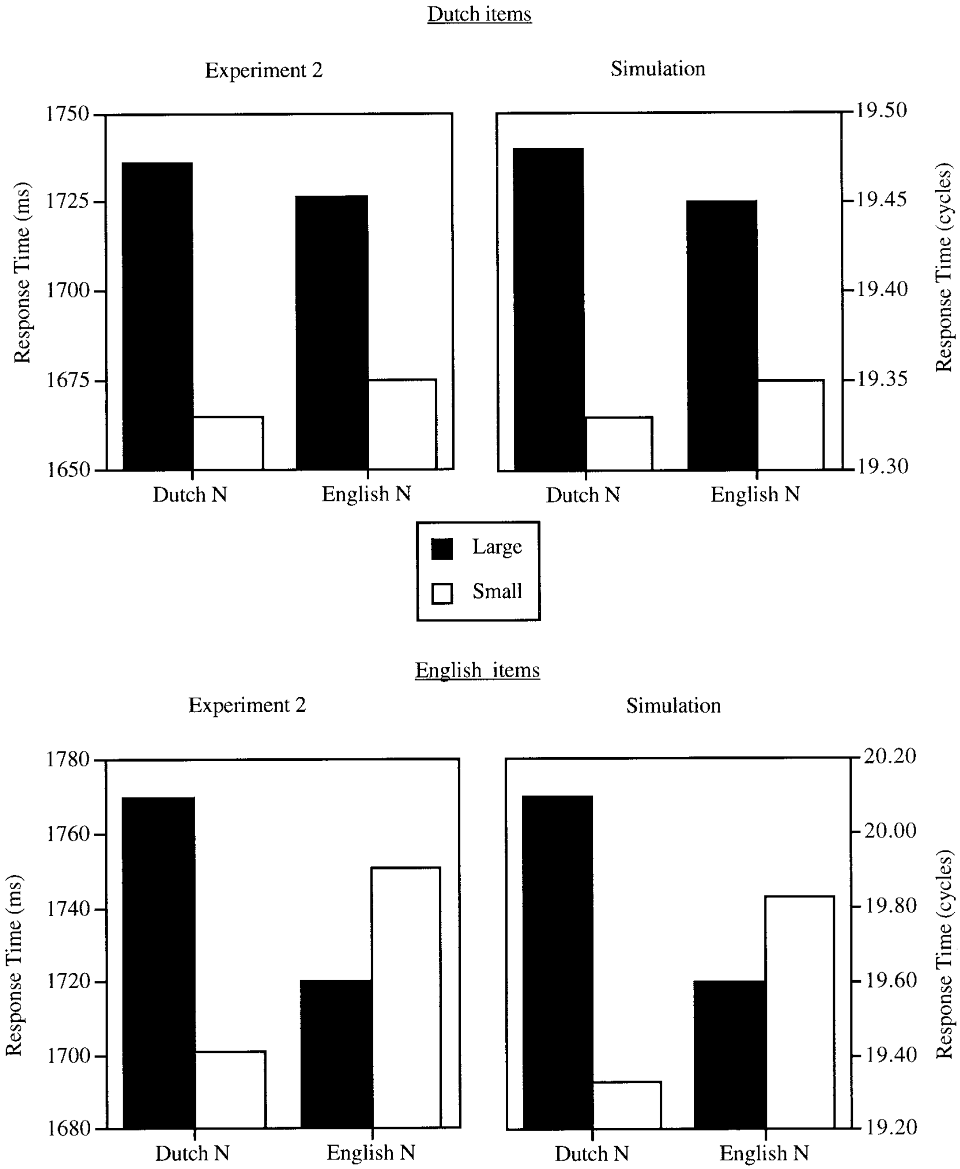

FIG. 3. Mean identification latencies of Experiment 2 (in milliseconds) and simulation results of the BIA model (in cycles) for Dutch N and English N effects on Dutch and English items. In the simulation a reduced upper limit was used for the resting-level activations of English items (−0.30), and the standard IA-model upper limit was used for resting-level activations of Dutch items (0.00). The top-down inhibition parameter from the Dutch language node to all English words was set to 0.03.

be simulated with the BIA model, but in a different way. The BIA model with only one lexicon (simulating monolingual word recognition) is equivalent to the IA model. As described earlier, Grainger and Jacobs (1996) have extended the IA model with multiple read-out criteria to account for monolingual lexical decision. They show that a model equipped with these criteria can in principle simulate monolingual facilitation effects of large versus small English neighborhoods. The current BIA model is not yet extended with similar read-out criteria, because it is not clear, for example, how summed lexical activity should be calculated in the bilingual case, across both lexica or for each lexicon separately. As a consequence, the model is not yet able to simulate the results of the generalized lexical decision task in Experiment 3, or the English lexical decision results of the Dutch/English bilinguals in Experiment 4.

In the next two sections we will discuss the theoretical consequences of the between-language interference effects and possible interpretations of the within-language facilitation effects obtained with English stimuli in relation to the monolingual literature.

Cross-Language Interference Effects in Bilingual Word Recognition

The present experiments have demonstrated that non-target language neighbors influence identification of target words. The simulation results from the BIA model presented in Figure 3 show that the model does indeed capture these inhibitory effects of between-language neighbors. The model also simulates our finding that between-language neighborhood effects were always stronger in L2 target words (English in the present study) than L1 target words. In the model this is a consequence of the lower average resting level activations of L2 words compared to L1 words. The reduced resting level of L2 word activation in the BIA model is designed to reflect the reduced exposure of bilingual readers to L2 words relative to L1 words.

Cross-language interference effects have previously been demonstrated in many different situations, and it would appear that these earlier observations also find a natural explanation within the BIA model. For example, the negative effects of changing languages on word recognition performance in bilinguals (e.g., Grainger & Beauvillain, 1987; Soares & Grosjean, 1986) can be explained in terms of the relative inhibitory state of the target language lexicon after processing a non-target language word. The significant diminution of this language change effect observed by Grainger and Beauvillain when target words had very language-specific spellings (and therefore had no neighbors in the non-target language) can be explained by the rapid recovery of the target language lexicon in such cases. According to the BIA model, the relative number of orthographic neighbors in the target and non-target language determines the speed with which activation in the target language node will dominate non-target language node activation.

Bijeljac-Babic et al. (1997) have recently provided further evidence for between-language orthographic inhibition in bilinguals. Using the masked prime paradigm with very short prime exposures, Bijeljac-Babic et al. compared performance to target words preceded by orthographically similar or dissimilar prime words that were or were not from the same language as the target word. Longer RTs were observed in the orthographically related prime condition, thus replicating the monolingual results of Segui and Grainger (1990). More interesting is that this orthographic inhibition effect was observed both within and between languages. This pattern of results was correctly predicted by the BIA model. Presentation of the prime word causes the corresponding word unit to rise in activation. When an orthographically related target word follows, the representation corresponding to the prime word continues to receive partial bottom-up support from the stimulus input (via shared letters). Thus, the prime word representation remains strongly activated during the initial processing of the target word and generates strong inhibition on the target word representation. That such inhibitory orthographic priming effects are observed across languages in bilingual participants is further evidence in favor of the non-selective access, integrated lexicon approach of the BIA model.

Cross-Language Differences in Orthographic Neighborhood Effects

We must now consider an unexpected aspect of the present results, namely, the different pattern of within-language neighborhood effects observed for Dutch and English words. Establishing the presence of cross-language neighborhood effects was most relevant to the bilingual goals of the current paper, but the differences found with respect to the direction of within-language neighborhood effects for

English and Dutch may have consequences for models of monolingual word recognition.

In both the lexical decision and progressive demasking experiments, we systematically obtained facilitatory effects of neighborhood density to English words. This confirms the already well-established picture for the lexical decision task (Andrews, 1989; 1992; Forster & Shen, 1996; Sears et al., 1995) but runs counter to prior observations with the progressive demasking paradigm and other perceptual identification tasks that require unique word identification (Carreiras et al., 1997; Grainger & Jacobs, 1996; Snodgrass & Mintzer, 1993; Ziegler et al., in press). With Dutch (native language) stimuli, on the other hand, within-language neighborhood effects were systematically inhibitory in both the lexical decision and progressive demasking tasks.

Explanations for this differential effect of English and Dutch neighborhood density can be sought in at least three possible directions: in terms of differences between languages, participants, and stimulus material (cf. Grosjean, 1997). As a first possibility, one might consider that the opposing effects reflect differences in the properties of languages. In her overview of monolingual neighborhood size and frequency studies, Andrews (1997) points out that a great majority of the orthographic neighbors of English 4-letter words share all but the first letter with the target word. Since the final three letters of these words often form what is referred to as the word body (the orthographic equivalent of the phonological rhyme), this implies that such units may play a critical role in determining the size and direction of neighborhood density effects. Thus, according to Andrews (1997), one possible source of cross-language differences in effects of neighborhood density is the relative importance of word bodies as functional units in the word recognition process. Variability across languages in the statistical regularities of spelling-to-sound mappings at different grain sizes is hypothesized to be a determining factor.

Compared to English, spelling-to-sound correspondences in Dutch are relatively regular (Van Heuven, 1980), and the role of the body in word naming seems to be less important in Dutch than in English (Martensen, Maris, & Dijkstra, in preparation). An analysis of all Dutch and English words from the CELEX database showed that on average English words have more rhyme neighbors (mean 12.3) than Dutch words (mean 8.5), while the mean number of orthographic neighbors of a word is about the same for the two languages (English, 5.2; Dutch, 5.5)[6]. Analysis of our stimulus material showed a similar pattern. Further research is needed to find out how differences in orthography and phonology across languages affect orthographic neighborhood density effects in visual word recognition.

Differences in the properties of the Dutch and English lexicons might also interact with characteristics of the bilingual participants and the stimulus material used in the experiments. For instance, since our bilinguals were unbalanced, the English and Dutch word stimuli could not be matched with respect to subjective frequency. If the direction of neighborhood density effects depends on target word frequency, an explanation could be sought in this direction. However, there is no conclusive evidence in the monolinguistic literature that this is the case (Andrews, 1997).

Furthermore, within-language facilitation effects for English may have a different origin in monolinguals than in bilinguals. Grainger and Jacobs (1996) propose that one of the criteria monolinguals use to make a lexical decision is a response criterion set on summed lexical activity. It is not clear how such summed lexical activity is calculated by bilinguals. The nonword results of Experiments 3 and 4 suggest that the bilinguals used summed lexical activity in the most activated lexicon rather than the sum of activation across languages. Also, in Experiment 1, bilinguals with a high L2 proficiency seemed to be able to affect the influence of their second language during the experiment. Both observations can be taken as evidence that the

[6] Our analysis showed that removing words from the English lexicon with more than one pronunciation did not change the average number of rhymes in English much (rhyme neighbors 12.3 vs 11.9; orthographic neighbors 5.4 vs 5.2). The Dutch lexicon contained only words with one pronunciation.

bilingual status of a participant plays a role in the different within-language neighborhood density effects for English and Dutch.

One further possible explanation for the facilitation effect in English relates to stimulus characteristics. Our Dutch and English stimuli were matched with respect to the number of neighbors they had in English and Dutch (see Table 1). However, it cannot be excluded that the actual number of English neighbors known by our bilingual participants was lower than that estimated on the basis of the CELEX database corpus. Not all test conditions would be affected equally by overestimating the number of neighbors actually known. The effect would be strongest for English words having many within-language neighbors. However, the presence of fewer English neighbors would (in the current view) imply less inhibition relative to the two other conditions, rather than more facilitation.

Further empirical research is obviously necessary to determine which (combination) of these sources (language, bilingual, stimulus material) affect(s) the direction of bilingual neighborhood density effects. As described above, the BIA model takes a stand here because it suggests that, at least for our bilingual participants, the observed within-language facilitatory effect of English N is due to the bilingual nature of our participants, implying reduced English frequencies (relative to Dutch) and asymmetric top-down inhibition.

Conclusions

Without doubt, there are alternative frameworks for developing a model of bilingual word recognition that is sensitive to factors shown to be critical in the present experiments (cf. Grosjean, 1997). We invite researchers with different orientations to develop more complex variants of selective-access or independent-lexica models that do so. In the meantime, we have shown in the present paper how the effects of non-target language neighbors on target word recognition in bilingual participants can be accommodated by a mechanism of mutual inhibition within an integrated orthographic lexicon.

Future work on cross-language neighborhood effects should provide further constraints on our modeling efforts within the area of bilingual word recognition. For instance, the possible influence of activated phonological representations on the present neighborhood density results must be examined. Given that the Dutch spelling system is more shallow than the English one, it cannot be excluded that our Dutch and English results have been differently affected by the potentially relevant information sources of lexical and sublexical phonology. Furthermore, simulation work on, for instance, bilingual homograph recognition will clearly be less than optimal until phonological codes have been implemented in the BIA model. The activation of phonological representations may be essential in allowing target language node activation to dominate over the non-target language node in the case of cross-language heterophonic homographs (such as Dutch/English GLAD, which is pronounced differently in Dutch and English). On this point, it will be critical to know whether only target language phonology or both phonological codes are automatically generated on presentation of such cross-language homographs and whether these codes activate language nodes as well. Work is currently in progress on this particular question (Dijkstra, Grainger, & Van Heuven, submitted).

The evidence presented in this paper suggests that the right question to ask may not even be whether we opt for a selective access or a non-selective access model of bilingual word recognition, but which mechanisms in the human processing system allow for just the right amount of interference or facilitation under particular experimental situations. Although it has been shown that the theoretically motivated mechanisms currently incorporated in the BIA model have sufficient flexibility to allow qualitatively correct simulation of some of the result patterns in this study, precise quantitative fits await further model development.

APPENDIX

Dutch Words Used in Experiments 1–3

Large Dutch N, Large English N: bons, borg, bril, dolk, hiel, klam, knie, oord, plek, rund, sein, spar, takt, tolk, vork, wolk, worp, woud, wrak, zalf **Large Dutch N, Small English N:** berg, beul, bouw, deun, dief, eter, fuik, kelk, kies, knal, kous, rede, snik, teug, touw, twee, unie, vals, verf, vies **Small Dutch N, Large English N:** brug, bult, draf, drie, fris, galg, hemd, heup, lach, meid, melk, munt, nota, pret, prik, smid, stug, vete, welp, wilg **Small Dutch N, Small English N:** akte, ambt, blad, erwt, ezel, gesp, gids, gips, inkt, joch, muts, ober, pech, pion, rots, snor, stro, toga, trui, veld

English Words Used in Experiments 1–4

Large Dutch N, Large English N: aunt, blue, farm, hawk, knit, left, loan, loud, maid, monk, moon, path, quit, shoe, suit, tool, verb, weak, wrap, zero **Large Dutch N, Small English N:** army, atom, bias, bird, diet, edge, germ, huge, butt, jerk, keen, knee, liar, lion, myth, noon, nude, obey, poem, poor **Small Dutch N, Large English N:** bath, bomb, busy, clue, coin, desk, dial, dirt, dish, firm, grey, hurt, iron, joke, lamb, limb, loss, milk, prey, rude **Small Dutch N, Small English N:** deny, duty, earl, envy, evil, folk, frog, guts, idol, kiss, okay, oral, oval, soup, true, twin, ugly, used, vein, view

Nonwords Used in Experiment 3

Large Dutch N, Large English N: aril, aunk, blag, boul, boup, braf, bret, dris, duef, elap, fram, frip, furk, gonk, heud, jeef, knat, knub, koup, loem, meem, merd, mots, oram, peit, pern, piot, pral, pred, rama, sluf, sluk, snus, sols, stui, tess, trum, tult, vene, zork **Large Dutch N, Small English N:** alof, besp, bito, bouf, daus, drot, epoe, etel, feik, goep, grul, heut, irok, jees, jeul, jund, jurf, kalp, kelf, kerd, keun, loga, morp, muig, mups, nazz, noge, nont, noto, obel, oune, pris, puif, reug, reun, slen, smir, viem, woup, zuls **Small Dutch N, Large English N:** aute, bele, bulf, ceot, chah, cham, clet, dolo, drid, dulp, feul, foug, fran, genk, girs, jant, jero, jert, liry, lurd, lurp, lusp, naul, nirk, nudo, orim, pani, prad, prog, puet, raut, reud, rion, ruze, seto, snam, tirk, tran, vich, vorn **Small Dutch N, Small English N:** aler, anas, arns, aurd, baun, cafa, chof, deim, dilm, drio, durs, enip, fenk, feup, frig, frus, giep, heif, hilp, jalp, jofe, kach, kiot, knaf, luet, maup, moug, nige, omil, paby, ridi, siom, taur, torp, tuni, twol, unar, vota, zous, zuke

Nonwords Used in Experiment 4

Large Dutch N, Large English N: aunk, blag, boul, boup, bret, dris, duef, elap, fram, frip, furk, gonk, jeef, knat, knub, koup, loem, mots, rama, sluk **Large Dutch N, Small English N:** bito, grul, jees, jeul, kalp, keun, morp, mups, nazz, nont, noto, oune, pris, puif, reug, reun, slen, viem, woup, zuls **Small Dutch N, Large English N:** jant, lurp, lusp, naul, nirk, nudo, orim, pani, prad, prog, puet, raut, reud, rion, seto, snam, tirk, tran, vich, vorn **Small Dutch N, Small English N:** drio, frig, jofe, kach, kiot, knaf, luet, maup, moug, nige, omil, paby, ridi, siom, taur, torp, tuni, unar, zous, zuke

REFERENCES

Altenberg, E. P., & Cairns, H. S. (1983). The effects of phonotactic constraints on lexical processing in bilingual and monolingual subjects. *Journal of Verbal Learning and Verbal Behavior,* **22,** 174–188.

Andrews, S. (1989). Frequency and neighborhood effects on lexical access: Activation or search? *Journal of Experimental Psychology: Learning, Memory and Cognition,* **15,** 802–814.

Andrews, S. (1992). Frequency and neighborhood effects on lexical access: Lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory and Cognition,* **18,** 234–254.

Andrews, S. (1997). The role of orthographic similarity in lexical retrieval: resolving neighborhood conflicts. *Psychonomic Bulletin and Review,* **4,** 439–461.

Baayen, H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database* (*CD-ROM*). Philadelphia: University of Pennsylvania, Linguistic Data Consortium.

Baayen, H., Dijkstra, A., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual route model. *Journal of Memory and Language,* **37,** 94–117.

Beauvillain, C. (1992). Orthographic and lexical constraints in bilingual word recognition. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 221–235). Amsterdam: Elsevier Science Publishers B.V.

Beauvillain, C., & Grainger, J. (1987). Accessing interlexical homographs: Some limitations of a language-selective access. *Journal of Memory and Language,* **26,** 658–672.

Bijeljac-Babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory & Cognition,* **25,** 447–457.

Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of orthographic neighborhood in visual word recognition: Cross-task comparisons. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **23,** 857–871.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and Performance VI* (pp. 535–555). New York: Academic Press.

Dijkstra, A., Grainger, J., & Van Heuven, W. J. B. *Recognition of cognates and interlingual homographs: The neglected role of phonology.* Manuscript submitted for publication.

Dijkstra, A., & Van Heuven, W. J. B., (1998). The BIA model and bilingual word recognition. In J. Grainger & A. Jacobs (Eds.), *Localist Connectionist Approaches to Human Cognition* (pp. 189–225). Hillsdale, NJ: Lawrence Erlbaum Associates.

Dijkstra, A, Van Heuven, W. J. B., & Grainger, J. (in press). Simulating cross-language competition with the Bilingual Interactive Activation Model. *Psychologica Belgica.*

Dijkstra, A., Van Jaarsveld, H., & Ten Brinke, S. (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism,* **1,** 51–66.

Durgunoglu, A. Y., & Roediger, H. L., III (1987). Test differences in accessing bilingual memory. *Journal of Memory and Language,* **26,** 377–391.

Dyer, F. N. (1971). Color naming interference in monolingual and bilinguals. *Journal of Verbal Learning and Verbal Behavior,* **10,** 297–302.

Ehri, L. C., & Bouchard-Ryan, E. (1980). Performance of bilinguals in a picture–word interference task. *Journal of Psycholinguistic Research,* **9,** 285–303.

Gerard, L. D., & Scarborough, D. L. (1989). Language-specific lexical access of homographs by bilinguals. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **15,** 305–313.

Grainger, J. (1990). Word frequency and neighborhood frequency effects in lexical decision and naming. *Journal of Memory and Language,* **29,** 228–244.

Grainger, J. (1993). Visual word recognition in bilinguals. In R. Schreuder & B. Weltens (Eds.), *The Bilingual Lexicon* (pp. 11–25). Amsterdam/Philadelphia: John Benjamins Publishing Co.

Grainger, J., & Beauvillain, C. (1987). Language blocking and lexical access in bilinguals. *Quarterly Journal of Experimental Psychology,* **39A,** 295–319.

Grainger, J., & Dijkstra, A. (1992). On the representation and use of language information in bilinguals. In R. J. Haris (Ed.), *Cognitive Processing in Bilinguals* (pp. 207–220). Amsterdam: Elsevier Science Publishers B.V.

Grainger, J., & Jacobs, A. M. (1994). A dual read-out model of word context effects in letter perception: Further investigations of the word superiority effect. *Journal of Experimental Psychology: Human Perception and Performance,* **20,** 1158–1176.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review,* **103,** 518–565.

Grainger, J., & O'Regan, J. K., (1992). A psychophysical investigation of language priming effects in two English–French bilinguals. *European Journal of Cognitive Psychology,* **4,** 323–339.

Grainger, J., O'Regan, J. K., Jacobs, A. M., & Segui, J. (1989). On the role of competing word units in visual word recognition: The neighborhood frequency effect. *Perception and Psychophysics,* **45,** 189–195.

Grainger, J., & Segui, J. (1990). Neighborhood frequency effects in visual word recognition: A comparison of lexical decision and masked identification latencies. *Perception and Psychophysics,* **47,** 191–198.

Green, D. W. (1986). Control, activation, and resource: A framework and a model for the control of speech in bilinguals. *Brain & Language,* **27,** 210–223.

Grosjean, F. (1998). Processing mixed language: Issues, findings and models. In A. de Groot & J. Kroll (Eds.), *Tutorials in Bilingualism: Psycholinguistic Perspectives* (pp. 225–254). Hillsdale, NJ: Lawrence Erlbaum Associates.

Guttentag, R. E., Haith, M. M., & Goodman, G. S. (1984). Semantic processing of unattended words by bilinguals: A test of the input switch mechanism. *Journal of Verbal Learning and Verbal Behavior,* **23,** 178–188.

Jacobs, A. M., & Grainger, J. (1991). Automatic letter priming in an alphabetic decision task. *Perception & Psychophysics,* **49,** 43–52.

Jacobs, A. M., & Grainger, J. (1992). Testing a semistochastic variant of the interactive activation model in different word recognition experiments. *Journal of Experimental Psychology: Human Perception and Performance,* **18,** 1174–1188.

Johnson, N. F., & Pugh, K. R. (1994). A cohort model of visual word recognition. *Cognitive Psychology,* **26,** 240–346.

Macnamara, J., & Kushnir, S. (1971). Linguistic independence of bilinguals: The Input Switch. *Journal of Verbal Learning and Verbal Behavior,* **10,** 480–487.

Martensen, H., Maris, E., & Dijkstra, A. (in preparation). *The body's role in naming Dutch words: Measurement and effect of phonological consistency.*

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception, Part 1: An account of basic findings. *Psychological Review,* **88,** 375–405.

McClelland, J. L., & Rumelhart, D. E. (1988). *Parallel distributed processing: Explorations in the microstructure of cognition* (Vol. 3). Cambridge: Bradford Books.

Monsell, S., Matthews, G. H., & Miller, D. C. (1992). Repetition of lexicalization across languages: A further test of the locus of priming. *Quarterly Journal of Experimental Psychology,* **44,** 4, 763–783.

Nas, G. (1983). Visual word recognition in bilinguals: Evidence for a cooperation between visual and sound based codes during access to a common lexical store. *Journal of Verbal Learning and Verbal Behavior,* **22,** 526–534.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation-verification model for letter and word recognition: The word-superiority effect. *Psychological Review,* **8,** 573–594.

Ransdell, S. E., & Fischler, I. (1987). Memory in a monolingual mode: When are bilinguals at a disadvantage? *Journal of Memory and Language,* **26,** 392–405.

Scarborough, D. L., Gerard, L., & Cortese, C. (1984). Independence of lexical access in bilingual word recognition. *Journal of Verbal Learning and Verbal Behavior,* **23,** 84–99.

Sears, C. R., Hino, Y., & Lupker, S. J. (1995). Neighborhood frequency and neighborhood size effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance,* **21,** 876–900.

Smith, M. C. (1997). How do bilinguals access lexical information? In A. de Groot & J. Kroll (Eds.), *Tutorials in bilingualism: Psycholinguistic perspectives* (pp. 145–168). Hillsdale, NJ: Lawrence Erlbaum Associates.

Snodgrass, J. G., & Mintzer, M. (1993). Neighborhood effects in visual word recognition: Facilitatory or inhibitory? *Memory and Cognition,* **21,** 247–266.

Soares, C., & Grosjean, F. (1984). Bilinguals in a monolingual and bilingual speech mode: The effect on lexical access. *Memory and Cognition,* **12,** 380–386.

Van Heuven, V. J. (1980). Aspects of Dutch orthography and reading. In S. F. Kavanagh & R. L. Venezky (Eds.), *Orthography, reading, and dyslexia* (pp. 57–73). Baltimore: University Park Press.

Ziegler, J. C., Rey, A., & Jacobs, A. M. (in press). Simulating individual word identification thresholds and errors in the fragmentation task. *Memory & Cognition.*

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